# THE STATE OF NEW ZEALAND'S ENVIRONMENT

1997

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for the

**The State of New Zealand's Environment 1997**

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## MESSAGE FROM THE MINISTER

The Resource Management Act 1991 has made the environment everyone's business. Through it, New Zealanders have chosen a development path which, above all, is meant to be environmentally sustainable. In taking this path we can no longer leave it to central government or future generations to correct our mistakes. We must be ecologically vigilant as individuals, households, businesses and communities. For that reason, this report is important to us all, not only in telling us where we have been and where we are now, but in helping us to chart where we are going.

In making choices about the state of our environment we need good information. Without this, we cannot identify our environmental impacts, set realistic targets, assess progress, detect past errors, or objectively weigh economic and environmental values. This report brings together a wide range of information to help in making some of those choices. Although the report's information comes from a variety of sources, the picture that emerges is far from comprehensive. Some issues, some areas and some time periods have been better monitored and studied than others. Some have not been monitored at all.

One message that does come through is that New Zealand's environmental information must be better coordinated if we are to derive maximum value from it. Although there are many information collectors out there, including local authorities, government departments, Crown Research Institutes, university scientists and special interest groups, much of their information is not collected regularly or in a standardised format. This makes it difficult to compare information from different parts of the country or to aggregate it at the national level.

This inconsistency also means that we cannot be sure that the picture that emerges from this monitoring truly tells us about the state of our environment While this obviously hampers our ability to reach definite conclusions, it does not provide a rationale for inaction. The importance of the environment to New Zealand's quality of life and economic welfare suggests that we need to be much better informed about the cumulative effects of our activities on our environmental assets.

As the Minister responsible not only for the Environment but also Crown Research Institutes, I am pleased to say that efforts are now well underway to address some of these information shortcomings. The Ministry for the Environment is coordinating the development of a set of core national environmental indicators, and the Ministry of Research, Science and Technology is developing research strategies to coordinate better, publicly funded research and analysis. This will mean that future reports will have more robust quantitative information on which the assessment of trends can be based.

Another message of the report is that there are no grounds for environmental complacency in New Zealand. Our clean and green image is under intense scrutiny both at home and overseas. We must be able to show that there is substance to this image and that we are prepared to acknowledge and redress the brown spots where they occur. This can only be done by comprehensive monitoring, fearless acknowledgment of the results and genuine attempts to resolve any problems uncovered by them.

While the report confirms New Zealand's clean and green image relative to our trading partners, it does force us to acknowledge that there are real threats to our environmental reputation: for example, the number of threatened species appears to be increasing, introduced pests are widespread, soil degradation has worsened in some areas, water pollution is common in rural streams, solid waste has increased in many urban areas, greenhouse gas emissions are continuing to increase, and energy wastage through overuse of motor vehicles and inefficient heating in the home and workplace are still the norm. Most of these problems are well-known and efforts to reverse or reduce them are underway. These problems have not occurred overnight, and similarly we will not able to offer solutions to them all immediately. But we must continue in our day to day actions to head in the right direction—cumulatively this will make the difference as to whether New Zealand does achieve a level of environmental sustainability that we can hand to our grandchildren with pride.

The path from here to environmental sustainability is a long one, and we do not have time to linger. The Government has developed its *Environment 2010* strategy in the hope that it will take us a considerable way along that path over the next dozen years. The Government through the Green Packages in the 1996 and 1997 Budgets has added impetus to its efforts as a contributor to our movement along the path. This is not some one else's problem however—it is the responsibility of all of us to achieve sustainable management of our resources and each of us must all play our part in that.

This report, and its successors, will play an important role by periodically allowing us to assess the environmental and information challenges that face us so that we may confront and overcome them.

**Simon Upton**
MINISTER FOR THE ENVIRONMENT
MINISTER OF BIOSECURITY
MINISTER OF CROWN RESEARCH INSTITUTES
ASSOCIATE MINISTER OF FOREIGN AFFAIRS AND TRADE

## PREFACE

New Zealand heads towards the 21st century at a time of growing environmental awareness on Planet Earth. This is not before time. Large parts of the globe have been radically changed by human activity. Forests and wetlands have shrunk in the face of expansion of farmland, cities and deserts. Our increasing demand for space, travel and gadgets has wiped out ecosystems and exhausted vulnerable soils. The volume and dazzling variety of our waste products has put increasing stress on the world's air and waterways. Many of our kindred species have been driven to extinction, while others cling precariously to an ever-decreasing share of the Earth's domain. Even the protective layers of greenhouse gas and ozone which respectively keep our planet from freezing by night and frizzling by day have been put at risk by the fumes we generate from our cars, power plants and machinery.

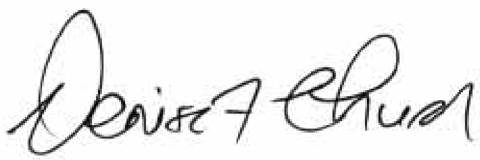
As our numbers and consumption levels have grown, the pressures we place on the environment have soared. The challenge for us as a nation, and as a species, is to develop economic systems and lifestyles whose cumulative impact is within the environment's limits to sustain itself . This has been the broad conclusion of virtually everyone who has thought about environmental issues over the past two decades, from citizen groups to national governments to international meetings. Sustainable development is now seen as the key to our future as a society, and as a species.

New Zealand has confidently embraced this challenge, both through the Resource Management Act 1991, and in signing the Rio Declaration at the UN Conference on Environment and Development in 1992. As a nation we are now formally committed to environmental sustainability, and under the Resource Management Act every community is now responsible for helping to achieve this.

The environment cannot speak for itself however. We can only tell if we are making things better or worse by looking at the world around us and regularly collecting helpful information and studying it. This requires careful measurement and observation and, from time to time, an overall analysis of the data to get a general picture of the state of the environment. This report is the first attempt to do this for New Zealand.

The report does not present new data but brings together a wide range of existing information, much of which has already been published in other forms. This has inevitably limited the scope of the report, as our existing information is still quite patchy. Some aspects of the New Zealand environment are not monitored at all. Others are monitored using different methods in different parts of the country, making it impossible to combine the information in a single big picture. In some cases, information comes from one-off examples or case studies because more complete information does not exist or has not been aggregated.

The report has two broad purposes—to inform New Zealanders of the state of their environment, and to help identify areas where our environmental information could be improved. I hope the report will be used widely and help public discussion, educational programmes and courses, and be a reference source for decision-makers. Further reports will build on this experience and, to that end, the Ministry for the Environment invites you, the reader, to send us your comments and suggestions on how future reports might be improved or enhanced.



**Denise Church**
CHIEF EXECUTIVE
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Crop and Food Research Institute; Forest Heritage Fund; Historic Places Trust; Institute of Environmental Science and Research (ESR); Institute of Geological and Nuclear Sciences; Keep New Zealand Beautiful Campaign; Landcare Research; National Institute of Water and Atmospheric Research; National Museum; New Zealand Pork Industry Board; Otago Museum; New Zealand Conservation Authority; Energy Efficiency and Conservation Authority; Electricity Corporation of New Zealand; Watercare Services; Maritime Safety Authority; Auckland, Hutt, Wellington and Christchurch City Councils; and most the country's regional councils.

The following government departments also contributed information, comments or assistance: Department of Conservation; Department of Survey and Land Information (now Land Information New Zealand); Ministry of Agriculture; Ministry of Commerce; Ministry of Fisheries; Ministry of Health; Ministry of Transport; Ministry of Social Welfare; Statistics New Zealand; the Treasury.

The cartography division of the former Department of Survey and Land Information (now Terralink New Zealand), drafted most of the maps in the report.

Many individuals contributed in various ways. Some prepared original text, graphs, tables or maps. Others sent key scientific papers. Some provided peer review comments or patiently endured interrogation by telephone. And some gave practical and administrative assistance. In most cases, the contributions were voluntary and were made in a spirit of generosity and cooperation. Not all these contributions got into the final document, and some that did were significantly altered on the way. Among those whose contributions or comments have been incorporated in the report are: Matthew Allen, John Annala, Joseph Arand, Bill Armstrong, Sarah Bagnall, Susanjane Baird, Gary Barker, Les Basher, Jessica Beever, Ross Beever, Hugh Best, Hugh Bibby, Paul Blaschke, Patricia Blutner, Paul Breen, John Braggins, Graeme Bremner, Patrick Brownsey, Peter Buchanan, Noel Burns, Dave Burton, Nicole Butler, Peter Castle, Martin Cawthorn, Tom Clarkson, Tom Chatterton, Doug Clover, Gill Cole, Ronda Cooper, Martin Cryer, Janet Davidson, Elliot Dawson, Steve Dawson, Peter de Lange, Mike Donaghue, Tutahanga Douglas, Maurice Duncan, Brian Easton, Chris Edkins, Howard Ellis, Rowan Emberson, Neil Ericksen, Garth Eyles, Allan Fife, Ray and Lyn Forster, Nick Gales, David Galloway, Dave Gilbert, David Given, David Glenny, Eddy Goldberg, Dennis Gordon, Ian Govey, Lindsay Gow, Bruce Graham, Ken Grange, Anthony Harris, Richard Haynes, James Holloway, Ian Jamieson, Peter Johns, Peter Johnston, Nigel Jollands, Craig Lawson, Brian Lloyd, Bob McDowall, Ian McFadden, Bruce McFadgen, Iain McGlinchy, Matt McGlone, Allan McKenzie, Eric McKenzie, Richard McKenzie, Richard McLachlan, Martin Manning, Bruce Marshall, Rob Mattlin, Paul Mosley, Harshila Narsey, Wendy Nelson, Don Newman, Peter Newsome, Sylvia Nichol, Jim Nicolson, Colin Ogle, Ricardo Palma, Murray Parsons, Geoff Patterson, Chris Paulin, Charles Pearson, Chris Perley, Rob Phillips, Helen Plume, Keith Probert, Sophie Punte, Geoff Read, Andy Reisinger, Chris Richmond, Michael Rosen, Ants Roberts, Clive Roberts, Jim Salinger, Jeff Sheerin, Graham Shepherd, Greg Sherley, Tony Silbery, Jim Sim, Marcus Simons, David G. Smith, Ian W.G. Smith, Kevin Steel, Tom Spier, Oliver Sutherland, Michael Taylor, Susan Timmins, Christine Tisdell, Regina Thompson, Dave Towns, Murray Ward, Kathy Walls, Brian Watts, Bob Wilcock, Hugh Wilde, Alan Woodger, Gregor Yeates, John Young, Bob Zuur, and Helen Zwartz.

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CHAPTER ONE

# INTRODUCTION

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## INTRODUCTION

This report to the nation describes New Zealand's natural environment, what we have done to it, and what we are doing now. It is written in the hope that, confronted by the available evidence, we can learn both from our successes and from our failures. In the short time that humans have been in New Zealand, we have dramatically changed the environment through such activities as harvesting, deforestation, wetland drainage, the introduction of pests and weeds, and the generation of pollution. The changes have generally led to economic improvement, but have been devastating for many indigenous species. In some cases, they have also had an economic backlash (e.g. through soil erosion, flooding, soil and water contamination, and air pollution).

It has to be said at the outset that much of this had to happen. Humans simply could not have survived here without making changes. Most of the indigenous plants were of limited use for food or fibre and most of the large edible animals were too slow breeding to be sustainably harvested. It is a tribute to the ingenuity and tenacity of classical Maori society that people survived here at all, and it is a tribute to the European settlers who came later that a prosperous and stable economy was built in such an apparently hostile environment. Today's New Zealand stands largely on the achievements of those vanished generations.

We may legitimately ask whether it was necessary to destroy quite so much forest, drain quite so many wetlands, introduce quite so many alien species, create quite so much pasture, and extinguish quite so many native species, but we cannot undo history. We can only learn from it and try to do better. In so doing, we must appreciate that our predecessors, both Maori and European, did not value the environment in quite the same way we do today. Like us, they valued species and environmental features that had economic, cultural or spiritual significance (i.e. resource or instrumental value), and they sometimes tried to sustain these as far as their knowledge and technology allowed, but they rarely valued nature for nature's sake. The ideas of protecting other species for their intrinsic value (i.e. their value to themselves rather than to us) or of sustaining complex ecological processes for their life-sustaining 'services' are largely twentieth century concepts that owe much to modern scientific thinking.

The Government's environmental strategy, *Environment 2010*, incorporates these new ethical and ecological dimensions, as do our key environmental laws, such as the Resource Management Act 1991, the Fisheries Act 1996 and the 1993 amendment to the Forests Act. These laws are explicitly based on the ethic of sustainability which obliges us to sustain the natural environment not just for our use, but for its ecological functions, its intrinsic value and its potential value to future generations. Under this ethic, the environment is no longer the economy's servant but its host, and extinctions and environmental degradation are no longer acceptable prices to pay in the pursuit of economic growth.

Putting the sustainability ethic into practice requires good information as well as good intentions. New Zealanders are familiar with the sophisticated battery of economic indicators and progress reports that regularly chart the state of the economy. The social and environmental spheres, however, are less well served. This was highlighted recently by the Organisation for Economic Cooperation and Development in its review of New Zealand's environmental performance (OECD, 1996). The OECD review noted that, despite our innovative environmental legislation and our clean, green, marketing image, New Zealand's lack of high quality environmental data is a significant barrier to effective environmental planning and management. The review recommended that high priority be given to producing this State of the Environment Report and to developing national environmental indicators. It also recommended that consideration be given to dramatically increasing the amount of environmental monitoring, and improving its coordination.

The limitations of New Zealand's environmental data were a frequent challenge in preparing this report. Although a considerable amount of information does exist, it is often of limited value for assessing national, or even regional, trends. This is because it is often out of date, confined to one particular time period or location, or gathered using different methods in different areas. Also in some cases information is simply non-existent. Progress is now being made toward overcoming these deficiencies through the Ministry for the Environment's national environmental indicators programme (see Box 1.1).

**Box 1.1**

### *Environmental Indicators: monitoring the vital signs*

New Zealand's unique environment has become a major component in marketing strategies for both our primary produce and our tourist attractions. In addition to our unusual birds, bats, frogs, and lizards, we do have clean air, fresh water, and green pastures compared to many countries. However, our environment has undergone massive changes in a very short time, and it is under constant pressure from human activities. In many cases, we do not know what changes are occurring within the atmosphere, our rivers, and our soils, why they are occurring, and the best way of stopping them. Good information is needed to make good decisions about the environment.

One form of information is the **environmental indicator**. An indicator is something that is measured regularly to show trends or sudden changes in the state of a system, population or individual. Simple indicators measure a single characteristic (e.g. the concentration of ozone in the atmosphere) while composite indicators combine information from several characteristics. The 'ecological footprint' is an example of a composite indicator. It combines information on land area, land use, consumption of land-based resources and population size to show how much land is needed to maintain the lifestyle of an average member of the population. The power of an indicator, whether it is simple or composite, lies in its ability to tell us whether things are getting better or worse.

Economists have used indicators to monitor the 'health' of the economy for many years. They have watched the fluctuations in economic indicators, such as food prices, house prices, the CPI (Consumer Price Index) and the GDP (Gross Domestic Product), to show the pressures on the economy, the state of the economy, and the effectiveness of any responses. Volumes of economic information are produced each month. Environmental scientists are not so well off. A number of nationally coordinated monitoring programmes do exist for such things as weather, some rivers, shallow lakes, groundwater, atmospheric ozone and greenhouse gases, marine toxic algae, and commercial fish catches. But the vast majority of environmental monitoring is not coordinated or standardised across the nation. One of the reasons for this is the decentralised nature of New Zealand's environmental management system.

The Resource Management Act 1991 requires the Minister for the Environment to monitor the effect and implementation of the Act and to monitor and investigate other matters of environmental significance as necessary. It also requires the Minister of Conservation to monitor the effect and implementation of coastal policy statements and permits. However, the main responsibility for environmental monitoring under the Act falls to local authorities. Because these are only required to monitor aspects of the environment relevant to their region, national environmental information is often difficult to asssemble.

A national *Environmental Indicators and Monitoring Programme* is now being developed for New Zealand by the Ministry for the Environment (1996a and 1996b). The idea is to standardise the key indicators being monitored throughout the country so that monitoring costs and expertise can be shared among local authorities, useful comparisons can be made between localities, and national trends can be identified. The programme has focused initially on indicators for land, water, and air and will then proceed to develop indicators for: waste; indigenous habitat and biodiversity; pests, weeds, and diseases; fisheries resources; energy; climate change; ozone depletion; and transport. The intention is to have the core set of indicators in place by the turn of the century allowing the environment to stand alongside economic and social considerations in the development of sound policy and equitable laws in the new millennium.

**About this book**

This report is organised in three parts. The first part provides contextual information for understanding the interaction between New Zealand society and the natural environment. It contains three chapters which describe: the land, people and cultural heritage (Chapter 2); production and consumption patterns, and the economic and social trends associated with these (Chapter 3); and the legal and institutional arrangements for managing the environment (Chapter 4).

The second part describes the state of our natural environment. It contains five chapters which focus respectively on: the atmosphere (Chapter 5), ambient air (Chapter 6), marine and fresh water (Chapter 7), land (Chapter 8), and biological diversity (Chapter 9). Each of these chapters has a standard format based on the OECD's 'Pressure State Response' framework (see Box 1.2). They are each divided into sections describing the state of the data, the nature of the environment, the pressures on it, its current state, and society's responses to it.

The concluding chapter reflects the report's main findings.

Every effort has been made to include the best available information up to mid-1996, though, in many cases, we have had to settle for data from earlier years or even decades. A considerable amount of information and comment was provided free by scientists, research organisations, regional councils and government departments. Although the report is scientifically based, the editors have tried to keep technical language to a minimum and have sometimes simplified complex information for ease of understanding. Any resulting inaccuracies are the responsibility of the editors, not the scientists and peer reviewers who contributed to each chapter.

All chapters were reviewed in their entirety by the following government departments whose factual corrections should not necessarily be taken as endorsements of the report's perspective or interpretive comments: the Ministry of Agriculture; the Ministry of Commerce (including Energy and Tourism); the Department of Conservation; the Ministry of Fisheries, the Ministry of Forestry; the Ministry of Health; Land Information New Zealand; the Prime Minister and Cabinet's Department; Te Puni Kokiri (the Ministry of Maori Development); Statistics New Zealand; the Ministry of Transport; and the Treasury.

Although this report is about the current state of the environment, the present is a child of the past and cannot be fully understood without some knowledge of the evolutionary, geological and historical processes that contributed to it. For this reason, all chapters review the recent past and some dig into the deep past, at times going back to the origins of life and of Earth itself. The point of this is to underline the vast evolutionary timespans that produced our natural environment and the very short timespans that can destroy it.

The deep history perspective also has the cautionary effect of showing that human existence, much less industrial society, is a very short and recent event in Earth history. If Earth's time were compressed into a single year, our ancestors would only have parted company with the chimpanzee at about two in the afternoon on the last day of that year. Modern humans would have evolved just 15–20 minutes before midnight. On this timescale, civilisation and agriculture are barely one minute old and the era of mass production and consumption is a mere second—so brief and unprecedented that its sustainability cannot be taken for granted, however 'natural' it may seem to us now.

**Box 1.2**

### *The Pressure-State-Response framework*

Much of our information on the environment is unconnected. Sorting through it and making sense of it is difficult without some organised framework or plan of attack. For this report, we have decided to use an approach developed by the OECD in which information is organised according to its ability to tell us about the pressures on the environment, the state of the environment and society's responses to environmental problems. The **Pressure-State-Response (PSR)** framework is based on a concept of causality. Human activities exert **pressures** on the environment, changing both its quality and the quantity of natural resources. These changes alter the **state**, or condition, of the environment. The human **responses** to these changes include any organised behaviour which aims to reduce, prevent or mitigate undesirable changes.

Under the PSR framework, a **pressure** might be a pollutant discharged from a factory, or draining into a river from the land; it could be the removal of forest from the land or over-harvesting by fishers and hunters; and it could be the release of gases into the atmosphere. The critical factor is the human element: environmental changes occurring through human activity, not simply as a natural process. This distinction may seem an arbitrary one to birds dislodged from a fallen tree. Whether the tree was felled by wind or a chainsaw, its impact is the same. From an environmental management perspective, however, the distinction is important. Pressures caused or abetted by human activity can, in principle at least, be controlled or modified. For this reason, the PSR framework tends to highlight human pressures more than natural pressures.

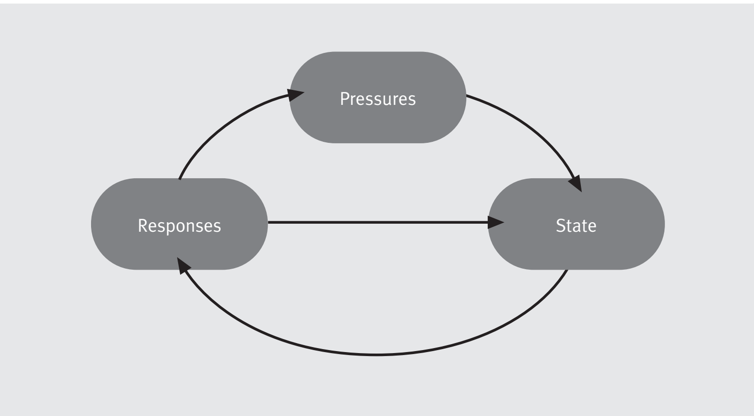
The **state** of the environment is its condition at a particular time. This is assessed by measuring various aspects of the atmosphere, air, water, land and biota (living things) to see whether they are changing (Chapters 5 to 9).

**Responses** are the organised actions people take to either reduce environmental pressures, or directly improve environmental conditions. These can include scientific monitoring and research, the imposition of laws and rules to make people change their behaviour, and the use of economic penalties or incentives to bring about voluntary behaviour change (such as taxes, fees, grants, subsidies, tradeable permits and quotas etc.).

In this report each of the core chapters (Chapters 5 to 9) contains separate sections on pressures, states and responses. While some pressures are mentioned only in a single chapter (e.g. CFC gas emissions into the atmosphere), others have multiple impacts and so recur in several chapters (e.g. fossil fuel burning by vehicles and industry, land and water use by pastoral agriculture). In some cases, the multiplicity of environmental impacts, and the interactions among different pressures are more complex than they appear in our discussion. The report tends to confine itself to **proximate** pressures (i.e. those which have the most direct impact on the environment). But proximate pressures are often influenced by more indirect social and economic factors (**distal** pressures) which are harder to expose. In developing responses to environmental problems it is important to consider the roles played by both proximate and distal pressures.

**Figure 1.1**

**The Pressure - State - Response model of environmental change**

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CHAPTER TWO

# THE PLACE AND THE PEOPLE

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## NEW ZEALAND'S LAND AND ENVIRONMENT

New Zealand is a cluster of islands in the South Pacific. Its three largest islands, the North Island, the South Island, and Stewart Island, are much bigger than most that dot the Pacific page of the atlas, and they lie mostly on a north-east by south-west axis. Together, they are more than 1,600 kilometres (km) long but only 450 km across at their widest point. Their combined area is 270,500 square kilometres ($km^2$), or 27 million hectares (ha), about the same size as the British Isles or Japan.

First named Nieeuw Zeeland by a Dutch map-maker some decades after Abel Tasman's 1642 voyage of discovery, the islands did not acquire their collective Maori name, Aotearoa (Land of the Long White Cloud), until this century—though the word was sometimes used earlier to refer to the North Island (Barlow, 1994).

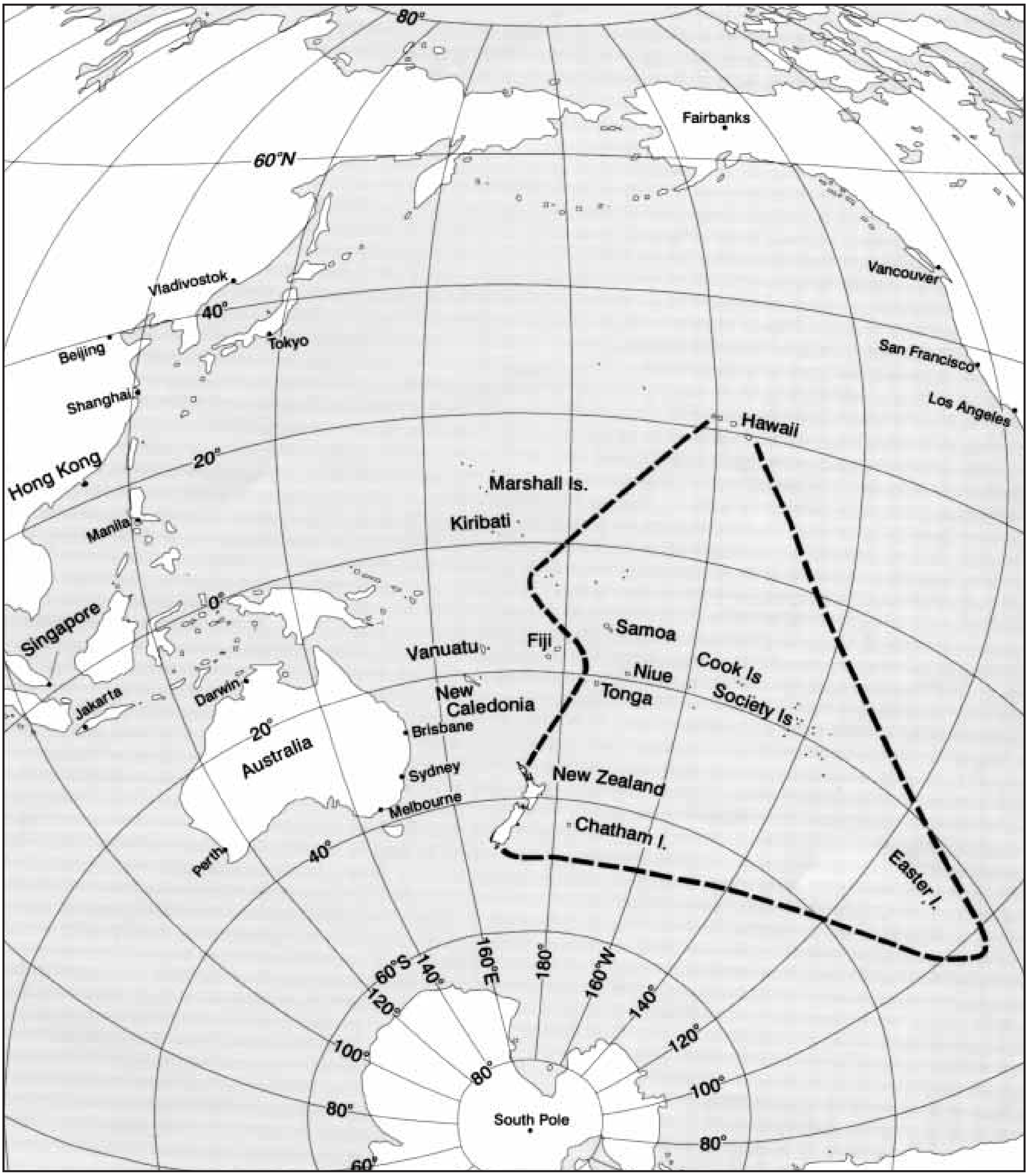
However you look at it, New Zealand is remote. Since parting from the ancient supercontinent of Gondwana 80 million years ago, it charted an independent course which steered away from other landmasses and well out into the Pacific. Its nearest continental neighbours are Australia to the west, Antarctica to the south and South America away over to the east.

New Zealand is often called 'the Shaky Isles'. Beneath its hilly surface are two colliding tectonic plates, the Pacific and Indo-Australian plates. Their first meeting about 135 million years ago is what thrust the New Zealand landmass out of the ocean on the east coast of Gondwana. The plates continue to push and slide against each other, periodically jolting different parts of the country and sending shudders through land and people. The mountainous surface is cracked and fractured by rows of fault lines and is pock-marked in the North Island by several active volcanoes. In the South Island the colliding plates have forced up a high, snow-capped range of mountains, the Southern Alps, which are rising at a rate of about 1 centimetre a year, just enough to compensate for the constant wear and tear of erosion in this high rainfall environment.

The Southern Alps include 18 peaks which tower above 3,000 metres, the highest being Mt Cook at 3,754 metres. The snow and ice from these mountains are carried away by 360 glaciers. The longest, Tasman Glacier, grinds its way for 29 km past the eastern slopes of Mt Cook down towards Lake Pukaki. Shorter, but more accessible glaciers, such as the Fox and Franz Josef, flow to the west and are well-known tourist attractions. Ultimately, the Southern Alps are drained by a series short, swift-flowing rivers on the west coast, and several wide shingle-bedded rivers on the east. The largest of these is the 322 km Clutha, which carries more water than any other river, but is not quite the longest in the land. That honour goes to the North Island's Waikato (425 km) which flows from the vast volcanic crater that holds the country's largest lake, Taupo.

The period of human settlement is now believed to be significantly shorter than the thousand years commonly quoted in popular accounts (see Box 1.3). Recent analysis of radiocarbon dates from archaeological sites suggests that humans have been here for no more than 750 years, give or take a century (i.e. arriving somewhere between A.D. 1150 and A.D. 1350). The first arrivals were Polynesian-speaking settlers who made New Zealand one of the remotest outposts of the 'Polynesian Triangle' (see Figure 1.1). When it was incorporated into the British Empire nearly 160 years ago, New Zealand also became the remotest member of that realm and is still the Commonwealth country furthest from Britain.

**Figure 2.1**
**New Zealand and the Polynesian Triangle.**



In Northern Hemisphere terms, New Zealand's location, between latitudes 33° and 47°, would put it in the middle of the Mediterranean Sea or the heartland of the United States. Spain, Turkey, and Japan all lie in roughly the same latitudinal zone on the globe north of the Equator as New Zealand does to the south. The British Isles lie much closer to the North Pole than New Zealand does to the South Pole. Small wonder, then, that although New Zealand is the 'least tropical' of the Pacific islands, the first British immigrants found the climatic conditions more benign than those they had left behind.

The climate of New Zealand reflects both its location and its geography: maritime, temperate, and breezy (some would say windy). The moist breezes blow mainly from the west, swirl up over the mountains, and generate heavy clouds which spill their rain as they rise. As a result, the west coast, particularly of the South Island, is wet and lush; the east coast is drier.

The winters are cool to cold, the summers are warm to hot. In recent years, as the power of the Southern Oscillation (the Pacific Ocean's see-sawing high and low air pressure systems) and the associated El Niño and La Niña weather patterns have become better understood, they have provided explanations for unusually cool summers—or equally unusual warm ones—and the droughts which sometimes parch the east coast of both main islands.

The climate is ideal for agriculture, and to the casual visitor, the country is a land of lush green farms and neatly fenced paddocks full of cows and sheep. Pine forests, big and small, are another, more recent feature. The number of farms and livestock tends to disguise the fact that less than one-quarter of New Zealand is less than 200 metres above sea level. Steep hills or mountain ranges, sometimes brown, bare, and badly eroded, sometimes green and clad in lush native forest, often form a backdrop to the scene.

Almost without exception, the animals and birds seen from the road on a drive through New Zealand, have been introduced and have some link to farming. The indigenous species are more shy. New Zealand parted company with the prehistoric supercontinent, Gondwana, 80 million years ago. This has produced species of plants, animals, and birds that are found nowhere else in the world, and that need either their ancient shadowy forest habitat or their remote windswept coastal rookeries to survive. Most famous among these is the flightless kiwi, a forest-dwelling bird that filled a niche normally occupied by mammals.

Apart from two small bats, that also took to 'walking' rather than flying, there were no mammals in New Zealand. Here, the role of predator fell to birds, such as the New Zealand falcon and the huge Haast's eagle, the latter now extinct along with its main prey, the giant moa. Other unique animals also succumbed to the impact of humans and their introduced species, while some only just survived.

The tuatara, a lizard-like reptile that roamed the islands of emerging New Zealand when dinosaurs ruled the Earth, and the giant tusked weta, an ancient wingless relative of crickets and grasshoppers, are still threatened with extinction. Unique trees, such as the kauri, the kahikatea, and the totara, have survived but their range has been dramatically reduced. In the higher latitudes and altitudes are the southern beech forests which once formed great swathes through the part of Gondwana which united New Zealand, Antarctica, and southern South America.

## NEW ZEALAND'S PEOPLE

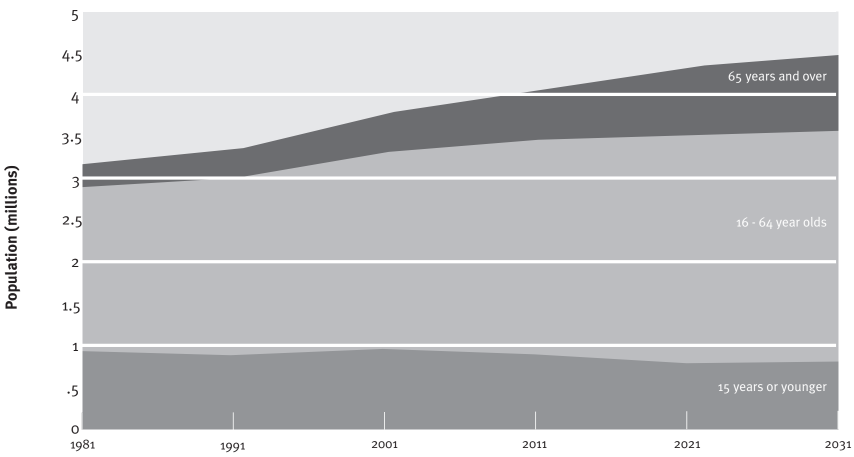
Ecologically, humans are new, very new, in the New Zealand environment. *Homo sapiens* is an African species that only began to disperse around the world during the ebbs and flows of the last Ice Age, within the past 100,000 years (4,000 generations) (Cavalli-Sforza, 1991; Cavalli-Sforza *et al.*, 1993 and 1994; Penny *et al.*, 1995; Stringer and McKie, 1996; Wilson and Cann, 1992). Asia, Melanesia and Australia were colonised by 50–60,000 years ago (roughly 2,400 generations), Europe by 35–40,000 years ago (about 1,600 generations), and the Americas by at least 15,000 years ago (some 600 generations). In this epic dispersal, which gave us the world's variety of languages, cultures, mythologies and physical diversity, New Zealand was the last major stopping point. The Polynesian ancestors of the Maori people began arriving here less than 30 generations ago (see Box 2.1).

New Zealand's original settlers may have numbered anywhere from 50 to 500, but population growth and more recent large-scale immigration from Europe and elsewhere have added considerably to the population since then. Today, New Zealand has about 3.6 million people and these are expected to reach between 4.3 and 5.4 million by A.D. 2031 (Statistics New Zealand, 1994b). Population projections are inherently uncertain, but assuming 'medium' fertility (i.e. a continuation of the present average of 2 children per woman) and average net immigration of some 5,000 per year, the population in 2031 will reach about 4.6 million—with a considerably increased adult and elderly population but a fairly constant under-15 population (see Figure 2.2).

This represents a population increase of almost 30 percent, and a density increase from about 13 people per square kilometre to 17. By global standards these figures are low. The world's population is expected to increase from its current 5.8 billion (44 people per square kilometre) to just over 9 billion (70 per square kilometre) by 2031—an increase of nearly 60 percent (Brown and Kane, 1994; United Nations Population Fund, 1994). Most of this increase will be in poor countries that are already heavily populated and running short of farmable land. The result could be large-scale population movements from which New Zealand is unlikely to remain isolated. This may make the immigration assumptions above seem rather naive. If so, the population in 35 years may be higher than 5.4 million.

**Figure 2.2**

**Recent and projected population levels in New Zealand (1981 - 2031)**




*Source: Statistics New Zealand*

**Box 2.1**

### *The peopling of New Zealand and the Pacific*

From linguistic and genetic studies, it is clear that the distant ancestors of the Polynesians came from Asia and spent some time in island Melanesia before entering the great ocean 2,000–3,000 years ago (Bellwood, 1991:Houghton, 1996; Gibbons, 1994; Green, 1994). Opinions differ on whether the ancestral Polynesians took the 'fast train' through Melanesia, sweeping through in just a few centuries, or spent thousands of years there, evolving and adapting over many generations. Whichever view is correct, the people who ultimately made the Pacific Islands their home were skilled sailors who also tended gardens, raised pigs and chickens and made pottery. This pottery, known as the Lapita culture, first appeared in the Bismarck Islands off Papua New Guinea around 3,500 years ago and reached Fiji, Tonga and Samoa by 2,000–2,500 years ago. Broadly similar pottery has been found in the Philippines, Marianas, and eastern Indonesia (Davidson, 1984).

Because the Melanesian islands were colonised by different groups from the Asian mainland as early as 40,000 years ago, researchers have wondered why it took so long for any of these groups to colonise the Pacific. One suggestion is that long ocean voyages could not occur until viable seacraft with sails were developed. Another suggestion is that physique may have been the limiting factor. Computer models show that long voyages in open canoes can be deadly for lightly-clad people because of body heat loss during the wet cold nights. But those whose bodies have a large mass relative to their surface area are less at risk. Among the world's peoples, the computer picked the large, muscular, Polynesians as the ones most likely to survive long sea voyages, suggesting that their physique evolved in response to ocean voyaging and that this, in turn, made more extensive oceanic migrations more viable (Houghton, 1996).

Fiji, Tonga and Samoa were settled first. The rest of the central Pacific appears to have been settled between about A.D. 300 and A.D. 900 following an expansion eastward from Samoa, probably to the Marquesas Islands and, from there, throughout the Pacific (Spriggs and Anderson, 1993). It is interesting to note that the Samoan island of Savai'i translates as Hawaiki or Hawai'i in the eastern Polynesian languages (Buck/Hiroa, 1949). Hawaiki is the legendary homeland of several Polynesian groups, including Maori. According to Buck/Hiroa, the island of Raiatea, near Tahiti, from which at least some Maori ancestors may have come, was also once known as Hawaiki. By A.D. 1,000 virtually all the Pacific Islands were occupied except for outliers such as the Tuamotus, Mangavera, Pitcairn and Henderson Islands, and the cold southwestern islands of Norfolk, the Kermadecs and New Zealand (Spriggs and Anderson, 1993). At some point, too, Polynesian seafarers reached the Americas and returned with the native American sweet potato, or kumara.

The Polynesian expansion throughout the Pacific has often been viewed as a desperate and chancy business, despite the people's own traditions that exploration and settlement were often planned. The traditional view is now receiving wider acceptance as more is learned about Polynesian seamanship and settlement patterns (Irwin, 1992; Finney, 1994; McGlone *et al.*, 1994). Their vessels were very seaworthy and the people were skilled navigators, relying not only on stars and prevailing currents and winds, but the flight paths of migratory birds (e.g. petrels, shearwaters, shining cuckoos) and the thick clouds of foraging birdlife that surrounded islands for hundreds of kilometres out.

The density and diversity of Pacific birdlife is hard to imagine today because many birds are now extinct and the survivors' numbers are kept in check by people and other introduced species. Archaeological evidence shows that, before humans entered it, the Pacific was a seabird and seafood paradise, with two or three times more bird species than exist now. Shellfish, turtles and some coastal fish lived longer and grew bigger than they do now. The seabirds were not limited to offshore islets or inaccessible bluffs and cliffs. They covered all available space, teeming in the undergrowth, the trees, and all coastal areas. Because they grazed thousands of square kilometres of sea, they packed a huge amount of biomass into minimal land area.

So meat-rich were the islands, that discovering one would have been the prehistoric equivalent of winning a lottery, and a sufficient motive to mount regular voyages of exploration (McGlone *et al.,* 1994). Many new settlers may have felt no need to take pigs, chickens and crop plants, being assured of an easy hunter-gatherer existence for several generations before wildlife depletion forced them to import these items from home islands. Following settlement, dramatic resource depletion usually occurred. At least a dozen uninhabited Pacific islands show evidence of past Polynesian settlement and seabird extinctions (Diamond, 1991).

The settlement of New Zealand may have followed this pattern. As the largest landmass in all of Polynesia, it was teeming with birdlife, seals and sea lions. The first settlers did not bring pigs and chickens, and Maori tradition suggests that the kumara was brought subsequently.

Theories about the first settlement of New Zealand have been widely debated for more than a century. A persistent belief of most European scholars has been that settlement was considerably earlier than indicated by Maori tradition. Last century a great effort was made by Victorian ethnologists to confirm this belief through study of the oral traditions. By selectively interpreting whakapapa (genealogies) and origin stories, not all of which were genuine, S. Percy Smith came up with the theory that New Zealand was discovered around A.D. 950 by a Tahitian called Kupe, and then settled following Kupe's directions in A.D.1150 by Toi and Whatonga. Finally, a Great Fleet of seven canoes arrived around A.D.1350 to complete the settlement.

This theory was widely believed until the 1970s when it was finally shot down by two different sorts of evidence—ethnology and archaeology. In 1976, Dr David Simmons published his painstaking reassessment of all the traditional sources on Kupe, Toi and Whatonga and the Fleet (Simmons, 1976). After carefully sorting authentic genealogies from bogus ones he found that they told a rather different, but consistent, story—a short story. Based on the average number of generations, none went back further than about A.D. 1300 Kupe, himself, dated back to the early 1300s. Toi and Whatonga were not immigrants at all, but lived in the Bay of Plenty in the late 1300s and early 1400s (though some more distant tribes placed them in the mythical homeland of Hawaiki about 20 generations earlier). The Fleet canoes did not all arrive at once, but came in small groups or singly. Some appeared to be migrations from one part of New Zealand to another. From all of this, however, Simmons was reluctant to conclude that New Zealand was actually settled in the 1300s. This is because archaeologists had found other evidence suggesting settlement as early as A.D. 800. Thus, the traditional accounts were relegated to the religious box where they have remained (e.g. Orbell, 1975, 1985).

The archaeological evidence for early settlement was based on radiocarbon dating, a technique for estimating the age of plant and animal remains (e.g. bone, wood, shells) from the amount of carbon decay that has occurred since death. When living organisms absorb carbon dioxide from the air, or from eating each other, the carbon atoms come in various forms, called isotopes. One of these, carbon-14 ($^{14}C$), is quite unstable and decays into $^{13}C$ and $^{12}C$ at a fairly regular rate. After death, the organism stops taking in $^{14}C$, so its age can be estimated directly from the proportion of $^{14}C$ remaining, relative to the other isotopes. Since the discovery of this technique in the 1950s, archaeologists have dated most New Zealand prehistoric sites and remains. While most date from the late 1300s on, some produced dates that seemed much earlier (Davidson, 1984).

Recently, however, the radiocarbon dates have been reassessed and, just as the first generation of ethnologists got it wrong, it now seems that the first generation of archaeologists did too. Careful reviews have found no reliable radiocarbon dates earlier than about A.D. 1250 (McFadgen *et al*., 1994; McFadgen, 1994; Anderson, 1991). Several factors led to the mistaken early dates, including historical fluctuations in the amount of each carbon isotope in the atmosphere, inbuilt statistical errors in the method used to calibrate the dates, and the phenomenon of 'inbuilt age' (McFadgen, 1982; McFadgen *et al.,* 1994; Anderson, 1991). Inbuilt age affects samples containing wood residues, such as charred firewood, canoes, dwelling remains and even insect and rat remains. The carbon in these samples is often from trees that were many centuries old when humans used them or animals gnawed on them. Shells in estuarine areas or near coastal limestone deposits can also be affected by inbuilt age, and on Pacific islands they can also contain ancient carbon that has leached from coral reefs (McFadgen and Manning, 1990; Anderson, 1991). As a result the early dates for most archaeological sites are now being revised and the history of human settlement throughout the Pacific is getting shorter (Spriggs and Anderson, 1993).

Most archaeologists now accept that inbuilt age has distorted New Zealand's radiocarbon dates and that first settlement is unlikely to have occurred before about A.D. 1200, though a few may still hold to the possibility of earlier settlement (e.g. Sutton, 1994). Very few, however, seem to have come to terms with the statistical quirks in the dating method or the historical fluctuations in atmospheric carbon isotopes. The small number who are trying to correct these calibration distortions predict that the first settlement date may eventually turn out to be as recent as A.D. 1300-1350 - a date which corresponds with the traditional genealogies (McFadgen *et al.,* 1994).

A recent report of 2,000-year-old rat bones has added some confusion to the picture, at least in the media, even though the bones were not accompanied by any evidence of early human settlement (Holdaway, 1996; Rudman 1996b). Rat bones are notoriously hard to date and, at this stage, the court is still out on their age as the Rafter Radiation Laboratory reviews the dates and the methodology. However, few, if any, archaeologists expect the rat bones to rewrite the emerging new view of New Zealand prehistory which shows human settlement to have been much more recent than previously thought and not a chance event but a deliberate and skilled achievement.

The environmental implications of population growth are, in one sense, easy to gauge. More people generally means more environmental pressure. However, it can also be argued that a larger population will provide a larger economy of scale with a bigger tax base and a larger marketplace from which to fund environmental protection services and technologies. Such services and technologies will be necessary because, as human numbers rise, so will the demand for water, energy and waste disposal services.

These pressures are more likely to be felt regionally than nationally because the population is very unevenly distributed. Half the people live in the upper North Island, a quarter live in the lower North Island and the remaining quarter live in the South Island (see Figure 2.2). For all New Zealand's rural landscapes and agricultural imagery, 85 percent of the population is concentrated in towns and cities, many of which, including the largest population centres in each island (i.e. Auckland and Christchurch), are prone to water supply shortages. Population increase has been particularly intense in the Auckland area, creating concerns not only about water supply but also waste management, coastal water quality and the spread of urban settlements over wetlands and high fertility farmland.

If sheer weight of numbers is one indicator of population pressures on the environment, the composition of the population is another. For example, the age structure of the population is changing. Although New Zealand has a comparatively young population the proportion of elderly is slowly increasing. This may have environmental implications, such as an increase in one person households, which may drive up household energy consumption, particularly heating. The increased demand for health care may compete with other public spending priorities, including the environment. The elderly will also be more reliant on motorised transport than younger people (though, on the other hand, they may wish to travel less). This may increase the demand for better public transport in urban areas but may also generate demand for road access into hitherto remote wilderness areas.

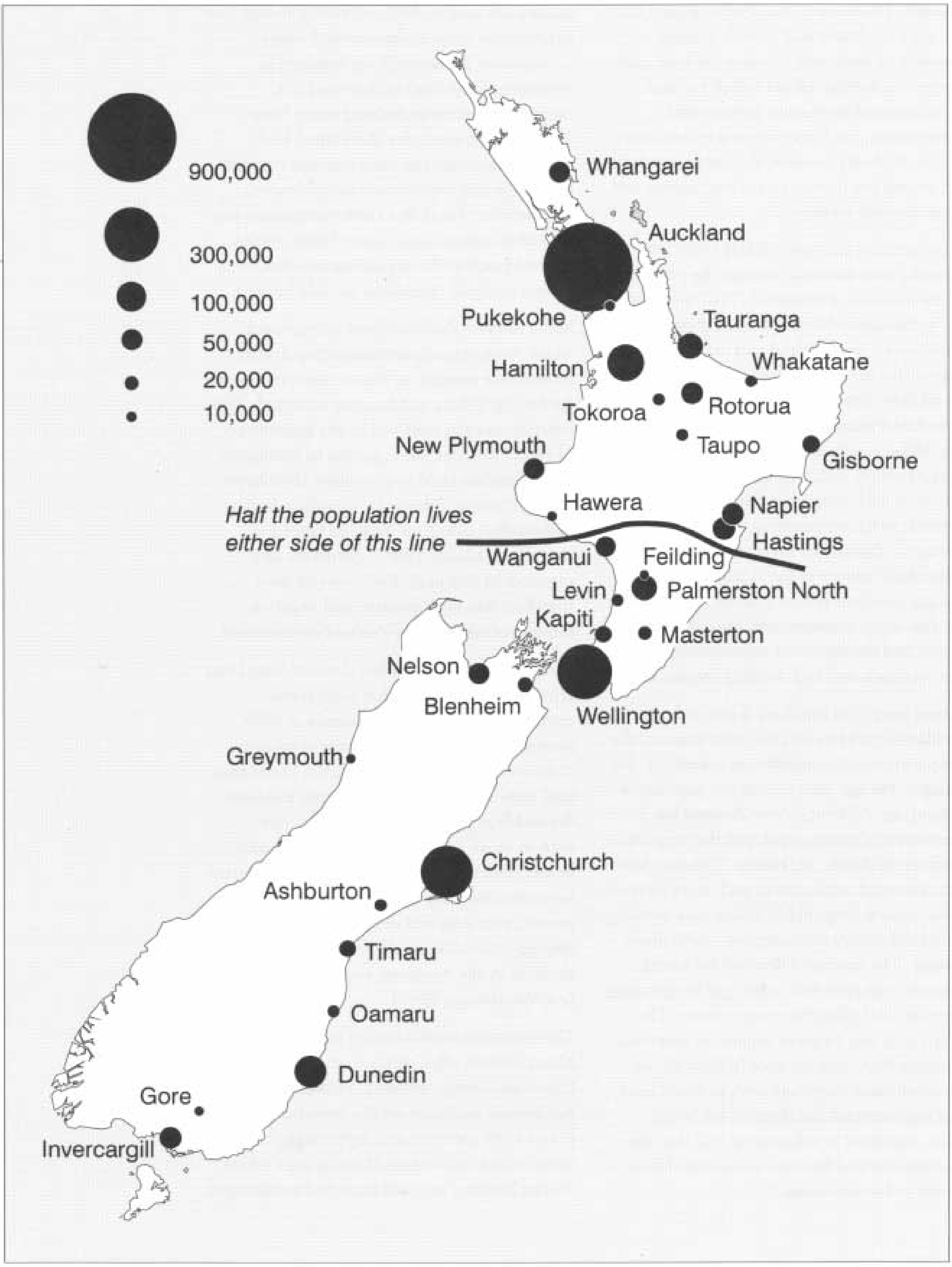
Ethnic diversity is another aspect of population composition that can have environmental implications. The cultural differences among groups can lead to different values, beliefs and practices on some environmental issues. Compassion for animals, for instance, is widespread in British culture and is a common element underlying many New Zealanders' concern for threatened birds, marine mammals and their habitats (though less so for fish, reptiles and invertebrates). On the other hand, the same compassion also underlies opposition to some forms of pest control (such as the myxomatosis virus for rabbits and cull operations on wild horses).

Many of New Zealand's pest animals and weeds were actually introduced by British immigrants wanting to pursue their traditional gardening, fishing and hunting activities. This practice was not confined to the last century. In recent decades, some groups of immigrant British anglers tried to propagate their home sport of "coarse fishing" by illegally releasing noxious fish into New Zealand lakes and rivers (McDowall, 1990). Attitudes and practices of distinctly British origin have therefore had both positive and negative influences on the New Zealand environment.

Some Asian groups in New Zealand have been criticised for practices that contravene environmental laws. For example, a 1995 survey of 30 traditional Chinese medicine shops in Auckland and Wellington found that half were selling illegally imported products derived from highly endangered species, such as musk deer, tigers, rhinoceroses and bears (Anderson, 1995). Ministry of Fisheries inspectors have reported that immigrant groups from Asia and contribute disproportionately to the over-harvesting of shellfish in the Auckland and Wellington areas (e.g. Weatherley, 1996).

The environmental values of the indigenous Maori culture often differ from those of European environmentalists. Maori, for example, put greater emphasis on the protection of places with ancestral and mythological associations, unlike non-Maori groups whose shorter histories here and imported mythologies

**Figure 2.3**
**Distribution of the New Zealand population in 1991.**



provide fewer ancestral or religious connections to the environment. Maori also put greater emphasis on conservation for human use, particularly natural food-bearing potential, and relatively less on conservation for intrinsic or aesthetic value (Barrington, 1995; O'Regan, 1994; Jeffreys, 1995; King, 1996; Kirikiri and Nugent, 1995; Moller, 1996; Roberts *et al.*, 1995; Taylor, 1994).

Cultural perceptions also differ in attitudes to water. Maori view water as a living thing, animated by a spiritual force, *mauri*, which pervades all of nature and can be easily defiled not only by pollution but by other actions (Douglas, 1984; McCan and McCan, 1990; Patrick, 1987; Taylor and Patrick, 1987). Similar beliefs are known from many other parts of the world, including India, the Americas and pre-Christian Europe (where their vestige survives in the Catholic tradition of holy water). However, few European New Zealanders share this view. The cultural difference means that Maori have tended to accord higher priority to wastewater discharge issues than have many mainstream environmentalists. It also means that perceptions of water quality can differ. Water that is chemically harmless can offend Maori sensibilities, while water that has passed through soil and therefore satisfies the Maori view on purity can contain contaminants such as nitrate (Hoare and Rowe, 1992).

At present, New Zealand's 3.6 million people can be classified ethnically into: European only (79 percent), Maori only (10 percent), Maori combined with European or other (5 percent), Pacific Island groups (4 percent), Chinese (<2 percent), Indian (<1 percent) and other (<1 percent). These rather precise percentages understate the multiple ethnic origins of many people and the diverse range of cultures and languages encompassed by the smaller categories. Pacific Island cultures include those from Samoa, the Cook Islands, Niue, Tokelau and Tonga, while the Chinese and Indian categories also include a variety of languages and cultures.

The ethnic mix continues to evolve through both intermarriage and immigration. In 1974, the Government adopted a policy which ended unrestricted immigration from Britain and Ireland and set down common criteria for immigrants from all countries. This system was based on an Occupational Priority List (OPL) which allowed entry to people who had been offered jobs for which no New Zealanders were skilled. The OPL system lasted until 1991 when it was replaced by a new system based on two sets of criteria: a General Skills Category (also known as the points system) and a Business Investment Category.

The purpose of the new system was to attract not only labour skills, but also entrepreneurial skills and investment capital. It remained in place for four years and attracted high numbers of new immigrants, especially from north Asian countries such as China, Taiwan and South Korea. It also brought hundreds of millions of dollars into the country, much of which was invested in real estate. Net migration over the period 1991-95 was 63,500, compared to a net migration loss of 35,000 in the previous five years (Bedford, 1996). In 1995, about 55 percent of the permanent and long-term immigrants were from Asian countries, about 32 percent were 'white nationalities' from Europe (mostly Britain and Ireland), Australia, North America and South Africa, and 13 percent were from elsewhere. In October 1995, the immigration criteria were changed yet again, with a renewed emphasis on English language competence among other things. Since then, immigration levels have fallen, especially from north Asia.

**The Maori population**

Linguistic and archaeological evidence suggests that the Polynesians who first colonised New Zealand came from central Polynesia (Davidson, 1984; Crawford, 1993; Biggs, 1994; Harlow, 1994). This is supported by genetic research on New Zealand's Pacific rats, or kiore, which are most closely related to rats in the Society Islands (e.g. Tahiti, Raiatea etc.) and the nearby southern Cook Islands (Matisoo-Smith, 1996; Rudman, 1996a). There seems little doubt that the voyages were planned and navigated. The sudden profusion of archaeological sites suggests that the settlers landed in various parts of the country over a relatively short period of time (McFadgen *et al.*, 1994; McGlone *et al.*, 1994).

At first, the abundance of meat from marine mammals and large birds probably allowed rapid population growth. Seals and moas bore the brunt of this heavy exploitation. However, once they began to decline, as they did by about A.D. 1500, the range of alternative food sources became more limited. The native plants are generally poor carbohydrate sources and the imported tropical plants, particularly kumara, only grew year round in the upper half of the North Island, and would not grow at all through much of the South Island. Although the first New Zealanders also ate the dogs and rats that they introduced, these animals are not herbivores and so were less inclined to convert leaves and grasses, which humans cannot digest, into meat, and more inclined to compete for more digestable food, such as birds and eggs.

Evidence from human skeletal remains shows that life was short and hard, despite the strong build of the people and the absence of infectious diseases. As in other preindustrial societies, the average age at death was around 30, with an estimated life expectancy of 45–50. Arthritis and spinal degeneration were common after age 25 and the small number who actually got beyond 40 to claim their allotted span had usually lost their teeth. From the small samples examined, tooth decay seems to have been more common in the early period when meat from seals and large birds was readily available. In the later period, tooth decay seems to have been replaced by tooth wear as vegetable fibre, primarily fern root, replaced meat in the diet (Houghton, 1980, 1996; Davidson, 1984).

Throughout most of the South Island and much of the North, the economy was largely based on hunting and gathering, with hunting being more common for tribes that ventured inland, and seafood gathering more common around the coast. Fishing was highly important everywhere, particularly for freshwater eels and, around the North Island and Cook Strait, coastal snapper.

Kumara gardening was also practised in the warmer areas, particularly the upper North Island where about 80 percent of the population lived. The process, known as swiddening, involved burning the forest edges and planting kumara in the ashes. After two or three seasons, the plots were surrendered to the fiercely growing bracken fern whose tangled root mass made further cultivation almost impossible (Cameron, 1961; Leach, 1980). A new kumara plot would be cleared while bracken root was harvested from the regenerating site. A decade or more later, when the bracken had been succeeded by light woodland, the site would be burnt off again for kumara.

Swiddening tends to be associated with small, impermanent, villages and this may explain why the Maori population often consisted of small groups frequently on the move within broad tribal areas. In some areas, however, where tribes were sufficiently powerful to resist raiders and territory loss, permanent gardens and settlements could be developed. Here, the soil was regularly renewed by adding sand and gravel to aerate it and perhaps suppress the regenerating bracken. Over the centuries, these Maori *plaggen* soils were built up to depths of 20–50 centimetres over large areas, particularly in the mid-Waikato basin (2,000 hectares), the Waimea Plains near Nelson (400 hectares) and in many coastal areas around the North Island and north-eastern South Island (McFadgen, 1982).

Although forest fires were occasionally ignited by lightning-strike throughout New Zealand's drier zones well before people came, fires became much more widespread and frequent after Maori settlement. Climatic conditions may have aided this process because the early centuries of Maori occupation seem to have coincided with a long dry period (Grant, 1994). By about A.D. 1600 the most vulnerable animals had become extinct or depleted, and much of the easily burned forest had been cleared and replaced by tussock, bracken and light scrub (see Chapter 8). For the next two centuries regenerating vegetation continued to be burnt. European settlers later intensified this process in converting vast areas to sheep pasture.

It is widely accepted that by about A.D. 1600 Maori society had entered a 'classical phase' in which territorial defence and tribal customs to allocate and regulate resource use became significant elements (Davidson, 1984). Different tribes developed customs for protecting historically significant sites (particularly ancestral burial grounds) and important food resources (e.g. some bird species, fish stocks, and shellfish gathering areas). Some sites were rendered tapu (sacred and off-limits), and some species were subject to rahui (temporary harvesting bans) or to complex tikanga maori (harvesting protocols). These customs, combined with climatic factors and the inherent limitations of non-metal technology, contributed to a more stable relationship between Maori society and the environment for the next two centuries.

Fortified villages, or pa, were built in the upper North Island during this period, perhaps to defend valuable garden areas. Warfare which was probably always present to some degree, was rife by the time Europeans arrived in 1769. Cannibalism was also widely practiced, with enemies and slaves providing a rare, but prized, treat which only men were allowed to eat in most cases (Buck/Hiroa, 1949; Davidson, 1984; Flannery, 1994; Vayda, 1960).

Settlement patterns varied greatly, depending on the main means of getting food (i.e. gardening or gathering, with or without hunting or fishing) and whether war or peace prevailed. Most of the population clustered in the north where it was warmer, or clung to the coastline where kai moana (sea food) was readily available. When the British explorer, James Cook, arrived in 1769 he found settlements ranging from 300 to 500 households, some in dispersed hamlets, some in large pa and some in isolated households.

Cook's surgeon, Forster, estimated the total Maori population to be around 100,000 in 1769, of whom barely 2,000 were in the South Island. In the early 1800s, population estimates by missionaries and settlers, who tended to live in high density areas, ranged from 106,000 to as high as 200,000 or more (Department of Statistics, 1990). These days, archaeologists and demographers consider the lower figures more plausible (Davidson, 1984; Fox, 1983; Pool, 1992). A recent thorough review of the evidence concluded that "the population would have reached barely 100,000 people before it suffered the shock of European contact" (Pool, 1992). Another recent estimate, based on a range of archaeological evidence, puts the population at no more than 80,000 in 1769 (Anderson cited in Houghton, 1996).

Whatever its exact size when Cook arrived, the Maori population suffered its first impact in the 1790s as a result of European diseases and the acquisition of guns. Whether these introductions led to an immediate population decline is not known. To some extent, they may have been offset by better infant survival following the nutritional improvements which came with potatoes, corn, livestock, and feral pigs and goats. The potato provided, for the first time, an abundant carbohydrate source throughout New Zealand (Cameron, 1961).

In the early 1800s Maori communities prospered considerably by converting large new areas of forest to agriculture. Potatoes grew best in soils cleared of virgin forest rather than regenerating scrub, so widespread potato swiddening led to renewed deforestation (Cameron, 1961, 1964). Entrepreneurial Maori traders supplied visiting ships with large quantities of potatoes, pork, wheat, maize and ropes made of harakeke (native flax), generally in return for iron implements including weapons. Some acquired their own flour mills and sailing ships. By 1836, Maori agriculture in New Zealand was seen as a granary for the growing Australian colony of New South Wales. However, that all changed with the large-scale immigration of Europeans which followed the signing of the Treaty of Waitangi in 1840 (see Box 2.2).

The first census of the Maori population, in 1858, found a total of 56,000 living here. This fell rapidly during the 1860s land wars to about 47,000 by 1874. In 1896 the population reached its lowest point, 42,000. By this time, Maori were perceived as a 'dying race', reduced by waves of European diseases, such as dysentery, diptheria, influenza, measles, whooping cough, tuberculosis and typhoid, as well as waves of warfare, both inter-tribal and with Europeans, which flared up in the 1820s, the 1840s and the 1860s. They had also lost most of their tribal land, much of it through legitimate sales, but also large areas through fraudulent or forced sales, and confiscation.

**Box 2.2**

### *The Treaty of Waitangi*

The Treaty of Waitangi, frequently referred to as New Zealand's founding document, was signed in 1840 by representatives of the British Crown and most of the country's Maori rangatira (chiefs). At the time, only a handful of European settlers lived here, but there had been 70 years of contact between Maori society and British seamen, missionaries, traders, sealers and whalers. Maori communities grew commercial crops for trade and export. European tools, weapons, clothing, Bibles, crops, livestock, medicines, tobacco and diseases—were widespread among coastal Maori communities, especially in the north, and European genes were also becoming more common. In fact, just a few years later, the Government would consider it necessary to pass an ordinance preventing European fathers from abandoning their Maori children.

Two versions of the Treaty were drafted, one in English and one in Maori. Only 39 rangatira signed the English version while more than 500 signed the Maori one. Broadly, the three articles of the Treaty state that:

I. the rangatira cede authority "absolutely and without reservation" to the Crown (though the type of authority continues to be debated because of language differences in the two versions);

II. the Crown promises to protect Maori entitlements to their land and other resources (though the nature of those entitlements is also debated because of language differences), while Maori wishing to sell land must (in the English version), or may (in the Maori one) offer it to the Crown first; and

III. Maori are conferred the rights and privileges of British citizens.

Because some of the words in the two versions are not exact translations, debate continues as to what was actually agreed in the Treaty. In the English version the rangatira ceded 'sovereignty' (which means supreme authority) to the Crown. In the Maori version, they ceded 'kawanatanga', a term first coined by Bible translators to convey the governorship role of the Roman procurator of Judea, Pontius Pilate. Also, in the English version of Article II, the Crown agreed to protect Maori 'possession' of their land and other resources. In the Maori version, it agreed to protect their 'te tino rangatiratanga' (supreme chieftaincy) over their lands, settlements and 'taonga' (possessions or valuables) (Orange, 1987). Most Maori believe that the rangatira did not intend to surrender their traditional authority over people and lands, but, rather, expected the Crown to protect this authority from outside challenges. For a decade beforehand, several Maori leaders had been requesting British protection. Some feared colonisation by the French, who were seen as ruthless, and others had tired of inter-tribal warfare in which British guns and 'riff-raff' played increasingly significant roles. British missionaries, settlers and traders also requested Crown protection with some wanting to legitimise commercial settlement aspirations. When the Colonial Office eventually did agree to acquire a new protectorate, it had several motives, including the protection of British trade in the region (Orange, 1987).

In the 150 years since the Treaty's signing, Maori communities have voiced many grievances over the Crown's failure to provide the protection promised in the Treaty. In some cases, the Government was not only negligent, but actively complicit in forced land sales, fraudulent sales, or outright confiscations. The introduction of trout, which preyed on native fish, and the failure to protect eel weirs and other traditional fisheries from development and drainage, added to the list of grievances. Eventually, in 1975, the Treaty of Waitangi Act was passed. It established an investigative body, the Waitangi Tribunal, to enquire into claimed grievances and, where appropriate, make recommendations to government on how claims might be redressed. Although the recommendations are not binding (except for land covered by the State Owned Enterprises Act 1986), they are taken very seriously. At first, the Tribunal could only investigate grievances arising after 1975, such as objections to sewage discharges near tribal fishing and food gathering areas. In 1985, however, an amendment extended its brief back to 1840 opening the door to long-standing land claims and also natural resource claims (e.g. fisheries, radio air waves). About 550 claims have been lodged and most of these are still pending. Natural resources are central to many of the claims, including the following examples.

**Te Atiawa claim 1983:** This claim was brought by the Te Atiawa people of Taranaki to stop a proposed sewage pipeline which would discharge effluent from the synthetic fuel plant at Motunui onto or near traditional fishing grounds. On advice from the Waitangi Tribunal, the Government funded a long outfall pipeline to protect the kai moana (sea-food).

**Kaituna claim 1984:** This claim was brought by the Ngati Pikiao people against a proposed pipeline that would discharge sewage into the Kaituna River. The Government accepted the Tribunal's recommendation in support of the claim and provided funding for an alternative scheme.

**Muriwhenua 1988 and Ngai Tahu 1992 claims:** These claims successfully asserted that the new fisheries management regime created by the Crown was contrary to Article II of the Treaty. At the same time, successful court actions led to the Maori Fisheries Act 1989 and the Treaty of Waitangi Settlement (Fisheries) Act 1992, which provided for a $280 million two-stage settlement that transferred to Maori interests a 50 percent share in the Sealord fishing company, a 10 percent share of existing fish quota, and 20 percent of the quota for any new quota management species.

**Indigenous flora and fauna claim (Wai 262):** This claim seeks ownership and intellectual property rights over New Zealand's native plants and animals, iwi control over their use and conservation, a share of future benefits from their use, and recompense for past denial of benefits. Lodged in 1991, initial hearings are commencing in 1997.

**Mohaka River (Wai 119):** This claim asserts Ngati Pahauwera ownership of the Mohaka River which had been recommended for a Water Conservation Order (WCO) by the Planning Tribunal. The Waitangi Tribunal recommended that the WCO include an agreement between the Crown and Ngati Pahauwera on a river management regime but the Resource Management Act provisions on WCOs prevent this.

**Waikato-Tainui claim:** This was a claim for compensation for the wrongful confiscation of lands and natural resources. It dated back to 1863 when, by Orders in Council under the New Zealand Settlements Act 1863, British troops attacked unarmed Tainui people and confiscated 1.2m hectares of land. Recompense of $170 million in land, money and assets was made to Tainui by the Crown in 1996, but natural resources such as the Waikato River were specifically excluded, and claims relating to them remain.

**Ngai Tahu claim (Wai 27):** This claim arises from the unreasonably low prices Ngai Tahu received for their land in sales last century, and from the Crown's failure to meet other commitments on land reserves and mahinga kai (areas where food is gathered). In late 1996 an agreement in principle was announced between the Crown and Ngai Tahu for a settlement involving land, money and assets, and provisions for conservation management by Ngai Tahu.

In December 1994, the former National Government released its *Proposals for the Settlement of Treaty of Waitangi Claims*, including the controversial 'fiscal envelope' proposal to set aside no more than $1 billion for all future Treaty settlements. The document also interpreted Article I of the Treaty as giving the Crown ultimate responsibility for the use of natural resources with Article II obliging the Crown to take into account other Treaty interests, such as traditional use claims. Article II was interpreted as guaranteeing Maori use of natural resources for cultural and spiritual purposes, as envisaged in 1840, but not ownership or control of those resources. At the end of 1996, the proposals were under review by the new coalition government.

To prevent future grievances, Treaty obligations are now recognised in our environmental laws and policies. For instance, fisheries legislation recognises Maori Treaty interests, and the Resource Management Act requires those empowered by the Act to:

- recognise and provide for the relationship of Maori and their culture and traditions with their ancestral lands, water, sites, waahi tapu and other taonga (section 6(e));
- have particular regard to kaitiakitanga (the exercise of guardianship by Maori) (section 7(a)) and;
- take into account the principles of the Treaty of Waitangi (section 8).

The Resource Management Act also has other provisions recognising particular Maori interests and requires decision-makers under the Act to provide for these in some plans and policy statements . The Act also requires iwi to be consulted during the preparation of plans and policy statements and to have the normal opportunities to participate in plan and consent processes.

The Environment Act 1986, and the Conservation Act 1987, also require the 'principles' of the Treaty to be taken into account when managing physical and natural resources. The Court of Appeal and the Waitangi Tribunal consider these principles to include:

- the essential bargain of the Treaty, vesting rights and obligations in both parties;
- the requirement of tribal self-management/rangatiratanga;
- the concept of partnership;
- the need for active protection of Maori interests; and
- the obligation to provide redress for past grievances.

Together, these laws explicitly recognise Maori environmental values and practices and codify the need for an effective working relationship between resource managers and Maori communities. Obligations within this relationship are still evolving, with the errors of the past providing key lessons for the future.

By the 1890s less than one-sixth of the country remained in Maori ownership, and a quarter of that was leased to Europeans. The remaining Maori land was mostly rugged and bush-clad, and unsuitable for agriculture. Living in poor conditions— often in insanitary, makeshift camps—most of the surviving Maori communities grew scarcely enough food for their own needs and relied increasingly on public works and seasonal work on European farms.

The turnaround in Maori health and population growth probably began in 1900 when the Department of Public Health was established and a generation of educated Maori leaders, such as Maui Pomare and Peter Buck/Te Rangi Hiroa, began to encourage better housing, improved nutrition, and vaccination against infectious diseases. They also convinced their communities to improve the quality of water supplies and adopt hygienic sanitation measures. As epidemics and infant mortality declined, life expectancy rose, and the population climbed rapidly. Between 1921 and 1951, the Maori population doubled, and then doubled again by 1971.

The rapid growth in Maori population coincided with another major change—the rapid urbanisation that followed World War II. The industrialisation drive of the 1950s drew large numbers of rural workers, including Maori workers, into the cities as labourers and factory workers. At the end of the war, 75 percent of the Maori population were still living in rural areas. One generation later, by 1970, more than 75 percent had moved to towns or cities and, by 1991, the percentage had grown to 81 percent.

#### *Maori today*

Today, people with Maori ancestry number around 560,000 (15 percent of the population). Most identify themselves as ethnically Maori (either alone or in combination with other ethnic affiliations) and are counted as such in official statistics, which show ethnic Maori making up 13 percent (around 480,000) of the total population. Although the Maori birth rate is declining, it is still higher than the national average, so that by 2031 the descendants of today's ethnic Maori will comprise slightly more than 15 percent of the population.

The traditional Maori social structure consists of groups and subgroups defined by common ancestry and location. Within this system, status was often conferred on the basis of whakapapa (genealogy). Today there are some 40 major iwi (tribes), most still based in rural areas and headed by hereditary rangatira (chiefs) and councils of elders. Each iwi is made up of several hapu (sub-tribes) which each contain many whanau (extended families). Each whanau is headed by a male kaumatua (elder).

By taking most hapu members away from their communities, the post-war urban migration removed them from the authority of their kaumatua and the support of their whanau. Social problems began to appear. Young Maori men soon had three times the imprisonment rate of young white males. Family life also began to suffer as the transition to suburban nuclear family life proved too difficult for some. Sole parenthood increased. The quality of housing was also relatively poor in many cases, reflecting the lower income status of most Maori workers.

These problems were compounded in the mid-1970s when the economy faltered and, for the first time in decades, unemployment returned to New Zealand. As always, unskilled workers were the first to bear the brunt. From the outset, Maori unemployment rates were higher than those of the general population and have remained so to the present day.

Compared to the rest of the population, Maori are more likely to be unemployed (16 percent compared to 5 percent of non-Maori in late 1996), without educational qualifications (65 percent compared to 40 percent in 1991), on income support (56 percent against 20 percent in 1991), in sole parent families (44 percent of Maori children against 18 percent in 1991), and renting rather than owning their home (40 percent compared to 21 percent in 1991). In 1993, Maori men were seven times more likely than non-Maori to be in prison, Maori women were nearly six times more likely to seek shelter at a women's refuge, and Maori of either sex were three times more likely to be victims of homicide (Statistics New Zealand, 1994a, 1995; Public Health Commission, 1994).

These disparities are also reflected in health statistics. Maori infants are twice as likely to die in their first year (13 per 10,000, compared to 6.5 for non-Maori), and their life expectancy beyond the first year is shorter (68 years compared to 73). Maori are twice as likely to smoke tobacco as non-Maori (38 percent compared to 19 percent in 1996), and are also twice as likely to develop lung cancer (about 200 cases per 100,000 in 1992, compared to 110 for non-Maori). Maori also suffer disproportionately from some other health problems, being four times more likely to develop diabetes, and twice as likely to be hospitalised for mental disorders and drug or alcohol problems (Ministry of Health, 1996; Public Health Commission, 1994; Statistics New Zealand, 1994a, 1995).

Despite the serious problems and disadvantages which these statistics highlight, they also hide the fact that, on some matters, Maori progress has been considerable. Maori health is actually better now than it ever has been, with life expectancy a decade longer than it was in the 1940s. Educational attainment is also improving, albeit slowly. Most significantly, recent decades have brought a cultural and political renaissance. This began among urban Maori in the late 1960s with calls for the revival of the Maori language, followed in the 1970s by strengthened calls for the return of alienated land. Several successful environmental campaigns against sewage outfalls near tribal waters also gave strength to the Maori voice.

Today, the Maori language is widely taught in schools and in pre-school Kohanga Reo, and is regularly heard on television and on radio (see Box 2.3). Land claims and other Treaty of Waitangi grievances are being recognised through the Waitangi Tribunal and, where appropriate, redressed. The Treaty itself now has greater status than it ever had before, with central and local government obliged to consult with Maori before making decisions on matters affecting them. This means that Maori views on resource management and environmental issues are now more frequently heard and acted on.

**Box 2.3**

### *Maori language: the spoken taonga*

New Zealand's short history of human settlement has bequeathed it only one indigenous language—Maori. This is fortunate because it has allowed a national rescue attempt to take place in which the education system, the media, government organisations and all tribes have been able to unite. In countries where many indigenous languages are spoken, such as Australia, Indonesia, Papua New Guinea, and throughout the Americas, such a united effort would be impossible. The worldwide spread of English and of several other major languages, such as Spanish and Arabic, has come at a great cost to the world's indigenous languages, many of which have been lost. Linguists estimate that 20–50 percent of the 6,000 surviving languages are no longer being taught to children and will become extinct in the next century (Kleiner, 1995; Vines, 1996). Only 600 languages appear to be expanding. Until recently, Maori was not among them.

New Zealand Maori belongs to a group linguists refer to as Eastern Polynesian, and is closely related to Cook Islands Maori, Tahitian, and Hawaiian. After the language reached New Zealand 700–800 years ago, it underwent small changes as it grew independently of its parents. Some dialectal variations crept in as tribes spread throughout the country. The most marked of these was probably the extinct Moriori dialect spoken on the Chatham Islands (Clark, 1994). The greatest change, however, occurred with the arrival of Europeans. Many new Maori words had to be created to deal with the avalanche of exotic ideas, species and objects that came with the new settlers.

Traditionally, Maori was a spoken, not a written, language. Genealogies and stories were passed on by word of mouth. The written version was developed by missionaries who published the first Maori Bible translation in 1827. For some decades after that, Maori remained the common form of cross-cultural communication. Surrounded by Maori neighbours, traders and playmates, many of the first European settlers and their children were fluent speakers of Maori. However, the language balance tipped in the 1860s when white immigration soared. The New Zealand public school system, established in 1877, installed English as the sole language, both in the classroom and the playground.

By the 1950s and early 1960s the Maori language appeared to be in danger of extinction. The move to save it was initiated in the 1960s by educated urban Maori, alienated from their culture and wanting to reclaim their heritage. By 1976, Maori was being taught to 11,000 pupils in 123 secondary schools while 100 primary schools were offering courses in Maori studies. Two decades later, more than half (58 percent) of all school children were studying Maori language. Another big step in reviving the language was the Kohanga Reo programme and the Kura Kaupapa Maori schools. Te Kohanga Reo is family based, similar in many respects to kindergartens or play centres, but where the children speak only Maori and learn about Maori culture and customs from their kaumatua (elders). The first Te Kohanga Reo opened in 1982. Today there are 802 of them with around 14,500 children in attendance. Kura Kaupapa Maori (Maori immersion) schools are schools where only Maori is spoken and the curriculum is based on Maori values. In 1990, there were six officially designated Kura Kaupapa Maori schools with 190 students. By 1995, this had risen to 38, with 2,450 students. Another 444 schools were offering some form of Maori immersion education to more than 25,000 students in 1995 (Statistics New Zealand, 1996).

In 1987, the Maori Language Commission was established to promote the Maori language and its use as an 'official' language of New Zealand, as a living language, and as an ordinary means of communication. One implication of Maori becoming an official language was its acceptance for use in court proceedings. When a Maori speaker exercises the right to to use Maori during court proceedings, the onus is on the presiding officer to ensure a competent translator is present. Testimony does not have to be recorded in Maori.

The revival of Maori language education has come just in the nick of time. The number of fluent Maori speakers had plummeted from an estimated 64,000 in the mid-1970s to just 10,000 by 1995, of whom 44 percent were aged over 60 (Statistics New Zealand, 1996). Today, about 60 percent of Maori aged 16 and over can speak some of their language, but with varying ability. The Kohanga Reo system is thought to be producing about 3,000 speakers each year, and the study of Maori language at tertiary level has been increasing. Maori language radio stations now broadcast throughout the country and European announcers and television presenters try to give the correct pronunciations of Maori names and place names. There is even a computer software programme which allows Maori language speakers to operate their PCs in the Maori language.

**The European population**

Most of New Zealand's European migrants came from England, either directly or via Australia, and significant numbers also came from Scotland and Ireland. Their origins are reflected in their speech. New Zealand English evolved from the accents of nineteenth-century Australia and southern England, with some Scottish influences in the lower half of the South Island.

Many other European nationalities came here in small numbers, including Germans, who numbered about 10,000 by the 1930s, Dalmation gum diggers around Northland's Dargaville, Scandanavian farmers around Dannevirke and Norsewood in southern Hawkes Bay, Italian fishermen in Wellington's Island Bay, Greeks in Wellington's Mount Victoria, French colonists at Akaroa, and some 30,000 Dutch immigrants who settled in various parts of the country during the 1950s and 1960s. In the last decade, white South Africans have become a significant immigrant group. Overall, however, the general tenor of New Zealand's language and culture has been shaped by the English and Australian influence, with American mass media also playing a role in recent decades.

The first European to see New Zealand was the Dutch explorer, Abel Tasman, in 1642, but he did not tarry after four of his landing party were killed by Maori. The next European contact came nearly 130 years later, when the British explorer, James Cook, reached New Zealand. Cook was closely followed by others. Throughout the 1770s a number of expeditions came and went, including several from France and one from Spain. Cook himself returned twice (in 1773 and 1777).

Whalers and sealers arrived in the 1790s, followed a decade or so later by missionaries and traders. The first mission station was established by Samuel Marsden in 1814 and other mission stations were established over the next twenty years, mostly concentrated in Northland. Harakeke (native flax) and timber were two early items of trade. Timber mills were established in the north by 1820 and a shipyard was built in the Hokianga Harbour in 1826. From 1829, shore-based whaling stations were established and became focal points for small European settlements. The total European population was still less than 2,000 in early 1840 when the Treaty of Waitangi was signed. That was soon to change.

Between 1840 and 1845, about 9,000 English settlers came out to establish settlements at Wellington (from 1840), Akaroa (1840), New Plymouth (1841), Wanganui (1841), and Nelson (1842). Without suitable farmland these enclaves became impoverished encampments whose very existence depended on the tolerance of the local Maori. However, in the late 1840s, sheep runs were established along the east coasts of both islands on extensive areas of tussock grassland purchased by the Crown from local tribes and then leased or sold cheaply to prospective runholders. The sheep multiplied and provided an economic base for the Otago and Canterbury settlements which were founded by Scottish colonists at Dunedin (1848) and English colonists at Christchurch (1850). By 1854, the European population had reached 32,500—about half the size of the Maori population.

The influx of European immigrants increased steeply in the 1860s and even more so in the 1870s. The 1860s land wars between the Government and several North Island tribes brought 14,000 British troops to the country. Their spending was a considerable boost to the economy, but nothing compared to the discovery of gold in Otago in 1861. In two years, Otago's population increased five-fold to about 60,000. Miners, many of them Irish, poured in from the spent goldfields of Australia and California. By the end of the 1860s, New Zealand's European population stood at around 230,000 and the Maori population was now outnumbered by almost five to one. Almost two-thirds of the European population were concentrated in the South Island.

In the 1870s, the administration of Julius Vogel borrowed large sums of money to fund public works (e.g. roads, railways, public schools and an expanded civil service) and immigration schemes. Some 115,000 assisted immigrants were brought out from England, Scotland and Ireland, as well as a special settlement from Scandanavia whose labours turned the 'Great Bush' around Dannevirke and Norsewood into a landscape of family farms. The availability of cheap farmland is what drew many of the immigrants. In their home countries, land was the possession of a small privileged class; few could aspire to be more than tenant farmers, and most had to support themselves as impoverished farm workers or as factory labourers in the crowded and dirty industrial towns.

However, farm life in New Zealand was less than idyllic. With no export markets for products other than wool, and with an economic recession dampening the domestic market from the late 1870s into the early 1890s, many small farmers struggled to subsist. In addition, without fertilisers, the naturally poor soils quickly deteriorated in some areas. Only after the establishment of a frozen meat and butter export trade in the 1880s did farming became more viable. By the mid-1890s, the economy was growing again. New settlers continued to arrive, farms multiplied and townships and cities grew while forests and wetlands shrank. New Zealanders began to introduce progressive social policies, such as the provision of an old age pension, the extension of the vote to women, a 48-hour working week and the recognition of unions as equal bargaining parties in labour disputes. By the turn of the century, the European population exceeded 750,000.

Features of European settler society up to this time included a highly transient workforce with a high proportion of young unmarried men. Agricultural employment was usually seasonal rather than permanent. Strong divisions existed between some ethnic groups, particularly Catholic Irish and Protestant Scots and English, with the Irish having lower levels of income and education, and higher levels of imprisonment. The social divisions lingered on into the middle of this century, particularly in the south. Because the European population consisted mostly of first generation settlers, many cut off from families and friends, problems of alcoholism, crime and loneliness were common among the men. This slowly changed as immigration continued to swell the population and the sex ratio normalised. Between the 1860s and 1900, the ratio of European males per 100 females changed from about 170 to 110. By 1930, after the arrival of some 200,000 more immigrants, the sex ratio was almost even.

Throughout most of this century, New Zealand's economic and cultural life remained heavily tied to Britain, which was frequently referred to as 'home'. New Zealand's entry into World War I (1914–18) and World War II (1939–45) was primarily inspired by loyalty to Britain. Although the main contribution to both war efforts was food production, New Zealanders also gave 30,000 lives—several thousand of them Maori. In the post-war years, New Zealand's prosperity was almost totally dependent on Britain which remained our key export market into the 1970s. The last period of assisted European immigration to meet labour and skills shortages stretched from the late 1940s through to the early 1970s. It came to an abrupt end with the deteriorating economic conditions of 1974 and the adoption of a more open immigration policy.

Socially and economically, today's European population is, on average, better off than the Maori and Pacific Island populations, having higher average incomes, life expectancy and infant survival, and higher levels of home ownership, education and employment. The European population has a lower birth rate than other groups, mainly because Europeans tend to have smaller families and start reproducing later in life. However, the large size of the European population means that, in absolute numbers, it still accounts for half or more of the nation's unemployment, poverty, illness and criminal convictions. In several illness categories, such as skin cancer and cystic fibrosis, Europeans predominate for genetic reasons. They also predominate in illnesses of the elderly simply because the overwhelming majority of the country's over-65 age group is European.

The European impacts on the environment in just 150 years have been dramatic and are discussed in detail in Part Two of this report. Many of these impacts were economically motivated, and pursued to varying degrees by both European and Maori, but many were the result of a distinctively British set of recreational and aesthetic values. These cultural values favoured the creation of open spaces and the importation of many environmentally damaging plants and animals (e.g. deer, rabbits, cats, ferrets, trout, heather, ivy) for no other reason than to recreate familiar aspects of the European environment for hunting, fishing or aesthetic purposes (McDowall, 1994; Park, 1995).

### Other ethnic groups

The demand for labour in the post-war decades also attracted many people from elsewhere. By 1971, 45,000 Pacific Island people of various nationalities had settled here. By 1991 they and their descendants numbered almost 150,000 and made up nearly 4 percent of the total population. In general, they share many of the disadvantages of urban Maori. They have similar rates of unemployment, are even more likely to be renting, and are more prone to some diseases (e.g. rheumatic fever). On some other indicators, however, they are intermediate between European and Maori (e.g. educational qualifications, imprisonment rate, tobacco smoking, infant mortality).

Asian groups encompass a wide range of cultures, many of them of Chinese or Indian origin. On most socio-economic indicators, Asian New Zealanders are similar to the European population. The first Chinese immigrants were goldminers. Some 5,000 were living here by 1874, but discrimination and immigration restrictions reduced them to 2,000 by 1916. The Indian population was also very small to begin with, numbering 1,200 in 1936. In the post-war years, more people of Chinese and Indian origin have settled here. By 1991, just before the recent immigration boom, their respective numbers were about 40,000 and 30,000. Under the new immigration rules from 1991 to 1995 Chinese numbers increased more than other groups.

## NEW ZEALAND'S CULTURAL HERITAGE

What constitutes 'cultural heritage' can be a matter of intense debate: what one person or group values, others may not; one person's trash may be another's treasure. The New Zealand branch of the International Council on Monuments and Sites (ICOMOS) defines 'cultural heritage' as something "possessing historical, archaeological, architectural, technological, aesthetic, scientific, spiritual, social, traditional or other special cultural significance, associated with human activity" (ICOMOS New Zealand, 1993).

New Zealand's ethnic groups each have distinctive histories and cultures that contribute in different ways to our cultural heritage. While the core elements of these cultures were imported from parent cultures overseas, much adaptation and evolution has occurred within the New Zealand environment, particularly with the Maori culture which is distinctive among Polynesian cultures. The result is an evolving mix of Polynesian, European, and also Asian, ways of seeing and doing, making each new generation of New Zealanders slightly different from the previous one and yet intimately linked to it.

No matter what the timespan, our cultural heritage connects us to all who came before us, whether they paddled here from Hawaiki or hoisted sail in the ports of England and Scotland. Most of those who made the traumatic break with their homelands came to settle and build a new life, though some, like sealers, whalers, and itinerant gold miners, soon moved on. Yet all of them—hunters, farmers, merchants and miners—left their stamp on the landscape, whether as beach middens, terraced hillsides, old buildings or graveyards. They also left their mark in the languages we have inherited, the traditional crafts we still value, the fashions we reinvent, the religious ideas that many still adhere to, and the scattered written records, photographs and artefacts of yesteryear. All of these are aspects of our cultural heritage.

A comprehensive review of all these aspects of our cultural heritage is beyond the scope of this report whose focus is primarily on the natural and physical environment. As a result, the following discussion is confined to those aspects of heritage that relate to areas, places and fixed tangible objects. Other aspects of cultural heritage, such as museum collections, creative arts, customs and languages, are not included, though Chapter 9 of this report contains a discussion of culturally important plants and their uses (see Box 9.13).

**Places of cultural heritage**

New Zealand's cultural heritage places and objects can be roughly divided into four overlapping categories: places of significance to Maori; archaeological sites; historic buildings and structures; and cultural landscapes (Parliamentary Commissioner for the Environment, 1996a).

**Places of significance to Maori** may include 'everyday' sites, such as marae (regular gathering places), pa sites and mahinga kai (food gathering areas), as well as waahi tapu (see Box 2.4). Literally translated, waahi tapu means sacred place, but this translation fails to capture the deep emotional and spiritual significance of waahi tapu to the people associated with a site. Urupa (burial grounds) are the most obvious example of waahi tapu, but others can include ana tupapaku (burial caves), ossuaries, pa where battles have occurred, other sites where blood has been spilt, tauranga waka (sites where ancestral canoes have been beached) and some mountains (Manatu Maori, 1991).

Strong bonds link the most important waahi tapu sites to their appropriate tribes. Each iwi, hapu or whanau (tribe, sub-tribe or extended family) has its own definition of waahi tapu which is valid only to them; none would be so presumptuous as to define waahi tapu for another group. Often, the existence or location of a waahi tapu is known only to the local tribe, or to some members of the tribe, who would not consider making that information public (Manatu Maori, 1991). Conversely, sites that are waahi tapu for one tribe may be treated with indifference, or even contempt, by members of another tribe.

Many places of significance to Maori can also be classified from a scientific perspective as archaeological sites. These are valued not for personal or spiritual reasons, but for the information they can provide to those scientists who are trying to better understand our past. However, these different perspectives mean that the relationship between Maori values and archaeological values is not always a comfortable one (Parliamentary Commissioner for the Environment, 1996a).

New Zealand has a wide range of **archaeological sites**. Maori sites include pa, pits, terraces and ditches, platforms, house remains, ovens, stone structures, mounds and middens, source sites (e.g. for rocks), working areas and made soils, caves and rock shelters, rock and tree carvings and drawings, tracks and trails, and botanical evidence (Daniels, 1979). Archaeological sites reflecting colonial history include evidence of early European buildings, industrial sites, gold fields, whaling sites and shipwrecks. Other archaeological sites record the history of contact between Maori and European, such as early meeting places and battle sites.

**Historic buildings and structures** are, to many New Zealanders, the most obvious face of historic heritage. As well as buildings, these places include fortifications, ruins, lighthouses, bridges, industrial sites and, of course, the many cemeteries whose monuments and plaques provide the last, and often only, tangible testimony to a person's existence. Historic buildings range from single outstanding buildings (e.g. Pompallier House in the Bay of Islands, New Zealand's oldest surviving industrial building) to whole urban settings, such as a street of terraced houses, or a block of commercial buildings (see Box 2.4).

The final category of heritage places is **cultural landscapes**. With the exception of true wilderness areas, nearly all of New Zealand's landscapes are cultural, in that they reflect the generations of interaction between people and the natural environment. In general however, the term landscape heritage refers to landscapes whose combination of natural and cultural features is considered to be important enough to be retained for future generations (Parliamentary Commisssioner for the Environment, 1996a) (see Box 2.4).

Box 2.4

### *Three examples of heritage sites and areas*

**Multi-storey inner-city flats (1940s)**

With the easing of the Depression in the 1930s, a severe housing shortage became apparent throughout New Zealand. The newly elected Labour Government built thousands of state rental houses from 1937 to provide the working classes with affordable accommodation of a reasonable standard. In addition to the rental houses, a small number of blocks of flats of reinforced concrete were built in Wellington and Auckland. The earliest block of flats, built in 1939–40, is known today as the Berhampore (or Centennial) Flats. Other examples are the Dixon Street Flats (1941–44) in Wellington, and the Symonds Street and Greys Avenue Flats in Auckland (both built in 1945-47) (Shaw, 1991; Gatley, 1995).

The construction of flats, rather than detached houses, was prompted by shortages of building materials, skilled labour, and land in the cities (Gatley, 1995). While the state houses were conservative and standardised in their design, the flats were far more progressive and reflect the modernist 'international style' commonly associated with 1920s Europe and characterised by flat roofs and a lack of ornamentation. The flats illustrate the modernist views of the Department of Housing Construction's chief architect, Gordon Wilson (1900–59). Wilson designed the Berhampore flats and oversaw the design of several other blocks (Shaw, 1991). The modernist influence also came from a number of refugee European architects employed by the Department of Housing Construction from 1939 onwards—notably Ernst Plischke, who designed the Dixon Street Flats, and Fred Newman, who designed the Symonds Street and Greys Avenue Flats. The European architects hoped that the democratic socialist views underlying their modernist designs would be well received by a Labour government that had already initiated a progressive housing policy (Shaw, 1991).

Because of their unprecedented scale, the Dixon Street Flats were used by the Government for propaganda purposes to show the efficiency of the Government's housing activities both in New Zealand and overseas. The construction job developed a high public profile, and the building was opened six months before completion so that the opening would coincide with the election campaign of September 1943 (Gatley, 1995). The good views, services and amenities made the Dixon Street Flats popular with their tenants (Wellington City Council, 1995). But in spite of their perceived benefits, multi-storey flats never really caught on as state housing, mainly because they failed to cater to families with young children—the group given top priority for state housing at the time (Gatley 1995). Today, the Greys Avenue Flats are registered as a category 2 historic place by the Historic Places Trust, and the Berhampore and Dixon Street Flats are listed as heritage buildings in the Wellington City Council's District Plan (Wellington City Council, 1995).

**The Collingwood goldfields dams (1850s)**

Just before Collingwood on State Highway 60 is a small monument commemorating the 1856 discovery of the South Island's first payable gold a few kilometres inland at Lightband Gully. Today, three dams are the most obvious relics of the Collingwood goldfields. The largest, known as Druggan's dam after its original builder, is now a significant water-bird habitat and popular day walk destination. The small earth and rock dam built by George Druggan in the late 1870s was later enlarged by the Slate River Sluicing Company to improve the water supply to its claim. Druggan's dam is notable for its puddled clay core - a technique which involved using horses to puddle clay laid between two outer walls of rocks and earth. A saga of water supply problems afflicted the Slate River Sluicing Company and it was finally wound up in 1909 after extracting only marginal amounts of gold from its claim. The dam was used on and off until the 1930s.

A second dam, the Parapara Gorge dam near Richmond Flat, was built of concrete around 1895. The most impressive effort, however, was made by the Collingwood Goldfields Company in building a dam across the outlet of Boulder Lake, high in the barren Quartz Range. Fifty pound bags of cement had to be carried in on workmen's backs for the last part of the climb to the 1000m dam site. A sawmill was set up to mill matai and rimu for the 8 kilometres of fluming needed to transport the water down from the dam. Over 100 tons of pipes and equipment were slung across the Aorere River by aerial ropeway. Sluicing began in August 1889, but the returns were much less than hoped for and, by November the following year, the company was in liquidation. The dam was eventually dynamited by graziers to regain the flats at the head of the lake. Today, the sluicing gear from the Collingwood goldfields has been removed to other sites, the flumings have long since rotted and even the tailings have largely re-merged into the natural landscape, but the remnants of the three dams are a lasting reminder of the huge human effort for so little reward (all information on the Collingwood dams from Hindmarsh, 1995).

**The Auckland stonefields (ca. 15th to 19th centuries)**

The basaltic lava stonefields of the Auckland region, covering more than 8,000 hectares, were occupied and used from early times. The Auckland region had one of the densest concentrations of early Maori settlement and many villages and fortifications were established on the volcanic cones and stonefields. The early tangata whenua (local tribes) modified the stonefields to form an elaborate gardening system, which included earth and rock mounds, boundary walls, terraces, storage pits and midden. Later, in the mid-1880s, Maori used these stonefield gardens to provide food for the growing settlement of Auckland (Parliamentary Commissioner for the Environment, 1996b).

Today the stonefields are one of the last remaining areas in Auckland where a visible record of past human settlement is written on the surface of the land. They provide outstanding examples of pre-European and nineteenth century Maori gardening techniques (Department of Conservation, 1994), and are also important for their cultural, traditional, archaeological, historical, social, scientific and landscape values (Parliamentary Commissioner for the Environment, 1996b). Nearly all of the archaeological sites on the Historic Places Act Register in Auckland are located in the stonefields. However, the stonefields have been extensively used for industrial subdivision and development, and parts have also been quarried for aggregate for the construction industry. It is now estimated that, of the original 8,000 ha of stonefields, only 200 ha remain, represented mainly by the Otuataua and Matukuturua Stonefields in South Auckland. According to Ngaati Te Ata tradition, the main tangata whenua of these stonefields are Wai O Hua, of whom Ngaati Te Ata are direct descendants (Parliamentary Commissioner for the Environment, 1996b). The stonefields therefore provide a strong cultural link between Ngaati Te Ata and their ancestors.

The Otuataua and Matukuturua Stonefields are of regional, national and international significance and are currently being considered by the New Zealand Committee of the International Council for Monuments and Sites for recommendation as a world heritage site (Bulmer, 1995; Parliamentary Commissioner for the Environment, 1996b). Both stonefields are privately owned, Matukuturua by a quarry operator and Otuataua by four farmers. Of the remaining stonefields, only two small sites with limited features are in public ownership. Although there is now a growing recognition of the cultural and historical importance of the stonefields, their protection (and, indeed, their use for aggregate extraction) has been hampered by conflicts between the desire to protect their heritage values, and the desire to extract their commercial value by mining for aggregates (Parliamentary Commissioner for the Environment, 1996b).

**Awareness of cultural heritage**

More and more people are showing their interest in our cultural heritage and its preservation. Membership of the forty-year-old Historic Places Trust, one of New Zealand's main heritage protection agencies, has increased by 10 percent annually in the past three years. Another indicator of growing interest is the sheer number of visitors at our heritage sites. Recent estimates of annual visitor numbers include 119,000 at the Waitangi National Reserve, 240,000–270,000 at the North Head Historic Reserve in Auckland, and 50,000 at the Arrowtown Chinese Settlement in Otago (Parliamentary Commissioner for the Environment, 1996a). In just two days, nearly 13,000 people visited the newly refurbished Parliament Buildings in Wellington.

It is not only New Zealanders who are interested. Visits by overseas tourists to a museum and/or art gallery, or to a historic site, ranked equal second and equal fourth respectively in terms of popularity in the International Visitors' Survey conducted by the New Zealand Tourism Board (1996). However, the recent report of the Parliamentary Commissioner for the Environment, *Historic and Cultural Heritage Management in New Zealand*, noted that, unlike natural heritage, there has been little public debate about the sustainability of our cultural heritage or about the notion that, like species extinctions, loss of cultural heritage is permanent (Parliamentary Commissioner for the Environment, 1996a).

**Managing our cultural heritage**

Aspects of our cultural heritage are managed under at least 20 different Acts of Parliament, and by a large number of agencies (see Table 2.1). The Parliamentary Commissioner's report concluded that lack of co-ordination and overall direction for all types of heritage protection is a problem in New Zealand.

The two leading national heritage protection agencies are the New Zealand Historic Places Trust/Pouhere Taonga and the Department of Conservation. The Historic Places Trust is responsible for promoting the identification and protection of New Zealand's cultural heritage. One of the main ways in which the Trust does this is by maintaining a register of historic places. The register is set up under the Historic Places Act 1993 (the HPA). The Trust monitors development proposals for properties or sites listed on the register and offers advice to landowners and developers. It also liaises with local councils to help them identify and protect sites in their district or city.

Many people are under the false impression that the Trust has the statutory muscle to stop the destruction or modification of a building or site. However, registration of a place or site does not equal automatic protection. Registration is merely an acknowledgement that the site is worth protecting. Even if a property is registered, the Trust cannot prevent it being modified, damaged, neglected, sold, or even destroyed. However, the Trust also has the status of a heritage protection authority under the Resource Management Act 1991, and can issue a requirement for a Heritage Order (see below) if necessary.

The role of the Department of Conservation is restricted by government policy to managing cultural heritage on the Department's land (Department of Conservation, 1995). In other words, the Department manages heritage resources which, because they are on conservation land, are already protected in some way. This limitation of the Department's role has caused a lot of debate, as the Conservation Act 1987 also gives the Department the task of advocating for and providing formal protection of significant heritage resources on land outside the conservation estate (Parliamentary Commissioner for the Environment, 1996a).

Local government also has an important role in managing our cultural heritage under the Resource Management Act but, as the Parliamentary Commissioner notes, the performance of councils at protecting our cultural heritage is highly variable. All places on the HPA Register must be included in the district plans of local authorities which are prepared under the Resource Management Act. Listing a place in a plan gives people the opportunity to voice their support for its preservation, but does not ensure its protection.

Another option under the Resource Management Act is the use of Heritage Orders to protect buildings or sites. A heritage order is a provision in a district plan which prevents anyone from doing anything that affects the heritage characteristics of the place without written consent from the appropriate heritage protection authority (i.e. a Minister of the Crown, a local authority, the Historic Places Trust, or any other body approved as a heritage protection authority under the Act). Where a heritage order is used, the protecting authority may be liable for some costs of maintenance and may also be required to buy the property.

Most registered historic places are privately owned and are often not available for public viewing. However, the greatest protection afforded to historic sites or places is where they are owned by a heritage agency, such as the Historic Places Trust. Local councils may also purchase buildings or sites to ensure their protection. The costs involved in acquisition, restoration, and on-going management, all limit the amount of places and property that can be given outright protection in this way. Beyond this, the thorny issues of private ownership and compensation costs make outright protection difficult to secure.

**Table 2.1**

**Organisations involved in historic and cultural heritage management.**

| |
|---|
| **Government Organisations** |
| *Department of Conservation* |
| *Department of Internal Affairs* |
| *Ministry for the Environment* |
| *Ministry of Cultural Affairs* |
| |
| **Local Authorities** |
| *Regional councils* |
| *District and city councils* |
| *Unitary authorities* |
| |
| **Non-government Organisations** |
| *New Zealand Historic Places Trust* |
| *New Zealand Archaeological Association (NZAA)* |
| *Institute of New Zealand Archaeologists* |
| *ICOMOS New Zealand (The New Zealand Committee of the International Council on Monuments and Sights)* |
| *New Zealand Institute of Architects* |
| *New Zealand Institute of Landscape Architects* |
| *Professional Conservators Group of New Zealand (PCGNZ)* |
| *Professional Historians Association of New Zealand/Aotearoa* |
| *New Zealand Planning Institute* |
| *Civic and heritage trusts* |
| *Historical societies* |

*Source: Parliamentary Commissioner for the Environment, 1996a.*

**Information on our cultural heritage**

It is difficult to get an overview of the state of New Zealand's cultural heritage because of the number of agencies involved in heritage issues, and the lack of a single, integrated database. Maori heritage sites are of greatest significance to tribal members, who often prefer to keep details of their location and significance confidential.

The major source of basic information on archaeological sites is the New Zealand Archaeological Association (NZAA) File of Site Records which is now maintained by the Science and Research Division of the Department of Conservation. The file contains 49,000 archaeological sites, but it has been criticised as being far from complete, with very uneven regional coverage. For example, in Northland, where there have been a number of of large surveys, there are 9,000 sites on the File (nearly 20 percent of the national total) but there are estimated to be twice as many unrecorded sites (Parliamentary Commissioner for the Environment, 1996a). It is commonly held among archaeologists that this proportion would be the same nationally (New Zealand Historic Places Trust Pouhere Taonga, 1996).

The other main source of information is the Historic Places Act Register. At the end of 1995, the HPA Register listed nearly 5,800 historic places, historic areas, waahi tapu, and waahi tapu areas (see Table 2.2). The historic places on the Register are classified as Category 1 or 2. Category 1 places are "of special or outstanding historical or cultural significance or value". These include Parliament House, Antrim House (which is also used as the the Historic Places Trust's headquarters), the old National Museum and Art Gallery, and Rita Angus Cottage in Wellington's historic Sydney St West.

Category 2 places are "of historical or cultural heritage significance or value". Among the hundreds of Category 2 buildings on the Register are an 1860s horse stable near Leeston in Canterbury and turn-of-the-century cottages in Wellington's Aro Street. Historic areas, waahi tapu and waahi tapu areas are listed on the Register but are not classified as Category 1 or 2.

Although the HPA Register lists 1,012 archaeological sites, these are but a fraction of the 49,000 known archaeological sites on the NZAA File. Almost all registered sites are in only five districts–Otago, Tasman, Gisborne, Whakatane and Western Bay of Plenty – reflecting, in part, areas in which major Trust-sponsored surveys have taken place.

**Condition of our cultural heritage**

Despite the increasing interest in protecting the physical remnants of our cultural heritage, much of it is being demolished, renovated, or ploughed under. The report by the Parliamentary Commissioner for the Environment concluded that New Zealand's heritage is in danger of being lost. Heritage protection for many places is not being achieved, and the permanent loss of many historic and cultural sites and places is causing widespread anxiety, particularly among Maori communities. Although some positive things are happening at the local level, significant permanent losses of all types of historic and cultural heritage are continuing (Parliamentary Commissioner for the Environment, 1996a).

Between 1984 and 1994, 42 buildings on the HPA Register were destroyed in Auckland (Auckland Regional Council, 1994). In Wellington, 41 buildings on the HPA Register (12 percent of all registered buildings) were

**Table 2.2**
**Listings on the Historic Places Act Register at 1995**

| | |
|---|---|
| *Buildings* | *4,676* |
| *Archaeological sites* | *1,012* |
| *Historic areas* | *90* |
| *Waahi tapu* | *12* |
| *Waahi tapu areas* | *4* |
| ***Total*** | ***5,794*** |

*Source: Parliamentary Commissioner for the Environment, 1996a.*

destroyed between 1980 and 1995 (Flinkenberg, 1996). The Parliamentary Commissioner's report notes that the rate of loss has probably slowed in the past 6-8 years compared with the period before this, but the slower trend is more likely to be due to economic factors than to more effective protection measures. Losses may have been even greater for Maori heritage and archaeological sites. In the Auckland metropolitan area, over 50 percent of pa have been extensively modified or destroyed since city development began (Parliamentary Commissioner for the Environment, 1996a). Six percent of the known archaeological sites in the Auckland region were destroyed or modified between 1979 and 1994 (Auckland Regional Council, 1994).

The main problems in preserving our cultural heritage centre on the issues of what should be saved and what should be sacrificed, the rights of the property owner versus the rights of the public and the nation, and the lack of clear direction or leadership in existing laws and institutional arrangements. However, there is also reason to be hopeful about the protection of our cultural heritage. The Parliamentary Commissioner's report notes that the new district plans of some local councils, particularly in major cities, have a stronger commitment to protecting heritage buildings and, in a few cases, waahi tapu and archaeological sites. There is a growing appreciation of the economic dimensions of heritage protection, and a greater readiness for councils to discuss with property owners the issue of "how can a new economic use be found for this building?" rather than focusing on "how can this owner be prevented from destroying this building?" (Parliamentary Commissioner for the Environment, 1996a).

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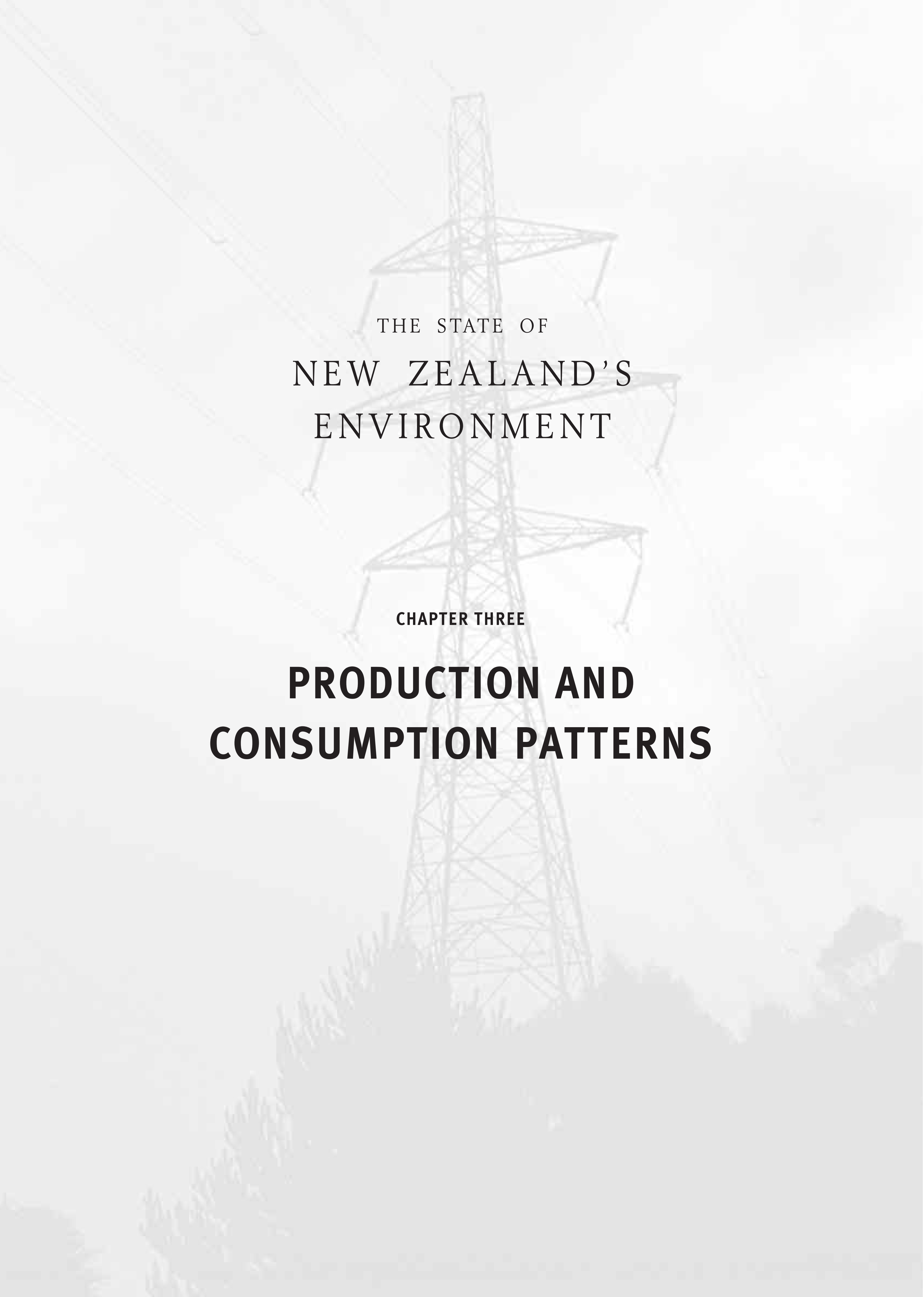


THE STATE OF

NEW ZEALAND'S ENVIRONMENT

CHAPTER THREE

# PRODUCTION AND CONSUMPTION PATTERNS

## CONTENTS

## PRODUCTION, CONSUMPTION AND ECOLOGICAL FOOTPRINTS

Production and consumption occur when we transform natural objects (or 'resources') into human biomass, consumable products (or 'goods and services') and waste. During **production**, we reshape or relocate objects by applying energy to them (either as heat or mechanical force). During **consumption**, we change these products by taking energy away from them (either directly, through eating or burning, or indirectly, through the wear and tear of use). Waste is an inherent part of the process. Waste energy is lost as heat, and waste materials are lost as gases (e.g. car exhausts), liquids (e.g. sewage) or solid waste (e.g. garbage). In this chapter we look at New Zealand's production and consumption patterns as reflected in our economic activities, our use of energy and our generation of solid waste.

The global scale of resource conversion, especially by the affluent fifth of the world's population, is much greater now than it was a mere century ago (Holway, 1992). New Zealand's pattern of resource conversion is fairly similar to Australia and the affluent societies of the northern hemisphere. In terms of productive land use (i.e. pasture and cropland, timber forests, roads and urban areas), New Zealand uses about 5 hectares of land per person to provide a year's supply of goods and services (see Chapter 8). This is a big 'ecological footprint'. The global average is a bit over 1 hectare per person (World Resources Institute, 1996). If everyone presently alive aspired to our level of 'land affluence' the world would need 28 billion hectares of productive land. That is twice the Earth's land area and about five times the area currently used for production.

The 5-hectare footprint is based solely on productive land use. When other resources are also considered (such as marine fisheries area and additional forest growth needed to absorb our carbon dioxide emissions) New Zealand's footprint becomes larger still—9.8 hectares according to a recent study commissioned by the Rio Summit's Earth Council (Wackernagel *et al.*, 1997). Among the activities that contribute to a society's ecological footprint are its energy use (see below, and also Chapters 5, 6 and 7), its generation of wastes that must be absorbed by land, air or water (see below and Chapters 5, 6, 7 and 8), its use of forest products, such as paper and firewood (see below and Chapter 8), and its use of farm products—particularly animal products (see below and Chapters 7 and 8).

Livestock production contributes greatly to the ecological footprint because large areas of land are required for fodder crops and pasture and large amounts of waste are generated by the animals themselves and the industries that process their products (see Chapters 5, 7, 8 and 9). For example, a cow must eat five plant calories to produce one milk calorie, and 10 plant calories to produce one calorie of beef (Bender, 1997). Societies whose food energy comes mostly from starchy plants rather than livestock have smaller environmental impacts because they only require about a quarter the land area to produce the same number of food calories (Breirem *et al.*, 1989; Cohen, 1996). This has a marked effect on the extent and patterns of land and water use and habitat replacement.

At present about 17 percent of the world's population lives in high-income countries where, on average, animal fat makes up more than 30 percent of the total calorie intake. In contrast, Africans typically derive only 6 percent of their calories from animal products (Bender, 1997). The implications of this for global sustainability are shown in Table 3.1 which gives an estimate of how many people could have survived on the world's 1990 agricultural output if everyone ate, respectively, like North Americans, Europeans, Japanese, Bangladeshis or subsistence horticulturalists. New Zealand would fall between Europe and the United States in this table, based on our high levels of fat consumption (Public Health Commission, 1993).

**Table 3.1**

**World population supportable in 1990 under different dietary regimes[1].**

| **Population that could be fed if everyone shared the dietary preferences and food system efficiencies of:** | |
|---|---|
| *the United States* | *2.3 billion* |
| *Europe* | *4.1 billion* |
| *Japan* | *6.1 billion* |
| *Bangladesh* | *10.9 billion* |
| *Subsistence only* | *15 billion* |

*Source: Bender (1997)*
*[1] The actual world population in 1990 was 5.3 billion.*

The percentage of animal fats in the New Zealand and North American diet has actually gone down in the past decade but, even so, from a global perspective, the 'New Zealand way of life' is not sustainable. The whole world could not afford to follow our dietary and land use patterns. Given the limitations of not only land area, but also water supply, the typical Western diet could support a maximum of less than 2.5 billion people—less than half the world's current population (Cohen, 1996). Even if the land did exist to provide everyone with butter, milk and meat, utilising all of this space for livestock production would effectively crowd the world's natural ecosystems and wild species out of existence. Whatever its economic sustainability, such a 'standing room only' scenario would not be sustainable environmentally.

New Zealand, then, is in a relatively privileged position compared to most of the world—a fact borne out by other ecological footprint indicators, such as our use of energy and generation of waste. New Zealand's energy use is comparable to that of other developed countries and slightly below the OECD average (see Table 3.2). Combining our household and industrial energy use, the average New Zealander requires daily about 120,000 calories of 'primary' energy (i.e. energy at the point of extraction or importation, prior to conversion losses), to yield some 78,000 calories of 'consumer' energy (i.e. energy in the forms of fuel or electricity). Compare this to our body's basic calorie requirement of about 2,400 calories per day.

Our production of wastes is also comparable to that of other OECD countries (see Table 3.2). Combining total household and industrial waste, the average New Zealander generates about 145,000 litres of sewage each year and nearly 900 kilograms of landfill waste (about 400 kg from households and nearly 500 kg from industry), with an additional 900 or so kilograms of construction and demolition waste going to cleanfills (Ministry for the Environment, 1997).

It is important to note, though, that the gross scale of land use, energy consumption and waste production are only rough guides to a society's environmental impact. The type of resource conversion is also important. If hill land is converted into production forest rather than pasture, flooding, sedimentation and soil erosion decline measurably because trees are more effective than pasture at holding soil and water (see Chapter 7). If energy is harnessed from renewable sources, such as wind or sunlight, rather than from burning fossil fuels, the impacts are much smaller because no waste heat or air pollutants are generated. And if sewage is converted into cleaner water through a treatment process fewer pollutants are discharged (see Chapter 7).

The extent to which we can alter our patterns of production and consumption is partly a matter for society to decide through laws, ethics, fashions and customs, and partly a matter of economic feasiblity. Economic feasibility is heavily constrained by markets (e.g. customer desires), resources (both natural resources and the creative ingredients of human knowledge and labour) and by the legacy of past practices such as the infrastructure, technology and attitudes of the main economic sectors. To understand our current production and consumption patterns, then, it is important to briefly examine the development of New Zealand's economy and its current state.

**Table 3.2**

**Living standards and production and consumption patterns in New Zealand and selected OECD countries.**

| Indicator | Unit measured* | Year | New Zealand | Australia | Canada | Japan | Mexico | Norway | Turkey | United Kingdom | United States | All OECD** | World** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Economy** | | | | | | | | | | | | | |
| Gross Domestic Product (GDP) per person [4,6] | Purchasing Power Parity (PPP) in US$ | 1995 | 16,851 | 19,354 | 21,031 | 21,795 | 7,383 | 22,672 | 5,691 | 17,756 | 26,438 | 19,410 A | ca 6,000 A |
| Total GDP (measured as expenditure) [4,6] | Purchasing Power Parity (PPP) in billion US$ | 1995 | 60 | 350 | 623 | 2,730 | 673 | 99 | 351 | 1,041 | 6,956 | 18,946 T | ca 24,000 T |
| Past economic growth [4] | average percentage GDP increase per year | 1985-95 | 1.7 | 3 | 2.2 | 3 | 1.6 | 2.6 | 4.4 | 2.2 | 2.5 | 2.2 M | md |
| Present economic growth [4,6] | percentage GDP increase per year | 1995-96 | 1.2 | 4.1 | 1.5 | 3.6 | 4 | 5.1 | 7.5 | 2.4 | 2.4 | 2.4 M | md |
| Primary sector (farming, forestry, fishing etc) [3,6] | as percentage of GDP | 1991-94 | 7 | 3 | 2 | 2 | 7 | 3 | 16 | 2 | 2 | 3 A | 6 A |
| Secondary (manufacturing, building, energy) [3,6] | as percentage of GDP | 1991-94 | 26 | 28 | 26 | 40 | 29 | 35 | 33 | 28 | 26 | 31 A | 36 A |
| Tertiary sector (services) [3,6] | as percentage of GDP | 1991-94 | 67 | 69 | 72 | 58 | 64 | 62 | 51 | 71 | 72 | 66 A | 58 A |
| International tourism [4] | as percentage of GDP | 1995 | 3.9 | 2 | 1.4 | 0.1 | 2.2 | 1.6 | 2.9 | 1.7 | 0.9 | 1.2 A | md |
| Trade dependency [6] | exports as percentage of GDP | 1993 | 24 | 15 | 30 | 9 | 8.8 | 31 | 9.8 | 22 | 7 | 14 A | 16 A |
| Subsidy equivalents to agriculture [4] | as percentage of agricultural production | 1996 | 3 | 9 | 22 | 71 | 13 | 71 | 30 | - | 16 | 36 A | md |
| Consumer Prices [4] | percentage change over a year | 1995-96 | 2.5 | 1.5 | 2.2 | 0.6 | 27.7 | 1.8 | 79.8 | 2.5 | 3.3 | 4.7 A | md |
| Short-term standardised interest rates [3] | percent | 1995 | 8.6 | 7.4 | 5.8 | 0.5 | 49.2 | 5.4 | 98.0 | 6.5 | 5.6 | md | md |
| **Energy and transport** | | | | | | | | | | | | | |
| Consumer energy [2] | tonnes of oil equivalent (TOE) per person | 1993 | 3.1 | 3.5 | 5.7 | 2.5 | 1.1 | 4.3 | 0.8 | 2.6 | 5.4 | 3.2 A | 1 A |
| Primary energy [2,4] | tonnes of oil equivalent (TOE) per person | 1994-95 | 4.3 | 5.2 | 7.9 | 4 | 1.5 | 5.5 | 1 | 3.8 | 7.9 | 4.7 A | 1.4 A |
| Fossil fuels (i.e. coal,oil, gas) [4,5] | percent of primary energy | 1995 | 68 | 94 | 74 | 81 | 87 | 53 | 84 | 88 | 86 | 83 A | 85 A |
| Nuclear energy [4,5] | percent of primary energy | 1995 | 0 | 0 | 11 | 15 | 2 | 0 | 0 | 10 | 9 | 11 A | 7 A |
| Renewables (e.g. hydro, geothermal, wood) [4,5] | percent of primary energy | 1995 | 32 | 6 | 15 | 4 | 15 | 11 | 16 | 1 | 5 | 6 A | 9 A |
| Energy intensity [2,4] | primary energy (TOE) per million US$ GDP | 1994-95 | 310 | 280 | 380 | 160 | 480 | 170 | 350 | 210 | 340 | 250 A | 150 A |
| Gross $CO_2$ emissions from energy use [4] | tonnes per person | 1993-95 | 8 | 16 | 16 | 9 | 4 | 8 | 2 | 10 | 20 | 11 A | 4 A |
| Motor vehicle abundance [2] | licensed vehicles per 100 people | 1993 | 55 | 57 | 60 | 51 | 1 | 46 | 6 | 42 | 75 | 50 A | md |
| Motor vehicle use [2] | kilometres driven per person per year | 1993 | 7,184 | 7,986 | 8,625 | 5,698 | 592 | 5,995 | 5,211 | 7,600 | 14,350 | 1,345 A | md |
| **Consumption patterns and waste** | | | | | | | | | | | | | |
| Printing and writing paper consumed [6] | tonnes per 1,000 people | 1992 | 47.8 | 43.3 | 84.9 | 75.9 | 8.1 | 37.9 | 3.3 | 56.2 | 86.6 | 58.6 A | 14.1 A |
| Televisions [6] | per 1,000 people | 1992 | 443 | 482 | 640 | 614 | 149 | 424 | 176 | 435 | 815 | 528 A | 151 A |
| Mobile cellular phone subscribers [6] | per 1,000 people | 1992 | 29 | 28 | 35 | 14 | 3 | 65 | 1 | 26 | 43 | 22 A | md |
| Solid waste generation [2,8] | kilograms per person per year | 1992-95 | 400*** | 400*** | 660 | 410 | 310 | 510 | 400 | 350*** | 730 | 400 M | md |
| **Environment and resource use** | | | | | | | | | | | | | |
| Land area [5] | millions of hectares | 1995 | 27 | 771 | 998 | 38 | 196 | 32 | 78 | 25 | 981 | 3,459 T | 13,098 T |
| Farmed land (crops and pasture) [5] | percentage of land area | 1991-93 | 52 | 60 | 8 | 14 | 52 | 3 | 47 | 72 | 45 | 37 A | 38 A |
| Forested land (natural and planted) [5] | percentage of land area | 1991-93 | 28 | 19 | 45 | 67 | 26 | 39 | 26 | 10 | 31 | 33 A | 32 A |
| Major protected areas [5] | percentage of land in IUCN categories I to V | 1994 | 22 | 12 | 8 | 7 | 5 | 17 | 1 | 21 | 13 | 8 M | 7 A |
| Exclusive Economic Zone (EEZ) [5] | marine fishery area in millions of hectares | 1995 | 483 | 450 | 294 | 386 | 285 | 203 | 24 | 179 | 971 | 4,338 T | md |
| Ecological footprint (land and sea area needed to supply resources and absorb wastes) [7] | hectares per person | 1996 | 9.8 | 8.1 | 7 | 6.3 | 2.3 | 5.7 | 1.9 | 4.6 | 8.4 | 5.7 M | 2.3 A |

*Sources: [1] Encyclopaedia Britannica (1996); [2] OECD (1995); [3] OECD (1996); [4] OECD (1997) ; [5] World Resources Instutute (1996); [6] United Nations Development Programme (1996)*
*T=total A=average M=midpoint (median) md=missing data na=not applicable*
**In most cases, rates and percentages are rounded to the nearest whole number. ** Excludes Czech Republic, Hungary, Poland and South Korea because of insufficient data.*
****NZ data are for 'residential' waste. Data for Australia and the UK are for 'household municipal' waste. All others are for 'municipal' waste (i.e. waste from households and small businesses disposed of through municipal collections or facilities).*
***** 'Latest' data are the most recent available, with most dating from the early 1990s but some dating from the 1980s.*

**Table 3.2 continued**

| Indicator | Unit measured* | Year | New Zealand | Australia | Canada | Japan | Mexico | Norway | Turkey | United Kingdom | United States | All OECD** | World** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Economy** | | | | | | | | | | | | | |
| Population [4] | millions of people | 1995 | 3.6 | 18.1 | 29.6 | 125.3 | 91.1 | 4.4 | 61.6 | 58.6 | 263.1 | 976.1 T | 5,716.4 T |
| Population density [5] | persons per square kilometre (=100 hectares) | 1995 | 13 | 2 | 3 | 332 | 49 | 14 | 81 | 241 | 28 | 28 A | 44 A |
| Urban population [5] | as percentage of total population | 1995 | 86 | 85 | 77 | 78 | 75 | 73 | 69 | 89 | 76 | 77 A | 45 A |
| Household size [1] | average number of persons per household | latest**** | 2.9 | 3 | 2.7 | 3 | 5.1 | 2.2 | 4.5 | 2.7 | 2.6 | 2.9 A | md |
| Human development ranking [6] | rank in UNDP Human Development Index (HDI) | 1993 | 14 | 11 | 1 | 3 | 48 | 5 | 84 | 16 | 2 | na | na |
| **Health and health services** | | | | | | | | | | | | | |
| Infant mortality [4] | per 10,000 live births | 1994-95 | 72 | 57 | 63 | 43 | 170 | 40 | 468 | 62 | 80 | 60 M | 630 A |
| Maternal mortality [6] | per 100,000 live births | 1993 | 25 | 9 | 6 | 18 | 110 | 6 | 180 | 9 | 12 | 33 A | 307 A |
| Male life expectancy [4, 6] | probable longevity at birth | 1995 | 74 | 75 | 75 | 76 | 70 | 75 | 65 | 74 | 73 | 73 A | 61 A |
| Female life expectancy [4, 6] | probable longevity at birth | 1995 | 79 | 81 | 81 | 83 | 76 | 81 | 70 | 80 | 79 | 80 A | 65 A |
| Deaths from heart disease (males) [6] | per 1,000 males aged over 65 | 1990-93 | 35 | 34 | md | 21 | md | 34 | md | md | md | 31 A | md |
| Deaths from heart disease (females) [6] | per 1,000 females aged over 65 | 1990-93 | 34 | 37 | md | 26 | md | 31 | md | md | md | 30 A | md |
| Cancer deaths (males) [6] | per 1,000 males aged over 65 | 1990-93 | 25 | 25 | md | 25 | md | 22 | md | md | md | 24 A | md |
| Cancer deaths (females) [6] | per 1,000 females aged over 65 | 1990-93 | 18 | 17 | md | 16 | md | 16 | md | md | md | 17 A | md |
| Road accident deaths [4] | per 100,000 of population | 1994-95 | 16 | 11 | 11 | '10 | md | 7 | 14 | 6 | 16 | 12 M | md |
| Suicides (males) [6] | per 100,000 people | 1989-93 | 24 | 21 | 21 | 22 | md | 21 | md | md | 20 | 21 M | md |
| Suicides (females) [6] | per 100,000 people | 1989-93 | 6 | 5 | 6 | 11 | md | 8 | md | md | 5 | 7 M | md |
| Doctors [4,6] | per 10,000 people | 1991-95 | 21 | 22 | 22 | 18 | 16 | 28 | 12 | 16 | 26 | 27 M | 20 A |
| Hospital beds [4] | per 10,000 people | 1991-95 | 7 | 9 | 5 | 16 | 1 | 14 | 3 | 5 | 4 | 7 M | md |
| Total health spending [4] | as percentage of GDP | 1991-95 | 8 | 9 | 10 | 7 | 5 | 6 | 3 | 7 | 14 | 8 M | md |
| Health spending per person [4] | expenditure per person in US$ (PPP) | 1991-95 | 1,203 | 1,741 | 2,049 | 1,581 | 386 | 1,821 | 272 | 1,246 | 3,701 | 1,581 M | md |
| Government share of total health spending [3, 4] | as percentage of total expenditure | 1991-95 | 76 | 67 | 72 | 79 | 57 | 83 | 50 | 86 | 46 | 78 M | md |
| **Food and nutrition** | | | | | | | | | | | | | |
| Food versus other spending [1] | percent of household spending going on food | latest**** | 16 | 19 | 13 | 24 | 37 | 24 | 33 | 19 | 11 | 20 M | 39 M |
| Daily available calories [1] | calories per person | 1988-90 | 3,460 | 3,302 | 3,242 | 2,021 | 3,061 | 3,221 | 3,197 | 3,270 | 3,642 | 3,421 A | 2,582 A |
| Excess calories [1] | percentage above FAO recommendations | 1992 | 39 | 20 | 16 | 24 | 35 | 21 | 36 | 32 | 41 | 34 A | 19 A |
| Pure fats and oils (animal and vegetable) [1] | percent of total calorie intake | 1980-90 | 16 | 14 | 19 | 11 | 13 | 17 | 16 | 11 | 18 | 17 A | 10 A |
| Animal products (excl. fish and pure fats) [1] | percent of total calorie intake | 1980-90 | 28 | 31 | 25 | 12 | 14 | 24 | 5 | 27 | 26 | 22 A | 12 A |
| Starches (e.g. cereals and potatoes) [1] | percent of total calorie intake | 1980-90 | 25 | 27 | 26 | 42 | 47 | 32 | 52 | 28 | 24 | 32 A | 57 A |
| Alcohol consumption [6] | litres per person per year | 1991 | 7.8 | 7.7 | 7.1 | 6.3 | md | 4.1 | md | 7.4 | 7 | 8.1 A | md |
| Grains fed to livestock [5] | percent of total grain consumption | 1994 | 47 | 60 | 76 | 46 | 38 | 66 | 31 | 50 | 68 | 60 M | 38 A |

*Sources: [1] Encyclopaedia Britannica (1996); [2] OECD (1995); [3] OECD (1996); [4] OECD (1997) ; [5] World Resources Instutute (1996); [6] United Nations Development Programme (1996)*

*T=total A=average M=midpoint (median) md=missing data na=not applicable*

**In most cases, rates and percentages are rounded to the nearest whole number. **Excludes Czech Republic, Hungary, Poland and South Korea because of insufficient data.*

****NZ data are for 'residential' waste. Data for Australia and the UK are for 'household municipal' waste. All others are for 'municipal' waste (i.e. waste from households and small businesses disposed of through municipal collections or facilities).*

***** 'Latest' data are the most recent available, with most dating from the early 1990s but some dating from the 1980s.*

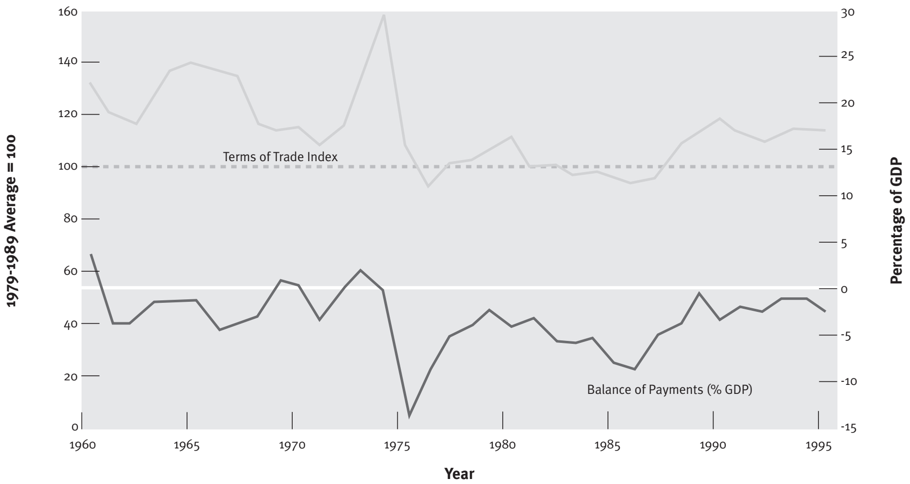
**Table 3.2 continued**

| Indicator | Unit measured* | Year | New Zealand | Australia | Canada | Japan | Mexico | Norway | Turkey | United Kingdom | United States | All OECD** | World** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Employment and unemployment** | | | | | | | | | | | | | |
| *Primary sector (farming, forestry, fishing)* [3] | *percent of total employment* | 1994 | 10 | 5 | 4 | 6 | 26 | 6 | 45 | 2 | 3 | 6 M | md |
| *Secondary (manufacturing, building, energy)* [3] | *percent of total employment* | 1994 | 25 | 24 | 23 | 34 | 22 | 23 | 22 | 26 | 24 | 27 M | md |
| *Tertiary sector (services)* [3] | *percent of total employment* | 1994 | 65 | 71 | 73 | 60 | 52 | 71 | 33 | 72 | 73 | 65 M | md |
| *Part-time employment 4* | *percent of total employment* | 1995 | 22 | 25 | 19 | 20 | 26 | 27 | 17 | 24 | 19 | 19 M | md |
| *Unemployment rate* [3] | *percent of workforce seeking and available for work* | 1994 | 8 | 10 | 10 | 3 | 4 | 5 | 8 | 10 | 6 | 8 A | md |
| **Income distribution** | | | | | | | | | | | | | |
| *Household income inequality* [6] | *income ratio of top 20 percent of households to bottom 20 percent* | 1981-91 | 8.8 | 9.6 | 7.1 | 4.3 | 3.6 | 5.9 | md | 9.6 | 8.9 | 6 M | md |
| *Income share of top 10 percent* [1] | *percent of national income* | latest**** | 29 | 28 | 24 | 32 | 38 | 27 | 42 | 28 | 33 | 27 M | 32 M |
| *Income share of bottom 40 percent* [6] | *percent of national income* | 1981-91 | 16 | 16 | 18 | 22 | 12 | 19 | md | 15 | 16 | 18 M | md |
| *Income share of bottom 20 percent* [1] | *percent of national income* | latest**** | 5 | 5 | 6 | 11 | 4 | 3 | 4 | 5 | 4 | 5 M | 5 M |
| *Women's income share* [6] | *percent of national income earned by women* | 1993 | 38 | 39 | 37 | 33 | 24 | 41 | 22 | 34 | 40 | 34 M | 32 A |
| **Women's position** | | | | | | | | | | | | | |
| *Status of women* [6] | *rank in UNDP's Gender Development Index (GDI)* | 1993 | 10 | 9 | 2 | 12 | 46 | 3 | 61 | 14 | 4 | na | na |
| *Empowerment of women* [6] | *rank in UNDP's Gender Empowerment Measure (GEM)* | 1993 | 5 | 15 | 6 | 37 | 31 | 1 | 92 | 18 | 9 | na | na |
| *Women in parliament* [6] | *percent of seats held by women* | 1993 | 21 | 14 | 18 | 7 | 14 | 39 | 2 | 8 | 10 | 14 M | 12 A |
| *Women in management* [6] | *percent of all managers and administrators* | 1993 | 32 | 43 | 42 | 9 | 20 | 31 | 7 | 33 | 42 | 20 M | 14 A |
| *Women in professions* [6] | *percent of all professional and technical workers* | 1993 | 48 | 25 | 46 | 42 | 44 | 58 | 29 | 44 | 53 | 47 M | 39 A |
| **Crime** | | | | | | | | | | | | | |
| *Police* [1] | *per 1,000 people* | latest**** | 159 | 222 | 12 | 208 | md | 152 | 64 | 238 | 314 | 159 M | md |
| *Reported assaults (including murder)* [1] | *per 100,000 people* | latest**** | 318 | 377 | 162 | 16 | 38 | 96 | 25 | 365 | 450 | 65 M | md |
| *Reported burglaries* [1] | *per 100,000 people* | latest**** | 2,942 | 1,963 | 1,674 | 188 | md | 74 | md | 2,404 | 1,099 | 1,098 M | md |
| **Education and science** | | | | | | | | | | | | | |
| *Expenditure on education* [3, 6] | *percentage of GDP* | 1992-94 | 7 | 6 | 7 | 5 | 4 | 7 | 3 | 4 | 7 | 5 M | 5 A |
| *Expenditure per primary student* [4] | *US $ (PPP)* | 1995 | 2,659 | 2,985 | md | 3,960 | 741 | md | 832 | 3,295 | 5,492 | 2,985 M | md |
| *Expenditure per secondary student* [4] | *US $ (PPP)* | 1995 | 3,951 | 4,871 | md | 4,356 | 1,477 | md | 587 | 4,494 | 6,541 | 4,632 M | md |
| *Expenditure per tertiary student* [4] | *US $ (PPP)* | 1995 | 7,337 | 9,036 | 11,132 | 7,556 | 4,264 | 8,343 | 2,696 | 8,241 | 14,607 | 7,447 M | md |
| *Pupil teacher ratios (primary)* [1,6] | *students per teacher* | 1992 | 18.5 | 18.4 | 17.8 | 19.7 | 29.6 | 12.9 | 29.3 | 19.6 | 20.1 | 18 M | 30 A |
| *Pupil teacher ratios (secondary)* [1,6] | *students per teacher* | 1992 | 13.4 | 12.4 | 17.8 | 17.2 | 17.7 | 11 | 25.6 | 13.7 | 12 | 13 M | 20 A |
| *Mathematics achievement score* [4] | *average national score in TIMSS survey****** | 1996 | 508 | 530 | 527 | 605 | md | 503 | md | 505 | 500 | 519 M | md |
| *Adults with upper secondary school education* [4] | *percentage of 25-64 olds* | 1993 | 34 | 27 | 28 | md | md | 53 | 13 | 54 | 53 | 38 M | md |
| *Adults with tertiary education* [4] | *percentage of 25-64 olds* | 1993 | 23 | 23 | 46 | md | md | 27 | 7 | 21 | 32 | 21 M | md |
| *Current tertiary students* [3] | *full-time students per 1,000 people* | 1993-94 | 28 | 23 | 41 | 29 | 15 | 32 | 19 | 18 | 31 | 26 M | md |
| *Tertiary science enrolment* [6] | *as percentage of total tertiary enrolment* | 1992 | 20 | 26 | 16 | 22 | 34 | 20 | 23 | 28 | 17 | 21 A | 25 A |
| *Scientists and technicians* [4] | *per 10,000 of the labour force* | 1991-94 | 37 | 64 | 52 | <99 | 4 | 69 | 7 | 51 | 74 | 47 M | md |
| *Research and development (R&D) spending* [4] | *US$ (PPP) per head of population* | 1994 | 157 | 305 | 330 | 601 | 382 | 370 | 19 | 379 | 646 | 310 M | md |

*Sources: [1] Encyclopaedia Britannica (1996); [2] OECD (1995); [3] OECD (1996); [4] OECD (1997) ; [5] World Resources Instutute (1996); [6] United Nations Development Programme (1996)*
*T=total A=average M=midpoint (median) md=missing data na=not applicable*
**In most cases, rates and percentages are rounded to the nearest whole number. ** Excludes Czech Republic, Hungary, Poland and South Korea because of insufficient data.*
****NZ data are for 'residential' waste. Data for Australia and the UK are for 'household municipal' waste. All others are for 'municipal' waste (i.e. waste from households and small businesses disposed of through municipal collections or facilities).*
***** 'Latest' data are the most recent available, with most dating from the early 1990s but some dating from the 1980s.*

**Figure 3.1**

**Terms of Trade and balance of Payments (1961-1995).**




## ECONOMIC PRODUCTION AND CONSUMPTION

New Zealand's economy, like most pioneer cultures, in its short history has been dominated by 'quarrying' rather than sustainable use (see Box 3.1). Its main industries rely almost wholly on resources originally imported from overseas. This is because the indigenous resources provide a rather limited economic toolbox. The soils are often poor, few indigenous plants are edible, and most of the large meat-bearing species were exterminated or depleted in the early days of human exploitation. Although the rocks are rich in limestone, we have few mineral resources other than ironsands to support heavy industry. Energy resources are comparatively abundant but are extracted at considerable environmental cost. Steep fast-flowing rivers are dammed in about 80 locations to provide 70–80 percent of the nation's electricity. Coal and geothermal reserves are abundant, but their use has environmental effects (see Chapters 7 and 8). Natural gas is also abundant, though the major field is declining fast. Oil, the nation's major source of fuel energy, is present off Taranaki, but most oil is still imported.

As a result, our agriculture and forestry are based almost exclusively on imported plant and animal species, and other key resources are routinely imported to sustain agriculture, industry and the consumer society. These include phosphate fertilisers (which we import from the Pacific Island quarry of Nauru), most industrial metals (which we import from various overseas quarries or as manufactured products), and oil (which we import mostly from quarries in the Middle East or as manufactured petroleum and plastics). Even when import controls were in place, and well before the oil shock of 1973, we generally spent more on imports than we earned through exports—resulting, ultimately in foreign debt and in private and public asset sales to overseas interests (see Figure 3.1).

**Box 3.1**

### *Once were quarriers*

The New Zealand economy did not have a sustainable beginning. At first it was a 'quarry' economy—that is, an economy where key environmental resources are depleted, either because they are non-renewable or because they are over-exploited (Easton, 1996). The quarry concept comes from mining, but the same word also means a hunted animal. Both senses of the word appropriately describe the first human economy in New Zealand when the main meat sources (inshore marine mammals and large birds) were heavily depleted and large areas of land were deforested. After this, a more sustainable economy developed based on fish, shellfish and fern-root, supplemented by bird hunting, and the cultivation of kumara in warmer areas and cabbage tree roots in cooler areas (McGlone *et al.,* 1994).

European contact triggered a second quarry phase. From 1791, European and American sealers and whalers plundered what was left of the coastal marine mammal populations. Once these were depleted, wool (from the east coast tussock lands of both main islands and the South Island high country), gold (from Otago, the West Coast, Nelson and the Coromandel Peninsula) and kauri timber and gum (from the upper North Island) sustained the economy for several decades. The 'mining' of the tussock lands was dramatic (see Chapter 8). In just 15 years, from 1855 to 1870, sheep numbers rose from 750,000 to 10 million by which time tussock-grazing had reached its natural limits. With added pressure from rabbits some areas soon had to be retired because of soil exhaustion.

Other unsustainable sources of income for nineteenth century settler society were **war**, namely the provisioning and servicing of British troops during the 1860s land wars, **land speculation** by foreign investors, and **overseas debt**, chalked up by the Vogel government in the 1870s when both the gold and the troops had gone. The Government borrowed twenty million pounds between 1870 and 1880 to fund growth. The railways were extended, roads were built, forests cleared, and schools were established. To achieve this, some 115,000 British and Irish labourers and domestic workers were given free passage to immigrate here.

Agriculture became the focus of attempts to establish a sustainable economic base. Cheap land was sold to new settlers and lowland forests were cleared wholesale. Hundreds of small farms were established based on crops and cattle. A wheat boom in the South Island lowlands was temporarily lucrative, but soils were rapidly depleted. Although the newcomers laboured mightily, without fertilisers to maintain soil productivity many were reduced to subsistence living. With high debt and low productivity, the country went into an economic recession which lasted into the 1890s.

The salvation of settler society was the invention of refrigerated shipping. When the ship *Dunedin* left for Britain in 1882 it carried frozen meat and butter which would eventually become the mainstay of the New Zealand economy for the next century. Without this invention, wool, canned meat and grain would have been our sole export commodities and today's New Zealand would have had a much smaller population, perhaps reminiscent of a slightly larger and slightly more prosperous Falkland Islands (Easton, 1996).

The frozen meat and butter trade encouraged a process of land development which eventually saw more than half the entire land area converted to sheep and cattle pasture. Agricultural expansion continued until the natural limit of grazeable land was reached by 1920, after which areas that were ungrazeable (e.g the North Island's deforested central plateau) were planted in fast-growing exotic pine trees to build a sustainable timber resource. This wholesale replacement of native wildlife and vegetation was tantamount to another quarry phase—the mining of our biodiversity. Its legacy can be counted today in the number of threatened species still struggling to survive in habitats that were decimated and fragmented by the expansion of agriculture (see Chapter 9).

From 1920 on, efforts to increase agricultural production and export income have been centered on the intensification of agriculture within its existing land area. After the Depression of the early 1930s and the wartime austerity measures of the early 1940s, this economic strategy flourished, aided by powerful friends overseas. The Western powers' stranglehold on Middle Eastern oil supplies ensured cheap oil for our vehicles and machinery while unrestricted access to the British market—something which was denied to most other countries—ensured above-average returns for nearly all our agricultural exports.

From 1939 to the mid-1970s New Zealand had a comprehensive social security system, free health care, free primary and secondary education, and full employment. Large numbers of state houses were built to provide cheap, high quality, rental accommodation to urban workers and their families. In the 1950s, the country embarked on an industrialisation programme. Large hydro dams were built and technology and raw materials were imported from overseas to help build up the domestic manufacturing sector. Once again, workers were imported in large numbers.

Although a small manufacturing sector had existed from early times, its development in the post-war years was nurtured by a protective umbrella of import licences and trade tariffs which restricted the quantity of goods imported and imposed a fee on imported items, pushing up their price relative to the locally made product. The import controls had not been introduced to support manufacturing but to conserve foreign exchange reserves during the Second World War when local shortages boosted demand for imported goods. However, the controls were maintained until the early 1980s, allowing New Zealand manufacturers to prosper despite relatively inefficient production systems and high labour costs.

As a result, consumer goods in New Zealand were often more expensive or of lower quality than those available overseas. This prompted the development of a resourceful do-it-yourself repair and maintenance culture which reused and recycled all manner of machinery and gadgets. The most visible feature of this was the preponderance of old cars whose lives were prolonged by a nation of backyard mechanics. These gave New Zealand a quaint and backward appearance to overseas visitors.

By the time of the first UN Conference on the Environment in 1972 (the Stockholm Earth Summit), New Zealand's economy was nearing the end of its long period of prosperity. From 1947 to 1966 the nation's terms of trade had fluctuated around a historically high level. Through the late sixties they faltered but recovered strongly on the coat-tails of a world boom in commodity prices which lasted from December 1971 to October 1973. Then came the Arab-Israeli war and, in response, the oil-producers announced their first major price rise. Within just a few months, fuel prices trebled and the New Zealand economy, whose oil and petrol was all imported, reeled with the impact. The price rise pushed up production and distribution costs—and prices. It became harder to sell our goods overseas, a problem that was compounded when our number one customer, Britain, joined the European Economic Community and began buying its goods from the neighbours. New Zealand's terms of trade plunged and a second oil shock in 1979 dealt another blow. Ever since, the nation has been struggling to recover the high growth rates enjoyed prior to 1974.

In the 1970s, steps were taken to diversify the economy and liberalise trade. Free access to the Australian market was achieved through Closer Economic Relations (CER). Agricultural production was increasingly subsidised. This encouraged the deforestation of steep 'marginal' land to extend sheep pasture, and the diversification of production into deer farming and horticultural crops such as kiwifruit. Sheep numbers reached a peak in the early 1980s. In the late 1970s and early 1980s a 'Think Big' development strategy was devised to make New Zealand more self-sufficient in energy and to attract energy-intensive heavy industries to the country (e.g. smelters, refineries and mills). Large sums were borrowed to develop the energy resources for Think Big, leading to soaring overseas debt and spiralling inflation. A wage and price freeze was slapped on the economy from 1982 to 1984 and marginal taxes were lowered to the benefit of upper income groups. However, the country's basic economic problems remained.

From the mid-1980s successive Governments brought in economic reforms that have taken New Zealand down a more free market path. The main reforms were: floating the exchange rate; limiting inflation to 2–3 percent; withdrawing production subsidies to farmers and manufacturers; lifting import controls; lessening the regulation of economic activities; restructuring government departments to clearly separate policy, service and commercial roles and remove conflicting objectives; corporatising and selling off commercially viable state-owned assets; restructuring local government to give greater local autonomy and accountability in planning, resource use and environmental management; ending compulsory unionism; cutting income taxes and imposing a general goods and services tax (GST); reducing and retargeting welfare benefits; and reforming the public health and education systems to put both on a more business-like and user-pays footing.

The social impacts of these changes are still being assessed and debated (e.g. Dixon, 1996; Easton, 1995, 1997; Krishnan, 1995; Mowbray, 1993; O'Hare, 1996; Snively *et al.*, 1990), but the economic effect has been to make New Zealand more competitive in the international marketplace and to speed up the process of diversification that began in the 1970s. The effect on production patterns has been to encourage a move away from inefficient subsidised activities (such as grazing sheep on marginal hill pasture) and into activities that have strong international markets (e.g. forestry, dairy and horticultural production). The effect on consumption patterns has been to open the door to a large quantity of affordable imported consumer goods, such as the second hand Japanese cars that have displaced older style British models from our streets.

In making the economy freer, the Government was careful not to also usher in a more laissez faire approach to the environment. In parallel with the economic and social reforms, the nation's environmental legislation and administration were reshaped around the principles of heritage protection and sustainable management (see Chapter 4). As a result, the Resource Management Act 1991 and several other key environmental laws now require resource users to safeguard the life supporting capacity of resources and ecosystems and ensure that they are passed on to future generations intact. By enshrining the sustainability ethic in law, New Zealanders are now better placed to resist the short-term temptations of the quarry economy.

### New Zealand's economy today

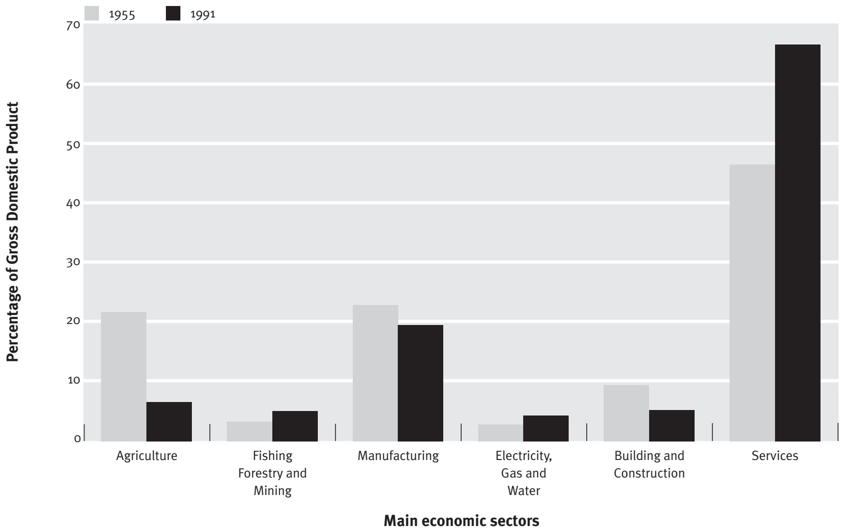
Today, New Zealand is a small trading nation whose Gross Domestic Product (GDP) per person places it among the richest 20 percent of countries in the world (Dalziel and Lattimore, 1996). GDP measures the total economic activity within a nation. It is an important economic indicator, but does not necessarily reflect the general well-being of a society since it cannot reflect the distribution of income or any forms of production based on social relations rather than economic ones (e.g. family care, housework). GDP also ignores any costs of production that are paid for by the environment rather than people (e.g. species extinctions, habitat loss, pollution).

Over the past 25 years (1971–1996) New Zealand's real GDP (i.e. GDP minus inflation) has grown by about 2 percent per year on average, though there have been considerable ups and downs over this period (Dalziel and Lattimore, 1996; OECD, 1993, 1995, 1996 and 1997). The early 1980s (1981–84) was a period of relatively high growth, averaging 3–4 percent, while the period from 1985 to 1992 had average growth of only 0.8 percent, culminating in the recession of 1990–1992. Growth soared to 4–5 percent per year during the recovery of 1993–95, boosted by a global rise in agricultural and log prices. Today, growth has slowed again and appears to be averaging about 1–2 percent per year, depending on the measure used (see Table 3.2). (Growth estimates can vary according to whether GDP is calculated on the basis of expenditure, as in OECD publications, or income, as in many New Zealand publications. Expenditure-based GDP currently has a lower growth rate than income-based GDP).

Because they provide the commodities for most of our exports, the primary sector industries (e.g. agriculture, forestry, mining and fishing) still play a greater role in New Zealand's economy than they do in most other OECD economies. However, the tertiary (services) and secondary (manufacturing, construction and energy) sectors contribute much more to GDP and provide much more employment (see Table 3.2). They are also increasing their share of export income. Overall, the services sector has increased its share of GDP since the 1950s, while the primary and secondary sectors have had both gains (e.g. fishing, forestry, energy) and losses (e.g. agriculture, manufacturing, construction) (see Figure 3.2)

**Figure 3.2**

**The changing structure of New Zealand's economy (1955–91).**




Sources: Department of Statistics, 1970; Statistics New Zealand, 1996

The service industries are those that do not convert material products into new forms (i.e. everything from the repair and maintenance trades through to health and education services, defence and policing, transport and communications, banking and finance, science, and even entertainment). It also includes non-market services provided by central and local government, which make up about 13 percent of GDP.

Today, market forces play a much greater role in the use of resources, subject to local or central government restrictions on their environmental effects. Farms and factories are no longer subsidised. Government spending is now more tightly controlled, public debt is declining from the record levels of the 1980s, and public overseas debt is now zero, though private debt is at an all-time high. Foreign ownership of land and resources has increased but so too has New Zealand investment overseas. Inflation levels are now comparable to those of other OECD countries (see Table 3.2).

These changes have influenced production and consumption patterns. On the consumption side, we have seen an increase in the range of imported consumer goods and a GDP-related increase in solid waste production (see Figure 3.12). We have also seen a widening gap in consumer spending power, with the top 40 percent of income earners benefitting from the past decade's changes while the remaining 60 percent have had a decline in their real incomes. The latter trend may help explain the relatively low level of 'green consumerism' here, despite the generally high level of environmental awareness among New Zealanders.

On the production side, the move to fully competitive pricing of energy is leading to a reduction of energy-intensive heavy industry. The removal of import controls has shifted industrial production away from import substitution and toward making light industrial products for export. The removal of agricultural subsidies has reduced sheep numbers, and triggered an export-led increase in intensive dairy and deer production. Horticultural exports have increased, as have log and fish exports. Overall, forestry, fishing, manufacturing and services are all bringing in an increasing share of dollars from overseas. One of the fastest growing earners of foreign exchange is a service industry which is not, strictly speaking, an export industry at all but an import one—tourism.

### *Tourism*

International tourism is now a major source of overseas income for New Zealand, comparable in scale to such high profile earners as meat, dairy and wool exports. Properly managed, tourism offers an alternative to unsustainable land-use practices such as over-grazing in the high country. It allows rural communities to earn money from crafts and tourism services. By adding economic value to land which is not being farmed, logged or mined, tourism may even encourage some people to reserve or restore indigenous forests, wetlands, and other habitats on their properties. The tourism industry can also be a powerful lobby for conservation in some areas. However, the industry can also have negative effects on the environment if it leads to overcrowding or to the establishment of roads and other intrusive tourist developments in previously unspoilt areas (see Chapter 9, Box 9.8).

Because it is a multi-sectoral industry, tourism does not appear by name in our standard industry statistics, so its exact contribution to the economy has to be estimated. Various estimates suggest that international tourists pumped almost $5 billion into the economy in 1995 as against total export income of almost $21 billion. This represents more than 20 percent of our overseas earnings. The estimated contribution of international tourism to New Zealand's Gross Domestic Product ranges from nearly 4 percent (see Table 3.2) to more than 5 percent (New Zealand Tourism Board, 1996a). The latter estimate attributes some 100,000 jobs to international tourism, rising to some 190,000 jobs when domestic tourism is also included.

### *Agriculture*

Agriculture dominates land and water use in New Zealand. More than any other sector, changes in its economic fortunes can have significant reverberations on the environment. Agriculture is a key sector of the economy, directly contributing about 5 percent to the nation's GDP and supporting a further 10 percent of GDP through those industries which process, transport, and sell agricultural products, and those which service the agricultural sector (Journeaux, 1996; Statistics New Zealand, 1996). It also contributes to 17 percent of our employment, roughly half on the farm and the other half in farm-related transport, processing or support industries (Ministry of Agriculture, 1996).

Livestock account for three quarters of our agricultural production (74 percent). Horticulture accounts for 13 percent, agricultural servicing 10 percent, and arable crops 3 percent. The vast majority of this produce is exported. Although agriculture's share of our exports decreased at a rate of one percent per year between 1986 and 1995, declining from 64 percent to 55 percent, it is still our dominant export sector. In no other OECD country in 1995, did agriculture account for such a big share of export income. Although total production has declined in the past decade, the quality and diversity of products has improved markedly because of increased off-farm processing and the development of many new export markets.

In the past decade, the changes in the economy and the Government's policies on agriculture have meant that New Zealand agriculture is now far more vulnerable to fluctuations in world prices and exchange rates, but also far more competitive in overseas markets. Prior to the recent reforms, the Government tried to cushion farmers and manufacturers from the immediate impacts of the market through producer boards (which purchased agricultural products at guaranteed minimum prices), various production subsidies, low interest loans and tax incentives (which helped offset the costs of production), tariffs and import controls (which ensured that locally produced goods remained cheaper on the domestic market than imported foreign products), and controls on overseas financial transactions and the foreign exchange rate of our dollar. By insulating farmers from international market trends, these policies discouraged them from adapting to new conditions and opportunities and permitted them to continue with inappropriate products and practices. When New Zealand's wholesale economic restructuring began in the mid-1980s, its effects on agriculture were dramatic. Beginning in 1984, government subsidies to agriculture were gradually reduced from 34 percent of gross revenue to almost zero in 1995. This makes New Zealand agriculture the least subsidised of all OECD countries (see Table 3.2). In most other OECD countries the level of agricultural subsidy rose or stayed the same over that period.

At present, few affluent countries have followed New Zealand's example in reducing agricultural subsidies and import barriers. As a result, it is still difficult to sell our produce in some of these affluent markets. Increases in the value of the New Zealand dollar have also added to the difficulty by making New Zealand produce more expensive overseas. The long-term answer is being pursued vigorously by New Zealand and other primary producer countries through international negotiations under the General Agreement on Trade and Tariffs (GATT). The GATT's general aim is to free up world trade. Considerable success has already been achieved in some sectors but this is not occurring as quickly in agriculture.

While the agricultural reforms of the past decade have benefitted the economy as a whole, they also brought considerable pain to many farming families and rural communities. Initially the changes led to lower farm incomes, higher debt, declining asset values and adjustment problems for the agricultural service sector. These problems were compounded by declining international prices for agricultural commodities and a rising exchange rate. Many people simply left the farm or sought off-farm work. Between 1981 and 1991, the proportion of the rural workforce engaged in agriculture declined from 47 percent to 42 percent. Farmers began to reduce their sheep flocks, particularly on steep unproductive land, increase their cattle and deer herds, and diversify into horticulture, dairying and forestry.

From 1990 to 1994 the agricultural sector recovered somewhat as farmer debt declined, expenditure and investment increased, and rural land sold for higher prices (Ministry of Agriculture, 1996). The process was assisted by an increase in world commodity prices and by a continuation of the steady rise in dairy and timber prices. The more efficient and intensive use of land has also led to higher productivity, and continued intensification is likely.

#### *Forestry*

New Zealand is rapidly developing into a major forestry nation, although our contribution to global forest product markets is still small. Forests cover 7.9 million hectares (29 percent) of our land area, of which 6.4 million hectares are indigenous forests (most of them protected) and 1.5 million hectares are planted forests. Our planted forests are dominated by radiata pine, which makes up 91 percent of the total, but other important species are Douglas fir and eucalyptus species. Altogether, 17.3 million cubic metres of wood was harvested from our production forests in 1996. Of this, 10.5 million cubic metres was exported, earning New Zealand $2.6 billion and making forestry products our third biggest export commodity (Ministry of Forestry, 1996).

New Zealand has a well established timber processing industry. Two-thirds of the timber harvested in 1996 was processed by New Zealand's four pulp and paper companies, five panelboard companies, more than 350 sawmillers and 80 manufacturers (Ministry of Forestry, 1996). Jobs in the forestry sector have been on the increase since 1991 and are forecast to keep rising, although changes in technology and mechanisation mean that the increases may be smaller than expected. In 1995, forestry contributed 2.5 percent of our GDP and directly provided jobs for more than 25,500 people. If jobs in timber-related industries are added to this, the figure rises to 30,456 jobs (Statistics New Zealand, 1996).

Perhaps the most significant aspect of New Zealand's forestry industry is its future potential. Our planted forests are still mainly young, with 61 percent of trees 15 years old or younger. We are also planting more and more forests—the estimated long term rate of new planting is 56,000 hectares per year. Together, these factors mean that by 2010 wood supply from our planted forests will have increased by 73 percent from current levels and forestry could be New Zealand's number one export earner (Ministry of Forestry, 1996). Although the increase in planted forests is by and large viewed favourably, some rural communities are concerned at the current rate and scale at which pastoral land is being converted to forestry. These concerns encompass landscape changes, infrastructure changes (e.g. roading requirements) and the effects of harvesting on ecological values.

The economic reforms have assisted the forestry sector. Deregulation of the economy since 1984, privatisation of the Government's forestry assets since 1990, changes in the taxation regime, and private sector acquisitions and restructurings have increased the economic performance and competitiveness of the sector. However, the future of the forestry sector also depends to a large extent on our ability to maintain healthy, disease-free forests and the overall environmental quality which contributes to successful marketing of forest products.

#### *Fishing*

Our fisheries resources are a valuable source of social, cultural and economic wellbeing for many New Zealanders. An estimated 20 percent of New Zealanders are recreational fishers. The seafood industry (which includes catching and processing fish) employed just over 10,000 people in 1995, an increase of more than 10 percent since 1992 (Ministry of Fisheries, 1996). Maori also have strong cultural ties to fisheries, which are recognised in common law and legislation. However, the benefits we get from the fishing resource depend on our ability to keep fish populations at sustainable levels and maintain the health of the marine environment as a whole.

New Zealand's Exclusive Economic Zone (EEZ), at approximately 1.3 million nautical square miles, is 15 times the size of the country's land area, giving us the fourth largest area for fishing in the world. However, much of this area has very deep waters and has low biological productivity. There are over 700 fish species in the EEZ, but only 130 of these are fished commercially and only 40 or so are commercially significant. The economics of the fishing industry is dominated at present by just a few species—orange roughy, spiny red rock lobster, paua, greenshell mussels, snapper, ling, squid and hoki (Ministry of Fisheries, 1996).

Although New Zealanders are eating more fish than they used to, the small domestic market means that the seafood sector is directed primarily towards export markets. Japan, the United States and Australia were the main destinations for New Zealand seafood in 1995, but the European Union and other Asian countries are also becoming important, with the EU market growing 6.5 percent in 1995, and exports to other Asian countries growing 14.4 percent. In 1995, fisheries accounted for 28 percent of our export earnings from Japan, 22 percent of our export earnings from the United States, and 11 percent of our export earnings from Australia (Statistics NZ, 1996).

Aquaculture, or marine farming, is also an important part of the New Zealand fishing industry. The aquaculture industry is based mainly on farming green lipped mussels, although pacific oyster, paua and salmon are also important. Research is progressing on techniques for farming other species such as kina, scallops, seaweed, snapper and sponges. In 1995, aquaculture export earnings were approximately $160 million (Ministry of Fisheries, 1996).

Both the total production from the fisheries resource and the export value of the resource appear to be levelling out, at least in the short term. In 1995 total production from the wild and farmed fisheries was over 650,000 tonnes, but the rate of increase in production has been slowing in recent years and is now reaching a plateau (Ministry of Fisheries, 1996). Three difficult trading years in a row (1993-1995) have resulted in static export earnings from seafood of around $1.2 billion in each of those years (Statistics NZ, 1996). In the longer term, however, the trend is towards increasing value, with the total value of fisheries production increasing from $913 million in 1989 to $1363 million in 1995 (Ministry of Fisheries, 1996).

New Zealand's approach to managing its fisheries resources underwent a radical change in the mid 1980s, from a free-for-all competitive fishing regime with some regulatory control, to a property rights approach known as the Quota Management System (QMS). Under the QMS, the Government sets annual catch limits and each fisher 'owns' a defined share of the allowable catch (see Chapter 9, Box 9.14). Further changes to fisheries management were introduced in the 1996 Fisheries Act which requires ecological considerations to be taken into account when setting catch limits.

The QMS provides greater certainty and security for each fisher and gives a greater incentive to fish sustainably. Around 40 species are currently covered by the QMS and these are subdivided into more than 150 individual 'stocks' for quota setting purposes (see Chapter 9). Eventually all commercial species will be brought into the system (Ministry of Fisheries, 1996).

The QMS is being watched with keen interest by other fishing nations who were also finding that their traditional means of managing fisheries were leading to depleted resources, overexpanded fishing fleets, low incomes for fishers, heavy dependence on government support and regulation, and conflict among fishing groups.

The QMS provides certainty and security for all participants in the fishing industry and, since its introduction, there has been substantial growth in the seafood processing and marketing sectors. Thirty-one species are currently covered by the QMS, and it is intended that eventually all commercial species will be brought into the system (Ministry of Fisheries, 1996).

One little-appreciated outcome of the QMS is that nearly all of New Zealand's fisheries resources are fished and controlled by New Zealand companies. This is because quota holders must be New Zealand residents or companies that are less than 25 percent foreign owned. In 1995, New Zealand boats caught 54.7 percent of the total commercial catch, and a further 45.3 percent was caught by foreign boats on charter to New Zealand fishing companies, with New Zealand companies also controlling the processing and marketing of the product. The catch by foreign vessels was negligible (less than 1 percent) and was restricted to the tuna fisheries (Statistics NZ, 1996).

#### *Manufacturing*

Manufacturing accounts for 20 percent of GDP and is becoming increasingly important in the New Zealand economy (Statistics New Zealand, 1996). In 1995, over 250,000 people, around 18 percent of the workforce, were employed in the manufacturing sector. Just over a quarter of these are involved in making fabricated products, machinery and equipment. Another quarter are in the food, beverage and tobacco industries, and around 11 percent are employed in each of a further three categories: textile, apparel and leather goods; wood processing and wood products; and paper and paper products, printing and publishing.

As can be seen from these figures, manufacturing statistics include categories of activity which are also counted under primary industries. The processing of food and textiles is often counted as a subset of agricultural production and employment, while forestry employment statistics frequently include those involved in wood processing and wood products. This serves to illustrate the interdependence of the manufacturing sector and the primary industries such as fishing, farming, forestry and mining.

As with the primary industries, the role of government in the manufacturing sector has changed over the last decade. Instead of providing direct support for the industry, the Government now aims to foster an environment in which businesses are responsible for creating, capturing and capitalising on their opportunities. The complete removal of import licensing in 1992, and the phased tariff reduction programme on imported goods which is still continuing, have lowered the cost of imported materials and opened the domestic market up to international influences. Manufacturing is now more reliant on general economic conditions and on the competitiveness of its supporting industries. The deregulation and privatisation of infrastructural sectors, such as transportation, energy, communications and finance, has therefore benefited the manufacturing sector.

### *Services*

The services sector is growing strongly in New Zealand. It includes activities such as central and local government services (including health, education, policing etc.), community services, trade, restaurants and hotels, financial services, communication services, electricity, gas and water supplies, and transportation and storage—in fact, all activities that do not convert material products into new forms.

The share of GDP contributed by these activities has grown over the last 40 years from around 45 percent to around 66 percent in 1992. This shift has been at the expense of agriculture and manufacturing (see Figure 3.2). About 12 percent of our GDP is from non-market services provided by central and local government. This shift toward a more services-dominated economy is a feature of all affluent societies.

It is sometimes suggested that a services-dominated economy is inherently more environmentally sustainable than one based on manufacturing or primary resources. However, it needs to be remembered that all service industries rely on the fuels, raw materials and manufactured items produced by the primary sector. All sectors, therefore, share some of the responsibility for the economically-driven pressures on New Zealand's environment, such as our patterns of energy use and waste generation which are discussed in the remainder of this chapter.

## ENERGY USE

Energy is not just a resource; it is the breath of the Universe. Energy binds the nuclear particles that hold atoms and all matter together. Its flow through organisms and ecosystems sustains all life, and its flow through machines and powerlines sustains modern society (see Box 3.2). Underlying all energy flows are basic physical constraints which are summarised in the Laws of Thermodynamics. The two most significant laws state that energy cannot be created or destroyed (that is, the sum total of energy in the Universe is fixed), and that energy moves from concentrated states to more dispersed states (that is, the amount of **ordered** energy in the Universe is decreasing).

This means that the daily struggle for life is basically a struggle for limited energy resources, with the gains of one organism or group often being at the expense of others. It also means that each energy transfer generates waste, either as heat or disordered matter. From this we can infer that, as society's energy flows increase, so does the potential for climate warming and pollution.

Energy is sought and consumed not for any intrinsic value that it may have, but rather, for the work it does (e.g. warming our bodies, powering our muscles or our cars, providing light when the sun has gone). Energy demand is therefore referred to as a 'derived demand'. In other words, the demand is not for the energy itself, but for the 'services' it provides. The provision of energy services makes up around 3 percent of New Zealand's GDP and it plays a critical role in our economy as an essential input into almost all our industrial, commercial, transport and household activities.

These days, energy is measured in joules (J). Lifting a cup of coffee from the table to your mouth takes about one joule of energy (Redshaw and Dawber, 1996). The standard 'food calorie' (actually a kilocalorie) is an older and less precise unit, roughly equivalent to about 4,186 joules. The large amounts of energy consumed by machines, cities and nations are commonly measured in larger units such as megajoules (MJ) or petajoules (PJ).

One megajoule is a million joules ($10^6$ J), or about 240 food calories. The recommended minimum food requirement is about 10 MJ per day, and the average New Zealander eats about 14 MJ per day (see Table 3.2). One petajoule is a million billion joules ($10^{15}$ J) and is equivalent to about 23,000 tonnes of burning oil, or the yearly electricity supply of a city the size of Napier. In 1996, New Zealanders consumed nearly 430 PJ of energy—almost 10 million tonnes of oil equivalent.

The other important unit of measurement is the watt (W) which is used to measure power. Power is the rate at which energy is converted from one form (e.g. heat) to another (e.g. electricity). One watt of electricity represents the conversion of one joule per second. A megawatt (MW) is one MJ per second. A megawatt-hour (MWh) is one MJ per second sustained over an hour—3,600 MJ in all. In a year, New Zealand's total electricity use comes to about 30 million MWh, or nearly 110 PJ, which is about 2.5 million tonnes of oil equivalent.

It is misleading to think of energy consumption just in terms of the final amount consumed by the car, electric light or heater. Before reaching us, many forms of energy are converted from their initial state (primary energy) into a more convenient state (consumer energy). Where conversion involves heat, large amounts of energy are lost. For instance, only 10 percent of the primary energy in geothermal steam is actually converted into electricity. In the case of synthetic petrol, about 50 percent of the primary energy is lost when converting it from natural gas (and approximately 60 percent of the remaining energy is lost in the car engine). Furthermore, some primary energy is diverted into non-energy products (such as plastics made from oil, and chemicals and fertilizer made from natural gas). This means our total energy consumption is actually much greater than our end use might suggest.

**Box 3.2**

### *Energy and human society*

Most of our energy comes from the Sun's radiation and from the forces of gravity and volcanic heat deep within the Earth. The Sun's rays provide the heat that keeps the Earth's temperature within the range of liquid water. That heat also creates the wind, ocean currents and clouds by raising air and water pressures and evaporating water. The downward pull of gravity powers the the fall of the rain, the flow of running water, and the movement of glaciers, avalanches and landslips. The violent energy of volcanic eruptions and upwellings shapes continents, shunts tectonic plates, triggers earthquakes, and heats the world's geothermal aquifers, geysers and mud pools. These are not the only energy sources on Earth. The atoms that make up all matter consist of particles held together by nuclear energy. This nuclear energy leaks slowly out of many substances through radioactive decay. Fifty years ago humans learned how to unleash it rapidly from substances such as uranium, thus releasing large amounts of heat and explosive power. Nuclear energy is not used in New Zealand but many countries use it as a fuel for heating steam to generate electricity, and as the explosive component in nuclear weapons.

The above energy sources shape the physical environment in which living things grow and die. But the energy for life itself is carried in chemical form, specifically the large carbohydrate and lipid molecules which provide us with food and fibre (i.e. sugar, starch and wood, vegetable oils and animal fats). These carbon-based (or organic) compounds are formed in a process called photosynthesis whenever sunlight strikes the chloroplasts of plants, algae or cyanobacteria. The carbon compounds forged by solar energy become fuel stores whose chemical bonds hold the energy until such time as they are broken down (or oxidised) through digestion, rotting or burning. At this point, the energy is chemically transferred to other molecules or is simply released as heat. Non-photosynthesising organisms (i.e. animals, fungi, protozoans and most bacteria) cannot capture the sun's energy directly and so must get it chemically by preying on plants, algae, cyanobacteria or each other.

In the struggle for energy, humans have emerged supreme. We did this, first, by colonising new land. This happened twice on a global scale. A million or so years ago, our ancestor species *Homo erectus* radiated out of Africa to occupy much of the Old World from Asia to Europe. Eventually, however, the species succumbed to the encroaching Ice Ages, except in tropical Southeast Asia (Swisher *et al.,* 1996). The second colonisation phase began about 100,000 years ago, when small bands of our own species left Africa to radiate throughout the world, displacing many large animal species, including the remaining *H. erectus* people and our Neanderthal relatives in Europe (Stringer and McKie, 1996). By occupying new land we increased our access to productive soils and to the energy-rich carbon supplies stored in the wild plants and animals that lived on them.

Another victory in our quest for energy services was the mastery of fire. Cooking expanded the dietary options by making some inedible food edible. It also enabled warmth to be generated from inedible plant material (i.e. wood). And, for the first time, it enabled large areas of land to be cleared of vegetation with very little effort. This was useful for hunting and for fostering grassland ecosystems rather than forest ones. One of the oldest known cooking hearths, complete with charcoal, tools and charred rhino bones, was lit by *Homo erectus* in the Brittany region of France between 380,000 and 465,000 years ago (Patel, 1995). Other fireplaces of similar age are known from southern France, Hungary, and China. Hundreds of thousands of years later, when our species ventured out of Africa, firesticks and flint were a vital part of the toolkit.

The next major energy revolution occurred in the last 5–10 percent of our existence as a species. This was the development of agriculture a mere 250–500 generations ago, following the last Ice Age (Bunney, 1994; Lewin, 1996; Normile, 1997). The capture and storage of photosynthetic energy in the form of grain and other crops greatly expanded the human energy budget. It also transformed the economy from one which depended on diverse natural ecosystems to one which actively replaced them with just a few crop and livestock species. The impacts of the agricultural revolution were later magnified by the domestication of the horse, the ox and the donkey for transport and labour, as well as the invention of the sail and wheel for transport, and of the windmill and waterwheel for mechanical labour. Agricultural wealth also allowed the accumulation of large amounts of food wealth, the growth of large non-productive sectors (e.g. priests, artisans and soldiers) and the capture and maintenance of large pools of human slave labour. The result was population growth and ever wider and more efficient colonisation and exploitation of the land's photosynthetic resources.

Today, a quarter of the Earth's land surface (24 percent) has been appropriated for pasture to convert the sun's energy into grass which is then converted into animal waste, metabolic heat and livestock products. A further 10 percent has been appropriated for agricultural crops. About 3 percent is occupied by human settlements. The remaining 62 percent is not used, being divided equally between forests (which are shrinking daily) and dry lands— deserts, ice and snow (World Resources Institute, 1994). By the mid-1980s, humans had commandeered almost 40 percent of the land's total photosynthetic energy—3 percent in food, animal feed and firewood, and 36 percent in crop wastes, forest clearing, desert creation, and conversion of natural areas to settlements (Vitousek *et al.,* 1986).

Although the agricultural revolution greatly increased the amount of photosynthetic energy available to human beings, it was only within the last four or five generations that an even greater energy revolution occurred with the harnessing of electricity and 'fossil fuels' (i.e. coal, oil and natural gas, and their derivative products, petrol and diesel) to drive machines and appliances. One tonne of burning oil releases as much energy as the hourly output of a herd of 16,000 work horses (around 44,000 MJ). As a result, a couple of modern trucks can do more work than the entire transport system of London, New York or Paris could 150 years ago (Foley, 1976). Discovering the fossil fuels was like finding vast new lands—literally. These energy-rich compounds occupy millions of 'ghost acres' beneath the ground (Catton, 1980). They are the remains of long-dead forests and marine life whose carbohydrates have been transformed into hydrocarbons.

Today New Zealanders harness energy from many different sources. Fossil fuels account for about two-thirds of New Zealand's energy, while hydro-electricity and geothermal steam make up most of the remaining third. Minor sources are firewood, biogas (from rotting vegetation), and solar heating and wind power (both generated by the sun's heat). Some of this energy is used directly for cooking and heating but most is converted into mechanical and electrical energy. The conversion of heat to mechanical energy occurs inside the cylinders of the combustion engine where controlled explosions rotate a crankshaft that is attached to the working parts of a machine. The conversion to electrical energy occurs inside thermal power stations where high pressure jets of steam, either from geothermal sources or from boilers heated by fossil fuels, spin giant turbines. These are attached to electromagnetic generators which create the electrical current that flows out along the nation's power lines. Hydro power stations achieve the same result by using flowing water (powered by gravity) to spin the turbines. The technique is basically a modification of that used in early industrial Europe when millwheels, or waterwheels, were placed in streams. The millwheel was attached to a shaft whose other end was attached to machinery inside the mill. As the flowing water turned the millwheel, the shaft rotated, driving the machinery. Today, the flowing water generates 70–80 percent of New Zealand's electricity

The energy revolution of the past century has allowed the average citizen in a developed nation to consume about a hundred times more energy than our hunter-gatherer forebears. We now live as our ancestors believed only gods could live, empowered with instant communication, instant light, rapid transport and the power of flight. We have built a near-magical world of aeroplanes and cars, plastics and other synthetic materials, hot water and frozen food, television and telephones, and so on. The accelerating spiral of invention and investment has created a world economy which is under constant expansion and growth. As part of this our aspirations keep rising to new heights of material comfort, including our desire for services (such as heat, light and locomotion) which consume a lot of energy. Even as our numbers multiply, we each hope to capture more of the Earth's resources than did our parents. This is the historical and global context in which modern New Zealanders are now using energy and planning their future.

### New Zealand's Energy Resources

The energy sources for pre-European Maori society were human labour (powered by food), fire (powered by wood), and in some areas geothermally-heated water. Wind power was also used to drive the sails of the first Maori canoes. The early European immigrants, refugees from the coal-powered Industrial Revolution, had much the same range of energy supplies—with one significant addition: the horse.

By the time it reached New Zealand, the horse was long established as the world's main work animal. Its main energy sources were oats and grass. But even as it got here, the horse-driven economy was being overtaken in Europe and North America by coal-driven steam locomotives. These 'iron horses' did not make an impression in New Zealand until the 1870s when sufficient coal began to be mined and when sufficient human labour arrived to build the railway lines. The horse remained dominant until the early days of this century, but finally succumbed to the Ford motor car and the Fordson tractor in the years after the First World War.

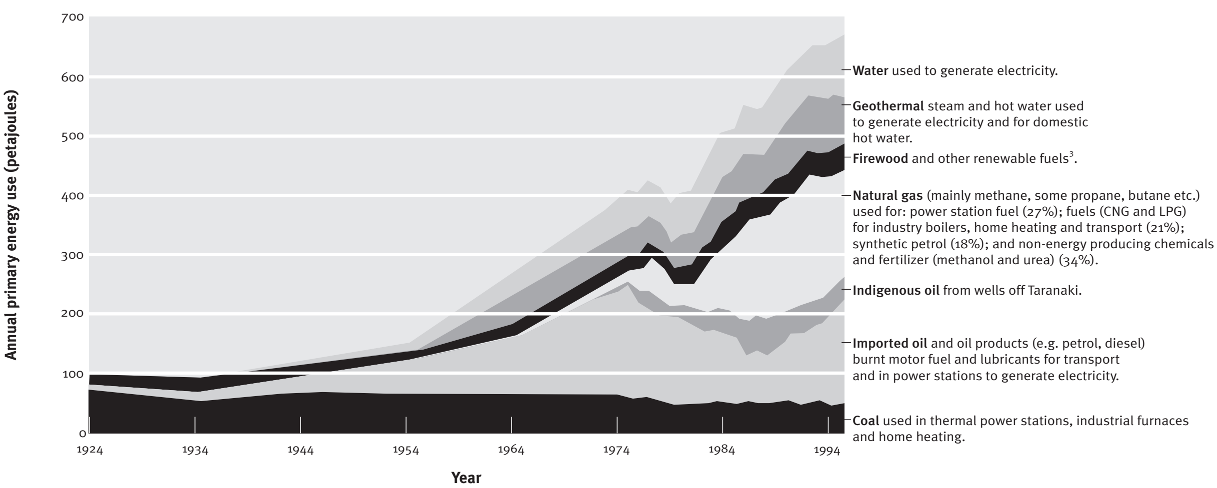
These petrol-driven vehicles also spelt the end of coal's dominance. But, unlike the horse, coal's lesser role was still secure, both as a train fuel and as the main fuel for domestic fires, industrial boilers and furnaces. It also became an important fuel for generating steam to make electricity. Coal production reached a peak in the 1920s, dipped slightly in the 1930s depression, and remained high for four more decades (see Figure 3.3).

From the 1930s, oil and hydro-electricity became increasingly significant as the car culture expanded and as networks of power lines filled the skyline on every street, connecting the nation's homes to a world of electric lights, ovens, refrigerators, heaters, radios, vacuum cleaners and washing machines. From 1950 to 1980, oil and hydro-electricity were the dominant sources of energy in New Zealand.

Following the second 'oil shock' after the Iranian revolution of 1979 the Government embarked on the 'Think Big' growth strategy which aimed to make New Zealand at least 60 percent self-sufficient in energy and to also attract foreign investment in energy-intensive industries. The strategy called for more hydro development, intensified oil exploration, and the use of our recently-discovered natural gas reserves, either directly or to manufacture synthetic petrol.

**Figure 3.3**

**Trends in New Zealand's consumption of primary energy[1,2].**




[1] Primary energy is the energy content of a resource at the point of extraction or importation. A third of the energy is lost after this point, either as waste heat (e.g. in generating electricity from fossil fuels and geothermal steam) or as non-energy products (e.g. methanol and urea from natural gas). As a result, the amount of energy actually consumed in mechanical movement, useable heat and electricity is considerably less than the amount extracted.

[2] Data are decadal 1924-1974, yearly thereafter.

[3] 'Firewood and other renewable fuels' includes wood, biogas (e.g. methane generated from rotting matter by bacteria) and industrial waste, but not water-based renewables (i.e. geothermal steam and hydro).

Source: Ministry of Commerce

A high dam was built at Cromwell on the Clutha River to generate electricity for a second aluminium smelter (proposed for Aramoana near Dunedin, but later abandoned). The New Zealand Steel mill at Glenbrook, south of Auckland, was expanded. Petroleum exploration was intensified off the Taranaki coast where several wells were already producing significant quantities of oil. Until the 1970s, New Zealand had imported all its liquid fuels (i.e. oil, diesel, petrol), but from the mid-1970s to the late 1980s locally produced oil increased and imported oil declined. The trend has since reversed, and will continue to do so as Maui gas continues to decline. Natural gas had only been lightly exploited until the late 1970s when the small Kapuni gas field was joined by the much larger Maui field and several other small ones.

Today, New Zealand has an abundance of energy resources, though some of these (such as Maui gas) are moving towards the end of their exploitable life, and others (such as wind power) are only just beginning to be recognised. In 1996 New Zealand was around 87 percent self-sufficient in its primary energy needs, but only 39 percent self-sufficient in liquid fuels.

It is conventional to divide energy sources into those which are renewable and those which are not, though the distinction is not always clear-cut. For example, hydro-electricity is generated by running water passing over a turbine. The water is renewable, but the dam itself is not if it silts up.

### *Non-renewable energy*

Oil, natural gas and coal are the main non-renewable energy sources in New Zealand. Oil provides around 32 percent of our total primary energy supply, gas around 27 percent and coal 7 percent. Together, these non-renewable sources of energy make up two-thirds of our energy supply (see Figure 3.3). New Zealand's coal resources are abundant, but our known oil and natural gas reserves are limited. Gas supplies are dominated by the Maui field, which accounted for around 64 percent of New Zealand's estimated total expected gas reserves in December 1995, and which produced 80 percent of net gas production in 1994. The Maui field is expected to reach the end of its economic life by around 2004–2006. Other reserves which have been discovered so far will allow production only at lower rates from then until around 2014. New Zealand's oil reserves are also found mainly in the Maui field.

Although nuclear energy has been used in some overseas countries, its use is not considered to be an option in New Zealand as many people have significant concerns about its long term environmental effects.

### *Renewable energy*

Renewable energy sources now make up around 34 percent of our total primary energy supply. The vast majority of this is water which provides energy in two forms: the gravitational energy of flowing water and the volcanic heat of geothermal water. The flowing water provides 15 percent of our primary energy in the form of hydro-electricity, while the geothermal energy provides 14 percent of primary energy, mostly as electricity, but also domestic hot water in some areas.

Many other renewable energy sources are potentially available in New Zealand, though little use has been made of most to date. Those that are used, or may be used in New Zealand include:

- **the wind**, whose energy can be harnessed by wind turbines and converted into electricity or used to pump water;
- **biofuels**, either in the form of solids (firewood and dry plant matter), liquids (mainly the alcohols, methanol and ethanol, which are extracted from wood or from purpose-grown crops such as sugar beet), or gases (mainly methane obtained from rotting organic matter at landfills, farms and industrial sites, or from purpose-grown crops);
- **direct sunlight**, whose energy is already used passively to warm homes during the day and dry out washing on clotheslines, and can also be harnessed more effectively for home heating through solar water heating panels and to charge electric batteries through photovoltaic cells; and

- **waves, tides** and **ocean currents**, whose energy can be harnessed by turbines similar to those of hydro power stations.

***Electricity***

Of the approximately 7900MW of installed peak capacity in 1995 around 66 percent is hydro, 28 percent is thermal, 3 percent is geothermal , with the remainder being co-generation plant.

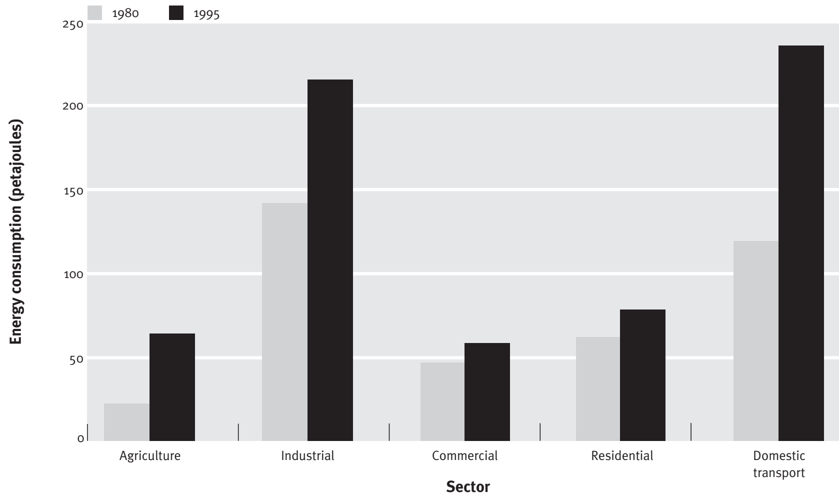
Most of New Zealand's electricity is generated by hydro stations. Hydro accounted for around 79 percent of electricity generation in 1996, although this varies from year to year depending on water inflows and electricity demand. Our hydro generation performance is all the more noteworthy as our dams at any one time hold only approximately 10 weeks storage; i.e. we fill and refill our storage lakes throughout the year.

New Zealand's thermal system is primarily dependent on gas to fuel the Huntly (1000MW) and New Plymouth (580MW) stations. In 1996 gas provided around 12 percent of our electricity, geothermal around 6 percent, and the remainder was made up of other forms of generation (e.g. coal fired power stations and co-generation) The Huntly station can run on either coal or gas (Ministry of Commerce 1997).

At present, most of our electricity capacity (94 percent) is in power stations owned by the two state-owned enterprises Electricity Corporation of New Zealand (ECNZ) and Contact Energy Limited. The remaining 6 percent is in small dams and thermal plants owned by local energy supply companies and large industries. In mid 1996, the ECNZ power stations included 27 hydro stations, three thermal (fuel-burning) stations, and one wind turbine (ECNZ, 1996). Contact Energy, which was established at the beginning of 1996, is a smaller company with just over 26 percent of the total electricity generating capacity. Its power stations include two large hydro stations, two geothermal stations and four thermal stations (Contact Energy, 1996).

**Figure 3.4**

**Energy consumption by sector in New Zealand[1].**




[1] 1980 figures for each sector are estimates.

*Source: Ministry of Commerce*

At present, the total capacity of the ECNZ and Contact Energy power stations is sufficient to generate 38 million megawatt hours (MWh) per year, even in a '1-in-60' dry year. This is 26 percent more than the 30 million MWh consumed in 1995. The stations' peak hour capacity is nearly 7,900 MW, though actual peak demand has never topped 5,500 MW. (Redshaw and Dauber, 1996)

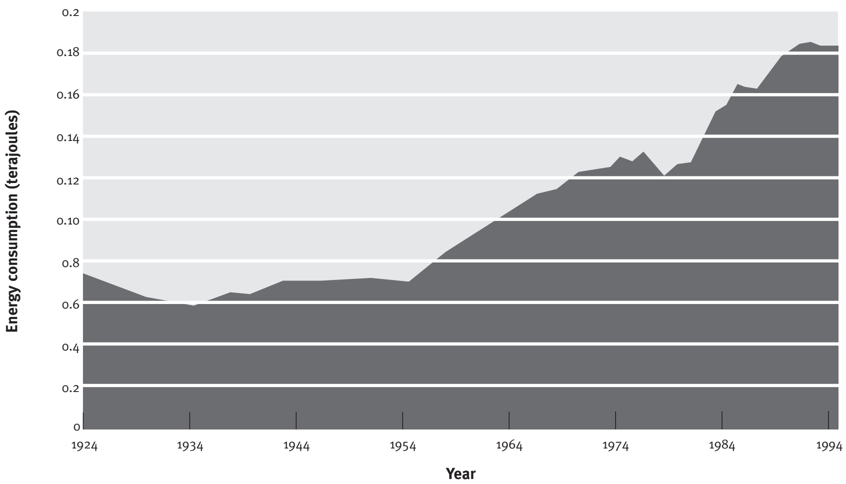
**Energy Consumption in New Zealand**

Each day New Zealand uses about 1.8 PJ of primary energy—or 506 MJ per person. This is about 35 times our daily food energy. However, not all this energy is actually consumed. In 1996, New Zealand's primary energy supply totalled about 665 PJ, of which only two thirds (some 427 PJ) made it to the consumer. A third was lost during extraction and use, mostly as waste heat. The remaining 66 percent was consumed as fuels and electricity.

Nearly half of this 'consumer' energy came from oil (46 percent) and a further quarter came from hydro and geothermal electricity (26 percent). The remainder came from coal (9 percent), gas (9 percent) and other renewable sources of energy, such as wood and geothermal water (10 percent). Some of this energy was used directly by us, but much of it was used indirectly because the energy was already 'embodied' in our

**Figure 3.5**

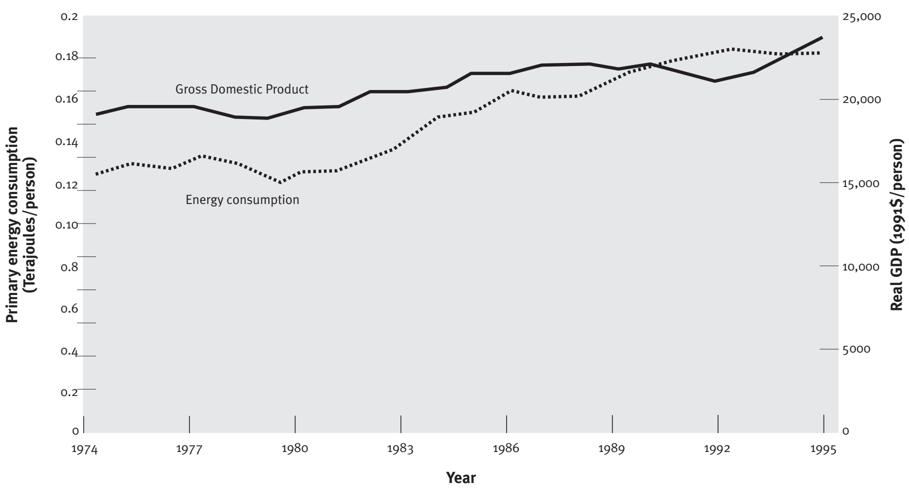
**Primary energy consumption per person (1924–1995)[1].**




[1] Primary energy is the content of a resource at the point of extraction of importation. A third of the energy is lost after this point, either as waste heat (e.g. in generating electricity from fossil fuels and geothermal steam) or as non-energy products (e.g. methanol and urea from natural gas). As a result, the amount of energy actually consumed in mechanical movement, useable heat and electricity is considerably less than the amount extracted.

**Figure 3.6**

**Energy use and economic growth in New Zealand 1974-95.**




*Source: Statistics New Zealand; Ministry of Commerce*

manufactured products. Even an item as commonplace as a recycled aluminium can, for example, embodies 7.5 MJ (see Table 3.5). This is more than half the average person's daily calorie intake, and is the energy equivalent of lifting the can to your mouth more than 7 million times. The embodied energy in a modern car is equivalent to about three years of petrol consumption. A television set embodies far more energy in its various manufactured parts than it will ever consume in electricity.

While energy consumption has increased in all sectors, the greatest growth between 1980 and 1995 was in the transport sector, whose share of total consumer energy rose from around 30 percent to 36 percent (see Figure 3.4). Agriculture's share also increased, from 6 percent to 10 percent. In contrast, industry's share declined slightly, from 36 percent to 33 percent, even though its total consumption was up. The residential and commercial sectors show the same trend. Overall New Zealand's energy consumption has increased markedly since the 1950s (see Figures 3.3 and 3.5), but the trend has not been entirely smooth. In the 1970s it was interrupted by the global price rise in oil. However, from the early 1980s to the early 1990s, it climbed more steeply than ever before. Although the population rose by only 17 percent between 1974 and 1995, energy consumption increased by 53 percent. In part, this was caused by the development and expansion of a number of energy-intensive industries as part of the Government's 'Think Big' strategy, such as aluminium smelting, steel-making, and the Taranaki-based petrochemical industries.

Although in other affluent countries energy intensity started to decrease from the late 1970s (as a result of rising oil prices and the increasing economic dominance of the services sector), in New Zealand this trend has only become apparent in recent years. In Canada, for instance, the decrease in energy intensity began in the years immediately following the first oil shock, whereas in New Zealand at that time due to other factors, energy intensity was boosted to an all-time high. Our energy consumption per person peaked a lot later, when GDP was falling (see Figures 3.5, 3.6).

Since 1991, the New Zealand economy (GDP) has grown, but energy consumption has remained relatively constant and energy intensity is now decreasing (see Figure 3.6). This reduction in energy intensity reflects several factors: a shift from energy intensive industries to less energy-intensive economic activity, technology uptake in a growing and increasingly competitive economy, a shift to fuel mixes which contain a relatively greater proportion of efficient fuels such as electricity; higher and increasing real energy prices, increased environmental awareness and policy measures to protect the environment, and increased uptake of energy efficiency. The Ministry of Commerce (1997) predicts that consumer energy intensity will continue to decrease at 1.5 percent per annum over the next 25 years for GDP growth of 3 percent per annum.

**Energy Policy in New Zealand**

Energy policy in New Zealand has undergone a radical change in recent years. Before restructuring, the Ministry of Energy controlled the nation's electricity, which was generated, transmitted, and sold to distributors by the Electricity Division of the Ministry. Other major forms of energy (i.e. coal and gas) were also government-owned or controlled (although there was, and remains, private ownership of some small coal fields). The Government had its own oil prospecting company and was part owner of a synthetic fuels manufacturing plant. Only our imported oil was fully in the hands of private enterprise. Under this system, energy prices were regulated by the Government whose main aim was to make energy affordable, both for social reasons and to stimulate economic growth.

Since the late 1980s the Government has taken various steps to distance itself from direct involvement in the energy sector. These measures include:

- separating the policy role from the delivery of electricity by establishing a State Owned Enterprise which was later split into a generating company (the Electricity Corporation of New Zealand) and a national transmission company (Trans Power);
- selling the Government's petroleum exploration company;
- selling the Government's interest in gas and gas transmission;
- deregulating the gas, petroleum and electricity markets; and
- promoting a competitive electricity generation market by dividing the Electricity Corporation of New Zealand (ECNZ) into two competing State Owned Enterprises (ECNZ and Contact Energy Ltd), each of which generates and sells electricity at wholesale prices to power supply companies which then retail it to consumers.

Today, there is no Ministry of Energy, although there is still a Minister. The old Energy Ministry's research and advisory functions are now handled by the Ministry of Commerce. Planning in the energy industry is now left to the market, while local authorities, acting under the Resource Management Act 1991, are responsible for making sure that energy producers avoid, mitigate or remedy any environmental impacts of their activities. An internationally competitive royalties regime to encourage investment in oil and gas exploration has been put in place.

Although the Government is no longer involved in energy planning or production, its energy policy objectives are "to ensure the continued availability of energy services, at the lowest cost to the economy as a whole, consistent with sustainable development" and, within this, to "facilitate the development of cost-effective renewable energy consistent with the Government's energy policy framework."

Rather than take a directive role, the Government promotes these objectives by facilitating structures to promote well functioning commercial systems, removing legal or structural barriers to innovation, promoting and adopting efficient energy practices, and analysing the resource potential, cost, and feasibility of renewable energy. Because the Government is a significant purchaser of a broad range of goods and services, it also has the opportunity to promote energy efficiency by example.

A major recent initiative has been the development of a wholesale electricity market (i.e. a market in which electricity generators sell electricity in bulk to distributors such as local electricity supply companies). One of the main reasons for setting this up is to make electricity prices reflect the full costs (including environmental costs) of supply. For example, it costs more to generate electricity from thermal stations than from hydro stations. In the past, that difference was masked by charging a standard average price for electricity.

Under the new system, whenever hydro stations are unable to meet extra demand and thermal stations are called on, the price will go up accordingly. Unlike the previous system, this provides a clear incentive for electricity consumers to limit extra demand and to make more efficient use of electricity. Economic analyses commissioned from the research group BERL by the Officials Committee on Energy Policy (1994) estimated that the demand for extra electricity by the year 2010 would have been twice as great under the old system as under the new wholesale market system.

The wholesale market also gives electricity suppliers an incentive to seek cheaper ways of making electricity, and creates an opportunity for new low-cost suppliers to become established (including those generating electricity from such non-traditional sources as wind, biofuels and solar power).

Apart from market reform, the Government has also taken steps to improve the ways we use energy, such as the Ministry for the Environment's Cleaner Production Programme and a range of initiatives undertaken by the Energy Efficiency and Conservation Authority (EECA). EECA is a small government agency that was established in 1992. It reports directly to the Minister of Energy and its staff are charged with promoting the conservation of energy resources and encouraging the adoption of energy efficient practices and technology.

To date, EECA's achievements include: the development of the Energy Saver Fund; the revision of energy efficiency provisions within the Building Code; the development of minimum energy performance standards; the establishment of the Energy Wise Companies Campaign, whose 650 member companies are committed to improving their energy use practices; and the provision of information and technical advice on methods of saving energy.

Much of EECA's activity is shaped by the Government's ten point Energy Efficiency Strategy launched in 1994. The Strategy's three-year $8.45 million programme includes a range of practical measures to increase energy efficiency and encourage the development of non-traditional renewable energy sources. Highlights of the Strategy include:

- the Energy Wise Companies Campaign;
- specific programmes to promote the more efficient use of hot water, commercial lighting, and industrial motors and drives;
- a "best practice" programme to provide information, motivation, and guidance to industrial energy consumers; and
- demonstrating technologies that are energy efficient and use renewable energy resources in order to promote their commercialisation.

**Future Energy use**

Energy forecasts by the Ministry of Commerce predict that consumer energy is likely to grow by around 45 percent between 1995 and 2020 (Ministry of Commerce, 1997). This prediction assumes 3 percent GDP growth per year and new gas discoveries sufficient to provide around 90–100 PJ a year from 2010. Total consumer energy demand is expected to increase by 1.5 percent a year, with growth strongest in the transport sector at 1.8 percent a year. To meet this additional demand, there is little doubt that some new sources will be required.

Most energy prices are expected to rise, with electricity prices (which are currently very low by international standards) growing the fastest because of the declining gas supply and the rising cost of building new power stations. Fossil fuels for power generation, transport and heating will also become more expensive. Oil prices are expected to rise to $US 25 per barrel by 2005 but stabilise thereafter. Coal prices are expected to remain stable throughout the period.

***Future use of conventional energy sources***

If we are to meet our energy needs with conventional energy sources, the key options seem to be:

- *discovering and developing new oil and gas fields*. Although many small gas fields have been found in the 25 years since Maui was discovered, some, such as Kupe, are currently too expensive to exploit. Moreover, the odds of finding another large field before 2004–2006 are getting smaller as the time horizon contracts. As the price of oil increases, this will provide greater incentive for further oil exploration;
- *importing more oil products*. According to some energy analysts, over half the world's oil has already been consumed and, at current rates, 80 percent will have been consumed by the year 2020 (Laharrere, 1995; Campbell, 1996). The remaining 20 percent is in reserves that are more difficult to access. Oil reserves in the US and Europe are expected to be depleted in 15–20 years. Middle Eastern supplies will be plentiful for some decades, but at higher prices;
- *using more coal*. Coal is abundant in New Zealand, but the largest deposits are of low grade lignite, while the higher grade bituminous and sub-bituminous coals used in coal-fired power stations are becoming increasingly expensive to mine;
- *building more dams*. It has been estimated that an additional 9,120 MW could be obtained from New Zealand's waterways by developing new sites and expanding some existing dams (Eden Resources Ltd, 1993); or
- *building more geothermal stations*. Geothermal resources are extensive and may contain 21–43,000 PJ of primary energy (Statistics New Zealand, 1994).

The Ministry of Commerce forecasts also predict that yearly electricity demand will grow from 106 PJ to 166 PJ between 1995 and 2020—a 1.8 percent increase per year. The Ministry expects that electricity suppliers will meet this demand by adding an extra 2,600 megawatts (MW) of generating capacity to the existing 7,900 MW, both through new power plants and improvements to existing ones.

Because most of the more economical sites for power stations have already been taken, new power stations will become increasingly costly to build. As a result, the cheapest options are likely to be developed first, namely, combined cycle and cogeneration plants (which use natural gas in combination with other fuels and processes), and also some geothermal development (see Table 3.3). Hydro and further geothermal development are likely to become affordable later, as wholesale electricity prices rise. Eventually the rising prices are expected to make large wind farms and new thermal stations economic.

Of course, cost alone is not the only factor influencing power station development. Other factors include capital turnover in the industrial and commercial sectors, strategic behaviour by other electricity generators, and environmental impacts. As a result, the actual order in which stations are built or improved may differ from the purely cost-based sequence shown here.

**Table 3.3**
**Possible sequence of new power station development, based on cost.**

| Type of power plant | Added power-generating capacity (MW) in each five-year period | | | | | Total |
|---|---|---|---|---|---|---|
| | 1996-2000 | 2001-2005 | 2006-2010 | 2011-2015 | 2016-2020 | |
| *Combined cycle natural gas plant at Stratford* | 400 | | | | | 400 |
| *Cogeneration natural gas plants (various)* | 160 | 115 | 75 | 50 | 50 | 450 |
| *Geothermal plants (various)* | 60 | | 200 | 150 | | 410 |
| *Hydro refurbishments and new hydro stations (various)* | | 300 | 100 | 200 | | 600 |
| *Wind farms (various)* | | 20 | 50 | | 130 | 200 |
| *Thermal power stations:* | | | | 150 | 400 | 550 |
| *Oil-burning* | | | | 150 | | 150 |
| *Coal-burning* | | | | | 400 | 400 |
| *TOTAL* | 620 | 435 | 425 | 550 | 580 | 2610 |

*Source: Ministry of Commerce (1997)*

Environmental impacts are particularly important. They set very real limits on the future development of conventional energy sources. While some combination of coal, imported oil, and large-scale geothermal and hydro development may seem economically feasible over the next few decades, their environmental impacts may no longer be acceptable or even sustainable. Environmental considerations could therefore favour wind farm development at the expense of some of the more conventional options.

### *Future use of renewable energy sources*

At present New Zealand has 17 small hydro stations which generate 44 MW (EECA and CAE, 1996). The latest review of renewable energy opportunities in New Zealand has concluded that the biggest contribution is likely to come from **small hydro schemes**, **biofuels**, and **wind power**. Some 174 river sites are technically suitable for weirs or dams associated with small power stations (i.e. those with a capacity no greater than 10 MW). Over 100 of these are in the North Island. If all 174 were developed, they could provide a total of 930 MW of electricity. Wind power has greater potential. More than 2,000 MW of electricity could be generated by the wind, if all potential sites were developed (see Box 3.3).

However, the greatest potential for future energy production comes from biofuel (EECA and CAE, 1996). The most common biofuels at present are firewood and forestry waste which currently produce about 32 PJ per year (over 4 percent of our total primary energy). By 2010, this will have doubled to 58 PJ. This is useful, but modest compared to the enormous potential of special purpose fuel crops. If just 1 million hectares of pasture land were converted to plantations of fuel crops, the annual energy yield would be around 540 PJ—85 percent of the nation's current primary energy supply.

Other biofuels include gases emitted by organic wastes from landfills, sewage treatment works, the food-processing industries, and farms. These are expected to contribute only a small amount. Their total potential energy yield is around 6–7 PJ per year, but the costs and practical difficulties of collecting it mean that the useable amount is lower. Biogas is collected and used on-site by some large farms and food processing plants and at several landfills in Auckland, Hutt Valley, Porirua and Dunedin. Christchurch's sewage ponds generate about 3 MW of electricity. However, these are waste management programmes aiming at greater efficiency rather than significant energy projects (EECA and CAE, 1996).

**Box 3.3**

### *Reaping the wind*

Lying across the path of the southern hemisphere's prevailing north-westerlies, New Zealand is constantly buffeted by strong winds and stiff sea breezes. This means we are ideally placed to harness wind power for electricity (EECA and CAE, 1996). At least a dozen parts of the country have the potential for wind farms and it is estimated that they could provide up to 30 percent of our current electricity consumption—three times the the capacity of the Clyde Dam (see Figure 3.7). The sites range from the far north to the deep south, with several located close to large towns and cities (i.e. west Auckland, New Plymouth, Palmerston North, Wellington and Hutt City, Christchurch and Invercargill).

Wind power is often mistakenly assumed to be a fluctuating power source whose supply is unreliable. In fact, wind patterns are less variable than the rainfall that supplies our hydro-electricity. Wind speed follows predictable seasonal patterns which vary from year to year by about 10 percent, compared to 20 percent variability for rainfall. Furthermore, the wind speed actually tends to pick up at the times of greatest need. It blows more strongly in the afternoon, when electricity demand is high, in spring when South Island hydro dam levels are at their lowest, and during cold weather, when heating needs are greatest. However, rain water can be stored, whereas wind cannot.

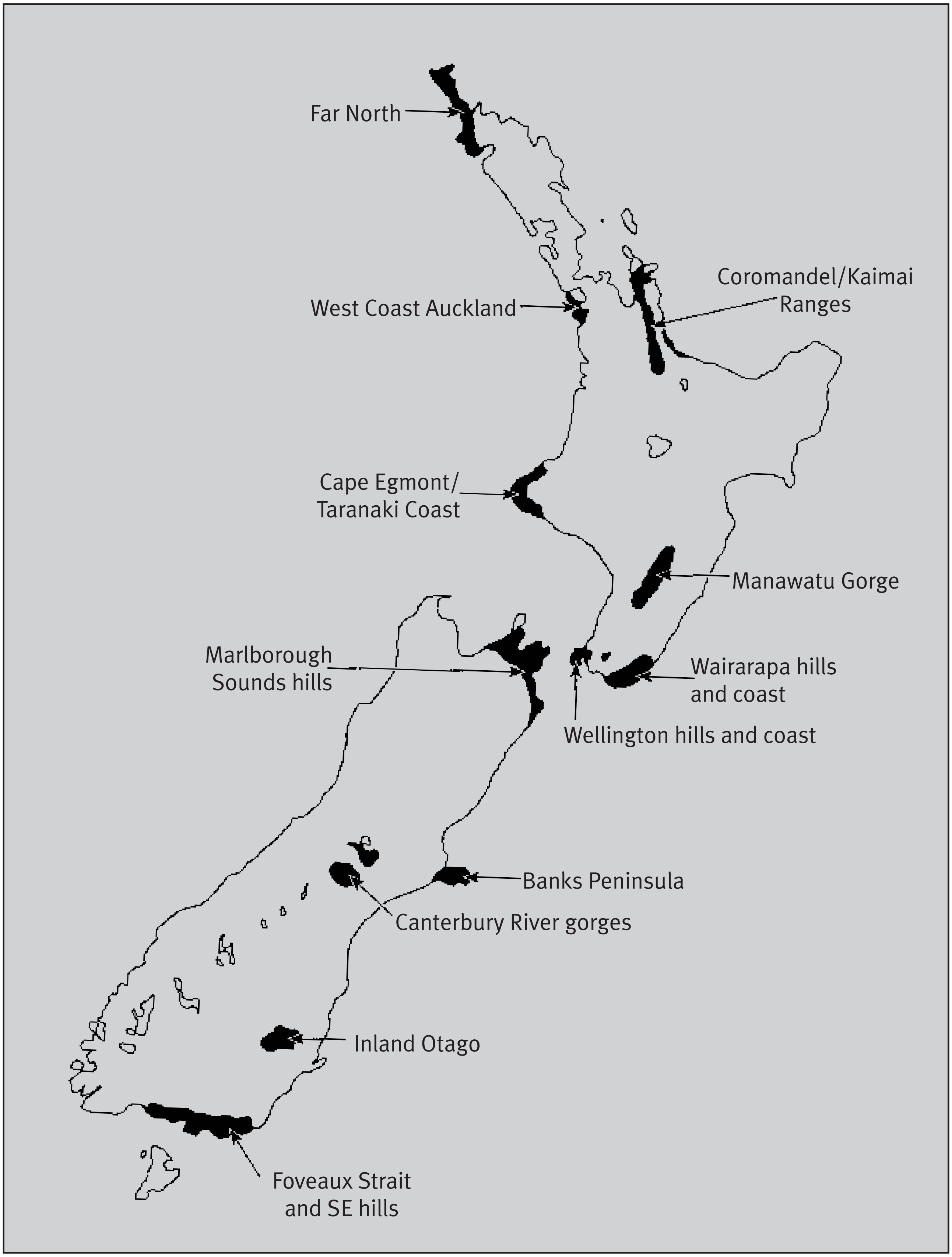
Compared to most other sources of new electricity, wind power is relatively cheap (only some biofuels and small hydro schemes are cheaper). The set-up costs are low because it does not require vast landscape engineering and construction works and can range in scale from one wind turbine generator (WTG), or windmill, to hundreds (EECA and CAE, 1996). Predictions are that, by 2020 AD, wind power will meet 10 percent of New Zealand's total electricity demand, and possibly much more. In fact, the 'fast take-off' scenario shows this target being reached by 2004 (Henderson, 1996).

In 1993, ECNZ installed a single experimental wind turbine on a hill in Wellington and found that it generated 1,000 MWh per year—a world record for its size. Three years later, in June 1996, New Zealand's first wind farm began operating at Hau Nui in the eastern Wairarapa hills. The site is within 40 kilometres of the nearest large population centres, Palmerston North and Masterton, and is owned by Wairarapa Electricity. The seven German-built wind turbines have a combined capacity of up to 3.5 MW of electricity (equivalent to a very small hydro power plant). Development of the site, including roading, installation of the power lines, and the erection of the windmills, took just 14 weeks. A much larger 60 MW wind farm is planned to begin construction in 1998 at a site in the Tararua Ranges as a joint project between Central Power and Merrill International (EECA and CAE, 1996).

Like all energy sources, wind farms have environmental impacts, though these depend on the location. Bird strike can be a problem in some circumstances. Some people find the visual impact of rows of windmills in the middle of a coastal or pastoral landscape to be quite offputting. The noise may also be disturbing in the immediate proximity. The scenic impacts were an important consideration when a resource consent for a wind farm at Baring Head on the Wellington coast was recently declined on the grounds that this was not an appropriate use of the coastal environment.

On the other side of the balance sheet, the environmental benefits of wind power are clear enough. Wind turbines produce no greenhouse gases or other air pollutants. The wind itself is free and limitless. Only 1 percent of the land on which a wind farm is built is actually taken up by the turbines so the surrounding 99 percent can be used for low vegetation land uses such as pastoral farming (though forests are not an option). And unlike conventional energy sources, which depend on mines, wells, and dams, site impacts are reversible. The windmills can be removed without leaving major scars on the landscape, a depleted resource, or a damaged environment (EECA and CAE, 1996).

**Figure 3.7**
**Areas with the potential for wind farms.**




*Source: EECA and CAE (1996)*

As for other forms of renewable energy, none are expected to be economic at least until 2005 A.D. Photovoltaics, for example, are currently too costly to install on most roofs. Wave power, tidal power, and ocean currents are currently all relatively expensive compared to conventional energy sources. Future electricity price increases or technological advances may change that but, for the moment, the only economic alternatives to big dams, geothermal stations and fossil fuels seem to be small dams, wind farms and firewood.

#### Environmental Impacts of Energy Use

Energy use has both direct and indirect impacts on the environment. The indirect impacts arise from the things that plentiful energy enables us to do, such as driving to or through sensitive ecosystems (creating vehicle and visitor impacts in forests and sand dunes), modifying landscapes, clearing forests and draining wetlands (made easier by heavy machinery), generating noise (from machinery and sound equipment), and generating hazardous wastes (from manufacturing processes). Other indirect impacts arise from the mining, manufacture and energy use that go into constructing power stations, turbines, generators and associated energy-extraction technology.

The direct environmental impacts of energy use arise from pollutants released in the extraction, storage, transport and use of fuels, and from the landscape and habitat changes caused by dams, power stations and power lines. In New Zealand these direct impacts include:

- **atmospheric pollution** from burning fossil fuels, with possible contribution to climate change through the build-up of climate-warming greenhouse gases (e.g. carbon dioxide). This build-up continues, despite a Government target of returning net emission rates to 1990 levels (see Chapter 5 for further discussion);
- **local air pollution** from fossil fuel emissions, including sulphur dioxide, carbon monoxide, nitrous oxide, particulate matter, volatile organic hydrocarbons, and other emissions, primarily from the transport sector (see Chapter 6). It is claimed that a coal-fired power station releases more radioactive material into the atmosphere than a nuclear power plant, because of the radioactive materials trapped in the coal (Redshaw and Dawber, 1996);
- **electromagnetic radiation** from power lines and communications transmitters (see Chapter 6). Although overseas studies have not shown clear links between human health and radio frequency (RF) electromagnetic radiation, public concern is sufficiently high for the siting of pylons and transmitters to have become a significant environmental issue in some areas (Parliamentary Commissioner for the Environment, 1996).
- **water pollution** by heavy metals from geothermal projects and oil spillage in coastal waters and stormwater. Geothermal stations can also raise surface water temperatures (see Chapter 7);
- **soil pollution** associated with the storage and transport of fuels (see Chapter 8);
- **habitat destruction** from the construction of hydro-electric power stations and the use of cooling water for thermal power stations (see Chapters 7 and 9); and
- **scenic and recreational** impacts of hydro and geothermal development. Geothermal stations lower the pressure of geothermal systems, reducing geyser and mud pool activity and hydro development alters the recreational and scenic resources of rivers and lakes. The creation of storage lakes also alters the surrounding land, flooding forest or farmland.

Many of these impacts can also have negative effects on human and ecosystem health. Other renewable energy sources also have some environmental impacts, but the scale of the impacts tends to be relatively small and site specific. They include smells and air emissions (from biofuels), scenery loss (which may be substantial, e.g. from wind farms and tidal power stations), and habitat loss (wherever natural vegetation needs to be cleared or rivers and landscapes need to be modified to install or supply an alternative energy plant).

#### *Managing the impacts of energy use*

Our environmental management in New Zealand is now effects-based, not sector-based. It is concerned with what is happening rather than who is doing it, and the same policies apply to all sectors. Under the Resource Management Act 1991, local authorities are required to sustain the environment by ensuring that environmental impacts are avoided, remedied or mitigated. Where this cannot be assured, prospective energy ventures are unlikely to be approved. Where they are approved, the cost of making the project environmentally sustainable will often add to the overall expense. For example, the gas-fired Taranaki combined cycle power station at Stratford was only approved on condition that the owners mitigate any additional greenhouse gas emissions by planting trees to absorb the equivalent amount of carbon dioxide that the plant added to the national total (see Chapter 5, Box 5.11).

At the consumer end, a considerable amount of our daily energy consumption is wasteful or plain unnecessary. This applies to both businesses and domestic households. Electricity, for example, however generated, is a relatively expensive form of energy, in money and in natural resources. Minimising its use is therefore a good way of saving costs and the environment. Local power supply authorities are now offering energy efficiency advice and services, such as Transalta's recent offer to Hutt Valley consumers of a $160 energy savings package that includes cylinder wraps, low-flow shower heads, energy efficient lights and an energy audit to identify other energy-saving opportunities. There are many ways to cut energy costs around the home (see Box 3.4).

Some large industrial sites are now installing co-generation power plants to harness energy from their waste materials while others are trying to make savings in other ways, such as making greater use of insulation, natural light, or longlife fluorescent bulbs.

**Box 3.4**

### *Saving the family joules*

New Zealand homes use about 13 percent of the total energy and 35 percent of the electricity consumed in the country (Dang, 1996). The biggest user of electricity in the home is undoubtedly water heating. Although electricity converts to heat with 100 percent efficiency, much of this then leaks away. For example, the heat losses from uninsulated hot water cylinders in New Zealand range from 5 MJ per day for a 135 litre A-grade cylinder (equivalent to the daily calorie intake of two people) to 24 MJ per day for a 450 litre D-grade cylinder (Eden Resources, 1993). Getting a thermal wrap for the cylinder and turning the hot water thermostat down to 55°C will cut water heat losses. Putting draught-proofing strips around doors and insulation in the ceilings will cut room heat losses.

Many household appliances vary widely in their energy efficiency. Different makes of freezer, dishwasher, washing machine, oven and hotplate vary by up to 50 percent, yet this is the last thing most of us think to ask about when we are purchasing new appliances. Electricity converts to light energy much less efficiently than it converts to heat. About 90 percent of the electricity burnt in a standard light bulb is lost as heat, not light. Lightbulbs have a limited life because of the necessary design tradeoffs between efficiency and lamp life. Most of the bulbs we use in our homes are designed for 230 volts, which means that they are more efficient, but have a shorter life, than long-life bulbs which are designed for 250 volts. Modern fluorescent lights are several times more efficient and last eight times longer than conventional bulbs. Unfortunately, they are also relatively expensive, making it impractical to switch over to them all at once. But in situations where the lights are in use for lengthy periods they do pay for themselves after several years—and have less impact on rivers and air.

Solar heating panels in the roof can provide hot water and room heating. Again, the initial expense is a deterrent, but solar heated homes use far less fuel or electricity than homes which rely on wood, coal or gas fires or electric heaters. These conventional heating sources will only be required as a supplementary heat source during cold weather. A far cheaper means of saving on room heating is to improve insulation with draught-proofing strips around doors and insulation in the ceilings.

Technical fixes are only part of the energy efficiency equation. Learning to lead a more energy-conscious lifestyle is also effective—and requires no installation costs, although there can be other costs involved in changing lifestyles (e.g. education). In fact, many modern energy uses are quite careless or frivolous. Behaviour changes that reduce the power bill include turning off lights televisions and computers when not needed, stopping draughts, shutting windows when the heater is on, putting on jerseys instead of turning on heaters, having briefer showers or fewer of them, and putting the plug in whenever the hot tap is running. Small things, but they add up.

Probably the greatest energy guzzler in most households is the car. For every 17 New Zealanders, there are 10 motor vehicles, counting commercial and private vehicles (Statistics NZ, 1996). The spaced out low-density arrangement of our cities and townships and the poor public transport means that we often live some distance from shops and workplaces and rely on motorised transport to get there. The trend in recent decades has been toward much less use of public transport and footpaths, and much greater use of private motor vehicles (see Chapter 6). Our relationship with our cars is a deep and passionate one.

In a 1993 survey of nearly 2,000 New Zealanders (with a 70 percent response rate and 3 percent error margin) 42 percent admitted that many of the short journeys they make by car could just as easily be walked, and indicated that they sometimes or often cut back on driving for environmental reasons (Gendall *et al.,* 1994). However, an equal number felt that driving their own car is too convenient to give up for the sake of the environment and a clear majority (55–74 percent) opposed the use of permits, tolls or charges to cut down on unnecessary car use. These results echo those obtained in overseas studies. In a recent British survey, for example, nearly 60 percent of respondents felt strongly that trying to reduce their car use would disrupt their family life and work (New Scientist, 1995). Even an Australian survey of Rainbow Alliance (environmental) supporters revealed that 46 percent could not lead a decent life without the use of private motor vehicles—though 87–94 percent of the sample agreed that cars should be kept from city centres and that urban areas would be more pleasant if people drove less (Knight, 1992).

Still, even for those of us unable to break the car habit, efficiencies are possible. Regular engine tuning can save 4 percent in fuel costs, and driving more slowly on the open road can bring big savings (Douglas *et al.*, 1992). The most fuel efficient speed for a modern car is about 60 kilometres per hour (kph). Yet, between 1984 and 1990, New Zealand drivers increased their average open road speed from 97 kph to 106 kph. Another way of becoming more fuel efficient is to purchase cars that have more fuel efficient engines. The fuel consumption of cars varies, but is currently around 8–9 litres per 100 kilometres for new cars. This is an improvement from the 11.6 litres consumed in 1979, and is predicted to reach 7.8 litres by the year 2000 (Douglas *et al.*, 1992).

## WASTE GENERATION AND DISPOSAL IN NEW ZEALAND

Every year, New Zealand industries and households discard over 3 million tonnes of construction and demolition debris to landfills and cleanfills. Averaged across the population, this represents about one tonne per person. In addition, more than 1 million tonnes of plant matter and food scraps are sent to landfills, representing about 320 kilograms of organic matter for each one of us. This is accompanied by 600,000 tonnes of paper and cardboard (about 170 kg/ person) and 220,000 tonnes of plastic (about 60 kg/person). These are the main items in our solid waste pile, but we also discard many other things in the course of a year, including, for example, 300 million steel cans (about 80 per person) and 30 million litres of used oil (about 8 litres each).

Large though these figures are, they pale beside the approximately 500 billion litres of sewage that flow into our 258 public wastewater treatment plants each year. Additional, unmeasured, quantities of stormwater and pasture run-off sweep tonnes of litter and animal waste from land into waterways. Furthermore, our chimneys and vehicle exhausts emit unmeasured tonnes of smoke and particulate matter into the air. In short, each of us discards many times our own bodyweight of waste each year, often with environmental consequences. Small amounts of waste are easily absorbed by the environment, but in larger amounts some wastes can be harmful. In the case of some toxic substances, even very small amounts can harm humans or other species.

The pressures which waste puts on the environment vary according to the particular waste stream. Our **airborne** waste stream consists of gases and small particles which are emitted by motor vehicles, livestock, fires, power stations and industrial processes. These float into the atmosphere sometimes contaminating the ambient air we breathe. In recent decades, airborne wastes have entered the upper atmosphere, altering the ozone layer and the 'greenhouse layer' several kilometres above us. Airborne contaminants are discussed in detail in Chapters 5 and 6 of this report.

The **water-based** waste streams include: sewerage systems, which pipe our excrement to treatment facilities and then into rivers or coastal waters; other 'point source' discharges which pipe treated or untreated wastes from farms, factories and mines into rivers and coastal waters; stormwater systems which channel rainwater from roads and urban properties into rivers and coastal waters (picking up street litter and contaminants on the way); and 'non-point source'discharges such as livestock excrement which is washed from paddocks into streams by rainwater. These waterborne wastes are discussed in Chapter 7.

The main **land-based** waste streams are: municipal landfills, once known as rubbish dumps or tips; cleanfills, which are landfills especially designated for uncontaminated construction and demolition waste; recycling and recovery centres which retrieve useful waste materials; incinerators, which reduce solid wastes to smoke and to ashes that are then disposed in landfills; litter, which is mostly discarded packaging waste but can also include other illegally discarded waste and materials falling of trucks and trailers; and tailings piles of waste rock produced by mining and quarrying operations, which can sometimes have elevated concentrations of heavy metals and processing chemicals. Sites where harmful substances have been dumped, spilled or allowed to accumulate are referred to as **contaminated sites**. The land-based waste stream is discussed in this chapter, except for contaminated sites, which are discussed in Chapter 8, and the impact of litter on coastal waters, which is discussed in Chapter 7.

Responsibility for managing waste disposal in New Zealand is largely in the hands of local authorities who manage landfills, refuse collections, sewerage and stormwater systems, air pollution discharges, and the assessment and clean-up of contaminated sites. Sometimes these tasks are undertaken directly by the authorities. Sometimes they are contracted out to private operators.

### Landfilled Waste

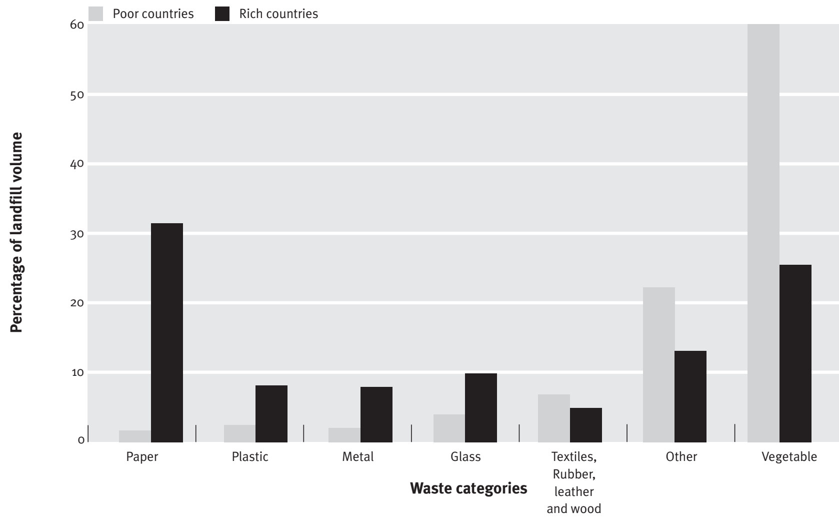
Landfilling is the most common method of solid waste disposal. Although landfill space is not quite the same problem here as in more densely populated countries, landfills in some of our larger urban areas are reaching capacity and the availability of new space is limited by local opposition (the 'not in my back yard' syndrome) and higher environmental standards (such as the need to avoid sites that could contaminate groundwater or streams).

The study of landfills is a relatively recent phenomenon, both here and overseas. One of the longest-running studies is being done by archaeologists at Arizona University who have spent twenty years digging into the landfills of Earth's most affluent nation (Rathje and Murray, 1993). They found that paper and cardboard waste makes up about 37 percent of a modern American landfill and is the fastest growing waste item. About half the paper waste is newspaper, and most of the rest is packaging, accompanied by phone books, computer printouts and magazines. Disposable nappies are a small part of the paper pile, accounting for 1–2 percent of landfill volume (or some 4,900–5,900 nappies per infant).

Although much of this waste is biodegradable, the anaerobic burial conditions in many landfills can prevent decomposition. In some cases, readable newspapers and edible food (e.g corncobs, hamburgers) remain intact for decades. Internationally, American landfills are at one end of the rich-poor continuum, having higher proportions of paper, plastics, metal and glass and lower proportions of vegetable waste (see Figure 3.8). Plastic waste, the archaeological marker of our time in history, makes up around 12–13 percent of American landfill waste.

The Arizona landfill study has also uncovered some of the behaviour patterns that generate waste. For example, when a food item becomes scarce people actually throw more of it away. Panic-buying leads them to hoard more than they need and, eventually, the excess ends up in the landfill. The scientists also found that over a third of the household waste disposed in rubbish bags is from fresh fruit and vegetables. This is partly because these deteriorate quickly, and partly because 25–50 percent of their weight is inedible skins, leaves, or centres. In contrast, takeaway and packaged food yields only 4–5 percent waste. Another finding was that, although poor families generate less waste than wealthy ones, they discard more packaging waste. This is because those on lower incomes buy smaller packets of everything.

**Figure 3.8**
**Typical landfill waste in rich and poor countries.**

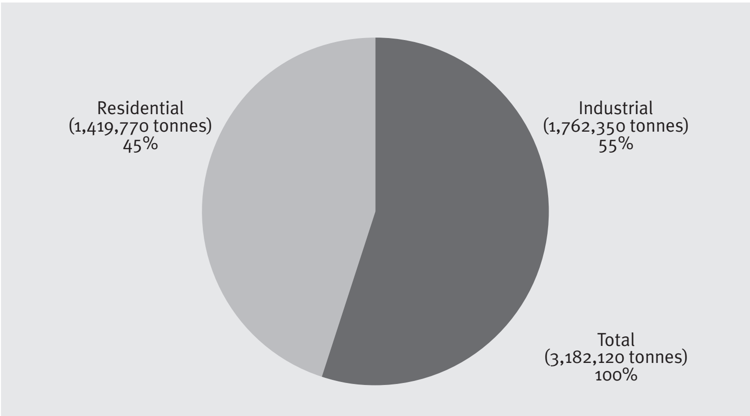



*Source: Cairncross (1993)*

Until recently, New Zealanders had very little information on the wastes going into our landfills. This has now improved and the latest information is summarised in the country's first *National Waste Data Report* (Ministry for the Environment, 1997). The process of gathering waste data only began in earnest in the late 1980s with a series of regional surveys funded by the Health Department. However, the methods used were not nationally consistent. Efforts to develop a more consistent approach began in 1990 when the Government set a national target of reducing solid wastes to 80 percent of their 1988 levels. To pursue such a specific target, accurate data were needed. The result was the Waste Analysis Protocol (WAP), a set of guidelines for local authorities on how to measure and analyse waste. The Protocol was developed by the Ministry for the

**Figure 3.9**

**Annual weight of landfilled waste in New Zealand in 1995.**




*Source: Ministry for the Environment (1997)*

Environment (1992d). Since 1993 a number of local authorities have used the Protocol to survey their solid waste stream.

A further source of information on landfilled waste comes from the national census of landfills which was conducted by the Ministry for the Environment in 1995. It revealed 327 legally operating landfills (down from 462 in 1987), 40 percent of which serve populations of under 1,000 people. However, as there is no formal definition of landfills in New Zealand, the number of tips containing waste (e.g. drilling mud dumps) is likely to be much higher than the 327 in the Census.

From the WAP surveys and the Landfill Census, it is estimated that approximately 3,180,000 tonnes of waste were landfilled in 1995 (see Figure 3.9). Some 1,420,000 tonnes (45 percent) of this was residential waste and some 1,760,000 tonnes (55 percent) was industrial waste (Ministry for the Environment, 1997).

Although no national information exists on the volume of waste going to cleanfills, surveys have found that cleanfills in the Auckland region receive slightly more construction and demolition waste than the total total waste entering Auckland landfills (Auckland Regional Council and Auckland City Council, 1996). Nationally, this suggests that cleanfills may receive more than 3 million tonnes of non-toxic waste annually.

Averaged across the population, each person sends about 401 kg of 'residential' waste to landfills each year. When industrial waste is included, our 'total' landfilled waste comes to 898 kg/person. At first glance, these figures seem high. The OECD statistics for 'household' waste ranged between 190 and 440 kg/person in the early 1990s, with a midpoint of 260 kg/person, while 'total municipal' waste ranged between 310 and 690 kg/person, with a midpoint of 400 kg/person (OECD, 1995). However, the comparison may not be quite valid.

For a start, New Zealand's 'residential' waste is higher than the OECD's 'household' waste because it includes bulky waste, such as garden and home renovation waste that is taken privately to landfills. In many other OECD countries, 'household' waste consists of rubbish bag collections while the bulky waste is counted among the 'total municipal' waste. Furthermore, New Zealand's 'total' waste is higher than the OECD's because, it includes landfilled construction and demolition waste. This is counted separately by most other OECD countries whose 'total municipal' waste is confined to homes, offices and small businesses. A better (though still imperfect) comparison, therefore, may be between New Zealand's 'residential' waste figure and the OECD's 'total municipal' waste (see Table 3.2).

District and city councils manage 87 percent of the landfills covered by the Landfill Census. Detailed questionnaires were completed for 271 of these. Of these, only 39 percent were being monitored for the quantity of waste they receive. Only a third (34 percent) were reported as having any clay underlying them, suggesting that the remainder have porous bases and are at risk of having leachate enter waterways. Despite the leachate risk, only 13 percent actually had systems for preventing leachate entering waterways, and only 17 percent monitored for leachate. Forty percent of landfills had diversions for stormwater, but only 9 percent treated the diverted water in some way, and only slightly more monitored it. Measures to control nuisance effects were reported for: litter (56 percent of landfills); odour (14 percent); dust (11 percent); and noise (4 percent).

The composition of New Zealand's landfill waste is dominated by organic matter (kitchen and garden waste) and paper (see Figure 3.10). The resulting waste profile falls somewhere in the middle of the rich country-poor country spectrum. This does not necessarily mean that we discard less metal, glass, plastic and paper than the rich countries, but only that these make up a relatively smaller proportion of our total waste because of the greater predominance of organic matter.

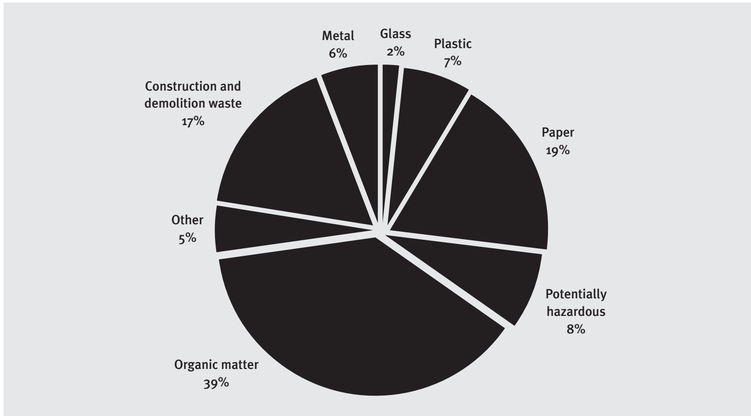
The composition of our landfill waste varies considerably from area to area and from season to season. The two items which vary most are organic matter (mostly kitchen and garden waste) and building waste. The 1995 WAP surveys showed that the percentage of landfill waste made up of organic matter ranged from 23 percent to 65 percent, while the percentage composed of building debris varied between 8 percent and 24 percent (Blake and Sweet, 1995). These variations are also reflected in the total volume. Christchurch's landfills, for example, receive 60 percent more waste in summer than they do in winter, most of the increase being organic matter. In fact, organic matter tends to make up a larger share of landfill waste in New Zealand than in most other industrialised countries.

The reason for this is that New Zealand has relatively little high density housing. Most homes have sections with lawns, gardens or trees that need regular mowing, weeding or pruning. Backyard composting was once commonplace, and pruned tree branches were once disposed of as firewood. But, as supermarkets supplanted family vegetable gardens and electricity and gas replaced domestic fires, landfill disposal became more widespread. Home composting is now making a modest comeback, but not enough to remove the organic segment of the landfill waste pile.

A half to two-thirds of New Zealand's household waste is disposed of in bags and bins which are collected each week. The remainder, consisting largely of garden and construction and demolition waste, is taken to the landfill in private cars and trailers. The composition of waste in the household bags and bins is shown in Figure 3.11. Almost half is organic matter and a quarter is paper. Plastic is the next largest item.

**Figure 3.10**

**Estimated composition of New Zealand's landfill waste.**




*Source: Ministry for the Environment (1997)*

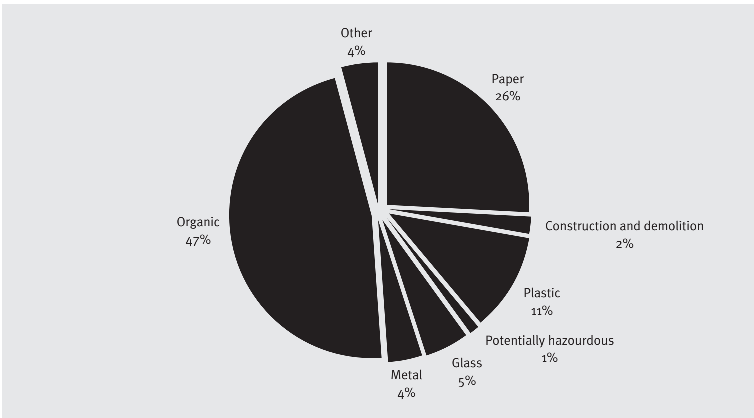
### Trends in waste generation

Assessing trends over the past decade or so is difficult because of both the ambiguous definitions and New Zealand's poor data prior to 1995. The OECD's average output of municipal waste per person rose by 28 percent between 1975 and 1992, from 390 kg/person to 500 kg/person (OECD, 1993; 1995). However, New Zealand's waste estimates over this period vary too widely to chart any reliable trends. In 1975, for example, our total municipal waste was estimated at 390 kg/person and in 1980 it was put at 662 kg/person (OECD, 1993).

More reliable trend data come from Auckland Region where total landfill waste, including industrial waste, has been monitored since 1983. The trend has been uneven but, by 1995, it had nearly doubled from 419,000 tonnes to 821,000 tonnes. In per capita terms, this was an increase of more than 60 percent per person. The OECD per capita increase over a similar period (1980-1992) was less than 20 percent. Most of Auckland's increased waste was generated during periods of high economic growth (see Figure 3.12). This reflects the changing fortunes of the construction industry, the changing consumption patterns of homes and businesses, and also population growth.

**Figure 3.11**

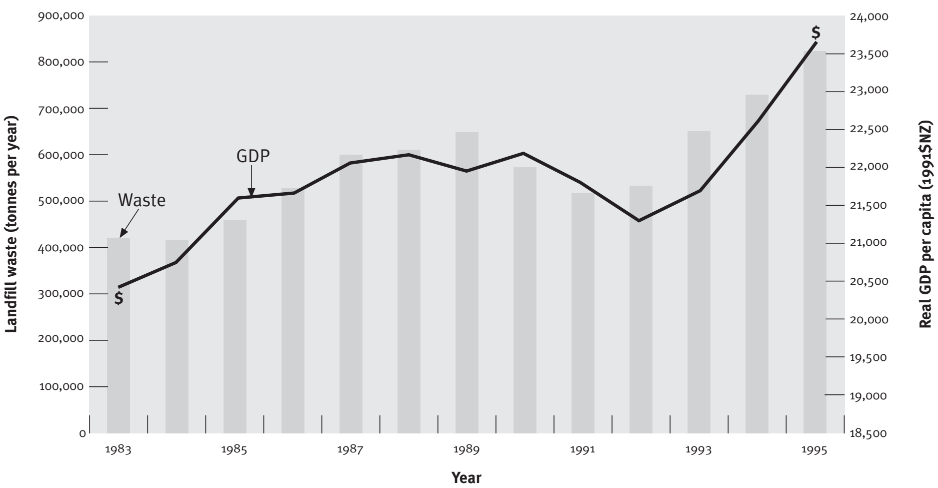
**The composition of household waste in bags and bins.**




*Source: Ministry for the Environment (1997)*

**Figure 3.12**

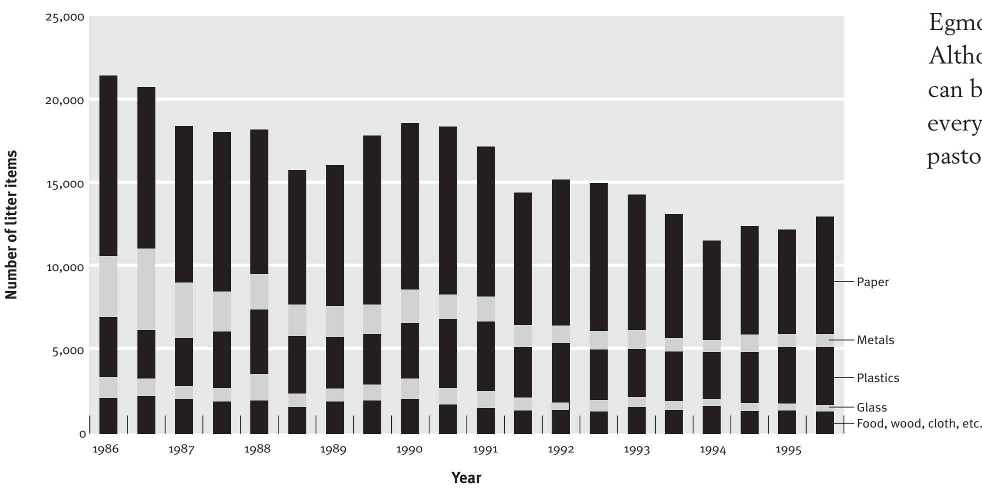
**Economic growth and waste disposal at Auckland landfills.**




*Source: Auckland Regional Council; Statistics New Zealnd*

**Figure 3.13**

**Litter trends in New Zealand (September 1986-March 1996).**




*Source: Keep New Zealand Beautiful Campaign*

Although the overall scale of waste generation appears to have increased, there is some evidence that people have become a little more responsible in how they dispose of their waste. Litter surveys have been conducted twice a year for the past decade by the Keep New Zealand Beautiful Campaign (see Figure 3.13). The surveyors systematically count and classify the litter discarded at over 100 regular sites throughout the country. Although litter represents only a small fraction of the solid waste stream, it is the most visible and widely dispersed fraction and has considerable nuisance value, especially in scenic areas. The survey shows that, although substantial amounts of litter are still discarded, the quantity declined from 1986 to 1994(Drum, 1994).

Just over half the litter is paper (53 percent) and a quarter is plastic (26 percent). The remainder is divided among metal (6 percent—half of it cans), glass (4 percent), and a miscellany of items, such as wood, ice cream sticks, food scraps, tyres, rubber items, clothing and construction material. The metal and glass proportions have declined significantly over the decade, while the plastics proportion has expanded. Much of the paper, plastic, metal and glass litter comes from discarded packaging, particularly food and drink containers.

In some areas, the packaging litter is not from human takeaways, but from cattle food wraps. In 1993, the Taranaki Regional Council estimated that 13,000 kilometres of plastic silage-wrapping are used each year by the region's dairy farmers. This is enough to encircle Egmont National Park 150 times. Although the wrap is biodegradable and can be disposed of by burial or burning, every year some escapes to festoon the pastoral landscape.

## Waste Management Policy in New Zealand

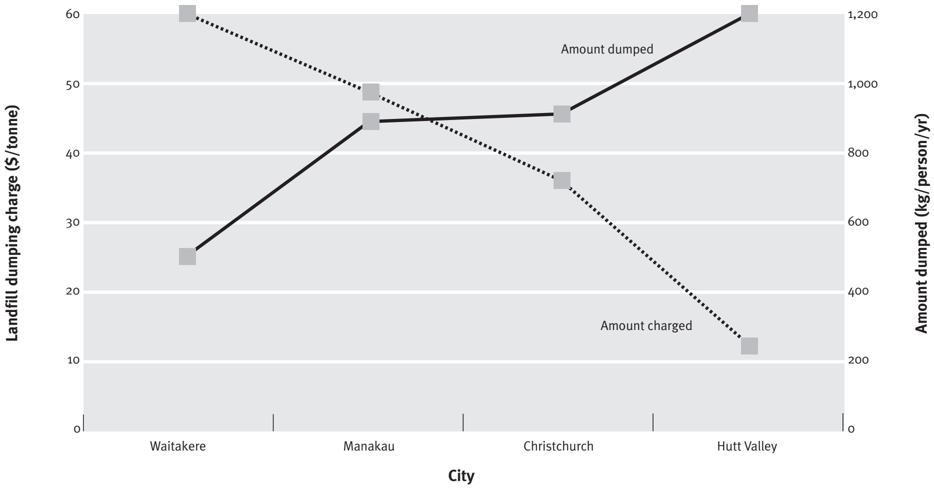
In 1990, the Labour Government announced a national waste management policy which included the target of reducing the nation's solid waste to 20 percent below its 1988 levels by 1993 (Associate Minister for the Environment, 1990). The policy had a profound effect. It stimulated the development of recycling programmes by local authorities and industry. It also spurred the development of national guidelines for monitoring and managing solid waste (Ministry for the Environment, 1992c, 1992d). In 1992, the National Government issued a revised waste policy (Ministry for the Environment, 1992b). Though broadly in agreement with the previous policy, it dropped the waste reduction target, and emphasised, instead, the importance of waste management programmes. Such programmes should, as far as practicable, ensure that waste generators meet the costs that their waste imposes on the rest of the community, and the programmes should also promote the internationally recognised waste management hierarchy.

The waste management hierarchy is a list of the six most effective ways to control waste in order of their environmental acceptability. It calls on waste managers to:

- **reduce** waste generating activities; or otherwise
- **reuse** products rather than discard them; or otherwise
- **recycle** waste materials to make new products; or otherwise
- **recover** any useful materials and energy; or otherwise
- **treat** the waste with processes that remove or reduce its impact; or otherwise
- **dispose** of the waste safely on land set aside for the purpose.

**Figure 3.14**

**Fees charged and amounts of waste dumped at four landfills.**




*Source: McLachlan (1993)*

In August 1996, the Local Government Act was amended to require that every territorial authority adopt a waste management plan incorporating the waste management hierarchy. The Government has also issued guidelines for cleaner production, and for landfill management and monitoring, and has negotiated voluntary waste reduction targets with industry, starting with packaging and used oil. If these policies prove ineffective, the Government will reconsider the use of regulations or economic measures (e.g. return deposit schemes). First though, before progress can be assessed, a national waste data set is being created using the Waste Analysis Protocol.

In late 1996, the new Government's *Coalition Agreement* reinstated a reduction target and included the following objectives for solid waste management:

- encouraging waste reduction at source, reuse of products and recycling of waste materials in order to reduce solid waste to half the 1990 level by the year 2000; and
- continuing to develop national standards and guidelines for landfills, solid waste disposal, and hazardous waste disposal.

**Table 3.4**
**Recycling rates for some common waste materials in 1993-94.**

| Recyclable materials | Collection for recycling as a percentage of: | |
|---|---|---|
| | Total consumption (1993) | Packaging only (1994) |
| *Paper and cardboard* | *39%* | *42%* |
| *Plastic* | *14%* | *8%* |
| *Aluminium* | *12%* | *41%* |
| *Steel* | *Not known* | *3%* |
| *Glass* | *Not known* | *36%* |
| *Used lubricating oil* | *23%* | *Not applicable* |

*Source: Ministry for the Environment (1997)*

One way of reducing the amount of waste at landfills is to increase the fee for dumping it. A 1993 study of local authorities' waste reduction initiatives found that disposal fees at landfills tend to be lower than the costs of landfill maintenance or expansion (Parliamentary Commissioner for the Environment, 1993). As a result, landfilling is seen as the cheap and convenient option in many cities and districts. The relationship between dumping fees and landfill waste volumes is shown in a 1993 comparison of four New Zealand cities (see Figure 3.14). Where fees are higher, businesses and householders have a greater incentive to produce less waste— or to dispose of it in other ways.

Evidence from the Hutt Valley suggests that illegal disposal has increased since landfill fees went up. The Hutt City Council has reported increased amounts of rubbish illegally disposed into streams and a consequent upsurge in rat and ferret populations in the valley. Other free alternatives to landfills include backyard incineration and composting. Because 40 percent of the nation's landfilled waste is decomposable matter, backyard composting is encouraged by some councils, such as Hutt City where 50 percent of surveyed residents now compost their organic waste.

At least a dozen local authorities have gone one step further and invested in community composting operations. The compost schemes in such places as Waitakere City, Taupo, Masterton and Devonport have reduced total landfill waste by 30–60 percent. In 1995, both Auckland and Christchurch commissioned composting plants, the largest in Australasia, at some $4.5 million each. In full production, the Christchurch plant will reduce the 'Garden City's' landfill waste by 20 percent and will also produce saleable compost (Young, 1995). Although composting plants have environmental costs (smells, noise, leached nutrients), some of these have been mitigated by restricting bulk composting to garden waste only, and by having a buffer zone between the compost and nearby residents.

Another approach to waste management has been to tackle it at the production end rather than the disposal end by encouraging businesses to minimise waste through better management and production systems (see Box 3.5).

### Recycling in New Zealand

Although, in theory, reduction and reuse are the most preferred waste management options, in practice most of the emphasis has centred on recycling. Various industries have developed recycling programmes and a number of community recycling schemes exist for residential waste. In 1996 these included:

- kerbside recycling collection bins in all or part of the following cities: Auckland, Waitakere, North Shore, Lower Hutt and Wellington, with plans to commence in Christchurch in 1997;
- kerbside collection of specific materials for recycling if placed in suitable bags (e.g. supermarket bags) in New Plymouth, Wanganui and Upper Hutt; and
- collection of recyclable materials at "drop off" sites or transfer stations for some materials (e.g. aluminium cans, glass,newspapers or cardboard) in most parts of New Zealand.

National data on the amount of recycled waste are limited, but recycling rates for some waste materials in 1993–94 are shown in Table 3.4. Since that time, the level of glass recycling has probably gone down because the major recycler no longer pays the transport costs of used glass. Conversely, levels of steel and oil recycling may have risen as a result of voluntary agreements between industry and the Government. The steel industry set itself the goal of recycling 25 percent of the nation's 300 million used cans by the end of 1996. The oil industry's Used Oil Recovery

**Box 3.5**

### *Making the marketplace cleaner and greener*

New Zealand businesses are required by law to be environmentally sustainable as set out in rules, plans and consents issued by local authorities or national legislation administered by central government (e.g. the indigenous timber provisions of the Forests Act 1949). To ensure that they meet these legal requirements, many firms are embracing **environmental management systems** (EMSs). These are methods and procedures by which a company regularly monitors and assesses its environmental performance to keep legally 'clean'. Some companies choose to go further by adopting the cleaner production philosophy. **Cleaner production** means using energy and resources more efficiently, minimising waste, and producing environmentally sound products and services for less cost and more profit. The cleaner production idea was developed by the United Nations Environment Programme (UNEP) and has been adopted by many businesses around the world.

The Ministry for the Environment helps develop guidelines for cleaner production and publishes case studies showing examples of energy efficiency and waste reduction techniques in different sectors (e.g. reusing heated water and other waste products, installing long-life bulbs, reusing towels, and so on). Case studies to date cover such diverse industries as: dairy production, cement, paint, plastic and leather manufacturing, meat retailing, the restaurant trade and tourism (Bailey and Mayes, 1994; Gilling and Bailey, 1994; Mayes and Bailey, 1993; Ministry for the Environment, 1992a, 1993; New Zealand Manufacturers Federation and Ministry for the Environment, 1993; Wellington City Council and Ministry for the Environment, 1996).

Companies choose to go green for several reasons: to gain a marketing advantage, to reassure customers that their products are of a consistent quality, to reduce costs by saving energy and minimising waste, to reduce risks to worker or customer health, thus avoiding litigation and, last but not least, to avoid the need for government rules and regulations. This last reason, the implicit threat of the 'big stick', has underlain New Zealand's policy on reducing greenhouse gas emissions, and was alluded to by the Minister for the Environment, the Hon. Simon Upton, at the launch of the Packaging Accord in June 1996. The Minister said that: "the Government's approach has been to rely on voluntary actions and programmes such as the Accord because we just don't know enough to regulate wisely or effectively at this stage". He added that action by free-riders to undermine voluntary initiatives such as the Accord would "make government regulation almost inevitable".

Besides entering accords with industry, government also encourages voluntary initiatives in other ways. It publishes guidelines on better environmental practice (e.g. on cleaner production, riparian strip management), has helped set up an ecolabelling scheme (see below), and helps fund environmental research and development projects through Crown Research Institutes (see Box 4.2), universities, local authorities and private consultants. Some of this funding comes from public sources as the Minister for the Environment's Sustainable Management Fund (SMF), the Department of Conservation, the Ministry of Agriculture, and the Government's Public Good Science Fund, but a growing amount comes from is directly funded by industry.

A key means of improving environmental performance is to set standards against which performance can be monitored and progress assessed. **Standards** are lists of criteria that must be met to achieve a desired level of performance. The three main types of environmental performance standards are:

- **ambient environment standards**, which state the minimum environmental conditions that must be maintained;
- **discharge or emission standards**, which state the maximum amount of a given pollutant that may be released into the environment; and
- **design standards**, which state the specific procedures or technologies that must be used to minimise environmental damage.

Some standards are imposed by law. The Resource Management Act, for example, empowers the Minister for the Environment to set national ambient environment standards (e.g. for water and air quality). However, in keeping with the voluntary approach, the Ministry for the Environment has so far opted to set guidelines only (see Box 4.1). The Act also empowers local authorities to set compulsory standards in the form of rules in district and regional plans, or as conditions in resource consents.

Many other standards are voluntary and have been devised by industry or international organisations to assist companies and organisations. These are most often design standards, though they can include discharge and ambient environment standards. The main international standards for ensuring consistent environmental performance and quality are those of the International Organisation for Standardisation (ISO). Among other things, the 'ISO 14000' series includes standards for Environmental Management Systems (ISO 14001 and 14004) and for ecolabelling (150 14020).

**Ecolabelling** can be anything from an advertising campaign to a complete quality assurance programme. In all cases, companies use ecolabels to market the environmental soundness of their operation, products or services. ISO has identified three types of ecolabel:

**self-declaration claims** in which a company produces its own label or product line and promotes it as being environmentally friendly;

**practitioner programmes** in which an independent third party assesses a company or its products against set environmental criteria and licenses its label to those that qualify; and

**report card systems** which list a product's performance or ranking on a range of environmental criteria, such as energy efficiency, use of natural resources, toxicity etc.

New Zealand's national ecolabel 'Environmental Choice' is a practitioner programme run on behalf of the Government by Telarc New Zealand. It was launched in 1991, in the midst of the economic recession. A company seeking to use the label pays Telarc a $1,000 application fee and has its product tested. If Telarc considers the product environmentally sound, the company can then buy the right to use the Environmental Choice label for between $3,000 and $15,000, depending on the product. So far, only three companies have the label, the paint manufacturers Levene and Resene, and Feltex Carpets. An attempt is now being made to revitalise the scheme. Another ecolabelling scheme, a report card system, is being developed by the food and beverage industry's Project 98 Trust. Both schemes are assisted by the Sustainable Management Fund.

While companies ask no more of an ecolabel than a few extra points of market share, some environmental economists had hoped for a lot more. The assumption was that the marketplace might prove an effective alternative to environmental regulation. Given the choice, environmentally concerned consumers would set up a demand for 'green' products, leaving the brown ones to wither on the shelf. However, recent British research has shown that green consumers are much like any other shopper (Coghlan, 1995). Their main priority is meeting their immediate needs at an affordable price. Although their environmental concerns are real, they are less pressing than the day to day concerns of food and finances. Shopping is therefore seen as a means to short-term ends rather than a means of solving wider problems. In Britain, only a small hard-core of 'confirmed' ethical shoppers, mostly vegetarian, consistently buy green products. The more numerous 'cost-conscious' environmentalists only buy green when they know they can afford it. The least consumer-conscious environmentalists, the 'couch thinkers', sympathize with ethical causes but do not link them to consumer behaviour (Coghlan, 1995).

Another British study compared two 'green' products which were both launched in 1986— unleaded petrol and green detergents (Motluk, 1995). Eight years on, the petrol's market share had risen from zero to 55 percent, while the detergents were stuck at 2 percent. The difference? Unleaded petrol sales 'escalated significantly' after two government kickstarts: a price incentive and a law requiring all new cars from October 1989 to run on unleaded petrol. The detergents were never subsidised or regulated (Motluk, 1995). New Zealand's experience with unleaded petrol was much the same (see Chapter 6). So, too, were the fates of ozone-friendly spray cans and refrigerators in New Zealand.

Within three years of their introduction, in the late 1980s, ozone-friendly spray cans had displaced the ozone-depleting CFC spray cans. Their market victory was assisted by their being small, low-cost items, no more expensive than the dirty cans they were replacing. In addition, the manufacturers and the public knew that the government intended to ban the CFC cans. In contrast, the ozone-friendly fridges, when they came, were more expensive than their CFC counterparts and the government had no plans to ban the CFC fridges. Needless to say, the green fridges sold only sluggishly against their CFC-containing counterparts at first. Sales only picked up after raw CFC imports were banned and all locally-made fridges thus became ozone-friendly. However, although raw CFC imports are banned, products containing CFCs can still be imported and low priced fridges, such as those imported from China, still sell well.

Programme, which was launched by the Minister for the Environment in March 1996, aims to recover 95 percent of available used oil by the year 2000. At present about 30 million litres are discarded annually, of which about 7 million (23 percent) are re-refined and sold (Ministry for the Environment, 1997). The remaining 23 million litres are dumped at landfills (7 million litres), burnt (5 million), poured on roads for dust control (4 million), used to lubricate chainsaws and stain fences (3 million), and lost or discarded in various unknown ways (4 million).

The packaging industry, which produces the most visible if not the most voluminous waste, is another to have entered a voluntary agreement with the Government. Under the June 1996 Packaging Accord, the industry accepted responsibility for minimising packaging waste and agreed to a strategy that includes codes of practice, performance objectives and monitoring of progress. It also agreed to work with central and local government to collect data, develop measurable indicators of packaging waste, establish an education programme, and support waste management options for packaging such as recycling.

Packaging waste is estimated to make up 10–14 percent of the waste going into New Zealand landfills (Ministry for the Environment, 1997). According to industry estimates, the development of lightweight packaging and the growth of recycling over the past decade have already led to packaging waste being 42 percent less than it would otherwise have been (Packaging Industry Advisory Council, 1995). On the other hand, packaging waste would be even less if the industry had not replaced **reuseable** packaging, such as glass bottles, with disposable containers, such as cardboard cartons, aluminium cans and plastic bottles (McLachlan, 1993). Although many of the disposable containers are recycled, it takes much more energy to recycle and reconstitute a container than it does to wash it (see Table 3.5).

**Table 3.5**

**Energy consumption[1] per use for 350 ml drink containers.**

| Container | Energy Use (kilojoules) |
|---|---|
| *Aluminium can, used once* | *7,500* |
| *Steel can, used once* | *6,300* |
| *Recycled steel can* | *4,100* |
| *Glass beer bottle, used once* | *3,900* |
| *Recycled aluminium can* | *2,700* |
| *Recycled glass beer bottle* | *2,700* |
| *Refillable glass bottle, used 10 times* | *640* |

*Source: Demanuele (1994)*

[1] *Includes treatment but excludes transport (which varies from place to place)*

The shift away from reuseable drink containers is linked to the expansion of the supermarket system, the rationalisation of the beer industry, and the deregulation of the milk industry and road transport in the past 30 years. A crucial factor in all of this was the changing transport costs as distribution centres became fewer and farther between and as new lightweight packaging made one-way containers much cheaper to transport. In the early 1980s, refillable beer, milk and soft drink bottles were collected and redistributed quite efficiently within local areas. Now the transport costs of bottle collection and redistribution are greater than those of the 'one trip' disposable containers. Whereas the word 'disposable' was coined for a new generation of packaging or product, 'reuseable' and 'refillable' are now needed to describe what was once the norm (McLachlan, 1993).

Of the 376 million litres of beer produced annually in the early 1980s, nearly half (48 percent) was sold in refillable bottles, and nearly all the rest was sold on tap (Department of Statistics, 1985). By 1993, the tap proportion had not changed substantially, but the refillable bottle proportion had fallen to less than a tenth (9 percent) of all beer sold, with disposable aluminium cans and non-refillable glass bottles, or 'stubbies', making up the balance. In 1985, milk was sold in returnable glass bottles all over the country, mostly through home delivery and shop dairies as supermarkets were reluctant to handle returnable containers. From 1986, milk in cardboard and plastic containers became freely available in supermarkets. By 1993, the supermarket share of retail milk sales had reached 29 percent, and was growing at more than 3 percent per year, and the percentage of milk sold in disposable containers had climbed to 85 percent (McLachlan, 1993).

Paper forms a large percentage of the total waste stream and over a third of it can be easily recycled. There are markets for clean office paper and newspapers which can be reborn five times before the fibre eventually collapses. These recycled paper products go into egg and apple trays, paperboard and some lines of recycled stationery. There is practically no market for 'mixed paper waste' (glossy magazines and 'junk mail') because of the costs of removing the impurities in it. Markets for recycleables fluctuate, and low prices paid for plastics and paper in particular can render commercial recycling unprofitable. The Parliamentary Commissioner for the Environment (1993) found that: "Without exception, councils and private waste haulers identified lack of adequate markets for recovered materials as an impediment to waste reduction." Despite these uncertainties, an increasing number of local authorites now operate recycling depots and kerbside recycling schemes where householders are provided with bins in which to place their recyclable rubbish. A 1993 survey of consumer behaviour showed that over 90 percent of people had access to recycling facilities for paper, plastic, glass, or metal and that 84 percent make some effort to sort these materials for recycling. Many areas also have collection facilities for the recycling of oil, CFCs, and acid lead batteries, though transport costs have constricted glass recycling to Auckland and Wellington.

Recycling depots are well patronised but are more prone to contamination from non-recyclable products than are kerbside collection schemes. This means the waste needs to be sorted, which adds an unacceptable labour cost. The energy (and air pollution) costs of transporting waste to depots are much higher than those of kerbside schemes because the former involve many individual car trips. But even kerbside recycling is more energy intensive than simply reducing waste production in the first place. However, kerbside and depot recycling is effective in reducing the flow of waste to landfills by up to 20 percent.

Local bodies tend to view recycling as necessary to reduce the burden on landfills. However, recycling is rarely self-funding let alone profitable, and is less environmentally-friendly than waste reduction and product reuse. Some have even argued that recycling is preferred by industry because the community subsidises the cost while allowing continued industrial throughput and a convenient environmental excuse for planned obsolescence (Fairlie, 1992). The planned obsolescence argument holds that many products are designed for limited lives rather than durability because the market for them has become saturated and manufacturers rely on replacements for sales (New Economics Foundation, 1994).

There is no doubt that recycling is strongly community driven, with a high public profile, and that it reflects the concern of citizens about the waste problem. But community-funded recycling is, arguably, an anomaly in a free market environment, a response to the failure to include the full costs of waste disposal and environmental protection in the market price of goods (Starr, 1991). The result is products that are so 'cheap' that we can 'afford' to just throw them away.

#### Disposal of Residual and Hazardous Waste

At the bottom end of the waste hierarchy are the **residual** waste products which are non-reuseable, non-recyclable, or outright hazardous. The non-hazardous items form the bulk of most landfill wastes and sewage. However, hazardous wastes need special measures, such as treatment (to denature or dilute the harmful ingredients), permanent storage, export, or incineration.

The scale of hazardous waste generation in New Zealand is only beginning to be understood (see Box 3.6). Potentially hazardous wastes are released into streams and estuaries from sewers and stormwater drains, into the air from chimneys and car exhausts, and onto land from many sources. An estimated 8 percent of the waste entering our landfills is potentially hazardous (see Figure 3.10).

The past disposal and careless handling of hazardous waste has left a residual problem of potentially contaminated sites in many parts of the country, the extent of which in practice is still not known for sure (see Chapter 8). The contaminated sites are now being investigated and, where necessary, cleaned up by central and local government. The Resource Management Act 1991 and the Hazardous Substances and New Organisms Act 1996 have been passed to prevent future occurrences.

In the past, some wastes have been exported because appropriate facilities were not available here and were unlikely to be built. Exporting these wastes is the most effective and efficient way of dealing with the small quantities for a small country. For example, hazardous wastes approved for export in 1995 included: 14,000 tonnes of vanadium slag to China and Russia;

**Box 3.6**

### *Hazardous wastes: the Auckland study*

Auckland region's hazardous waste for 1995 was recently surveyed with assistance from the Ministry for the Environment's Sustainable Management Fund (Auckland Regional Council, 1996b). A very broad definition of hazardous waste was used, covering virtually anything that might harm human, animal or plant health, or might have negative ecological effects. This includes substances with any of the following properties, or with the potential to develop them through chemical breakdown, recombination, or accumulation: explosiveness, flammability, oxidising capacity, toxicity, corrosiveness, radioactivity, and eco-toxicity. In a departure from other surveys of this sort, biological substances were included, such as animal and vegetable waste, because of their potential to rot and pollute waterways. This definition of hazardous waste combined and extended those used in both the Waste Analysis Protocol and the Hazardous Substances and New Organisms Act.

The 1996 survey was not the first to study hazardous wastes in the Auckland region. The largest industrial zones are centered there, and surveys had been conducted as far back as 1983. One of the problems in getting reliable information is the sheer diversity of waste sources and the lack of any records. Most of the surveys looked at the business sector because households are known to produce relatively little hazardous waste. In fact, the proportion of hazardous substances (excluding biological matter) in household waste sent to landfills is less than 1 percent (Auckland Regional Council, 1996a; Blutner *et al.*, 1994; Hodge, 1994; Holley, 1994; Ranacou, 1994; Taranaki Regional Council, 1994). Household hazardous wastes include such things as used oil, paints and thinners, garden pesticides, and spent car and torch batteries. In contrast, the much larger quantity of hazardous waste generated by the business sector includes: timber treatment chemicals; metal finishing wastes (e.g. cyanides, chromium sludges, acids and alkalis, degreasing chemicals); pesticides; asbestos from old building demolitions and renovations; sludges of mineral acids and alkalis; bitumens, tars and oils; solvents, inks, dyes and paints; polychlorinated biphenyls (PCBs); tannery and fellmonger wastes (e.g. chemical wastes, such as sulphides); and pharmaceutical and laboratory wastes.

In 1990, a breakthrough in identifying major sources occurred when the Auckland Regional Council surveyed some 1,500 businesses and found that 95 percent of the non-biological hazardous waste was coming from just three sectors: manufacturing (68 percent); transport and storage (18 percent ); and the heterogeneous sector called community services (9 percent), which, according to the New Zealand Standard Industrial Classification, includes repair services, panel beaters, spray painters, drycleaners, laundries, photographic processors, hospitals, the military and even funeral directors. Following this lead, the 1996 survey focused exclusively on these three sectors. A sample of 1,862 was drawn, representing about 8 percent of Auckland's 24,000 manufacturing, transport and service businesses. A third (609) of these generated hazardous wastes—some 4.6 million tonnes annually. Nearly all of this was liquid sewage, with only 1.9 percent in solids and 0.4 percent in sludges, powders or gases. Roughly half the waste was organic matter (e.g. from abattoirs and supermarket leftovers) and the rest was inorganic (e.g. metals and chemical compounds). The most common hazardous wastes were: corrosive acids and alkalines, present in 1.9 million tonnes (Mt) of sewage; industrial liquids containing metals (1.8 Mt); scrubber sludges (1.5 Mt); animal wastes (1.3 Mt); and industrial organic liquids (0.9 Mt).

The Council had hoped to estimate from this the total amount of hazardous waste generated in the region. Unfortunately, the variability between business premises prevented this. However, more reliable data came from the 'hazardous waste operators' interviewed in the survey. These are companies that run disposal operations, such as sewerage plants, incinerators, landfills, and recycling plants, or that transport wastes to disposal sites. It turned out that some 110,605 tonnes went to landfills and 5,392 tonnes went to incinerators, but the amount of trade waste going to sewers was very uncertain. Despite the uncertainty, it was estimated that some 13,000 tonnes of hazardous solids (mostly biological waste) may have entered the sewerage system. Suspended in water, this was estimated to have produced a very dilute soup of perhaps 9.5 million tonnes—about a tenth of the region's total sewage received at sewage treatment plants.

Although the 1996 survey did not settle the question of how much hazardous waste is generated and disposed of in the region, it did reveal that the quantities are higher than previously thought, and it did uncover deep flaws in the management, disposal and monitoring of hazardous wastes. With no legal requirement to keep records, few companies know precisely how much hazardous waste they generate or dispose of. Many were unaware that some of their wastes were hazardous and had little knowledge of how to manage or dispose of those they did consider hazardous. Although this lack of knowledge was widespread, among both the generators and the operators, few companies felt the need for improvement or outside advice, suggesting that hazardous waste management is a low priority for most companies (Auckland Regional Council, 1996).

340 tonnes of PCBs to France; 120 tonnes of of spent cell lining to Australia; and 100 tonnes of copper alloy dross to the United Kingdom (Ministry for the Environment, 1997). Smaller tonnages of aluminium dross, tungsten carbide grindhouse residue, zinc oxide baghouse dust and spent lead acid batteries were also approved for export.

These are maximum figures. The actual quantities exported are often much lower (e.g. 120 tonnes of PCBs actually went to France in 1995). The Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal now requires that hazardous wastes be disposed of wherever possible in their country of origin. Signatory countries, including New Zealand, must try to reduce transboundary movements of hazardous wastes and are required to report annually on the amounts exported and imported.

Incineration of solid wastes is only used on a small scale in New Zealand, though it is heavily used in densely populated areas overseas. Waste is reduced to a much smaller volume of ash, which can be removed to landfills. Some of the waste also escapes as air emissions which include greenhouse gases and potentially hazardous gases, such as heavy metals and dioxins. These emissions are generally lower than from ordinary burning because of the very high temperatures at which they are burnt (more than 1000°C).

Our largest incinerator is at Auckland International Airport. It can burn 700–2,000 kilograms of waste per hour. The US-designed incinerator is intended to handle aeroplane and airport waste which, by law, must be incinerated to reduce the chance of harmful organisms entering the country. Medical and quarantine waste is also incinerated at the facility. Because the waste stream is a very wet combination of organic waste (such as food left-overs), mixed plastics, papers, glass and tins, natural gas is added for adequate burning. The incinerated ash is only 20–25 percent of the initial waste volume. Because the fee for using the incinerator is high, international airlines prefer to dispose of their waste overseas, particularly in Sydney. As a result, the incinerator is substantially under-utilised (EECA, 1996).

New Zealand also has four smaller incinerators licensed to burn commercial medical and quarantine waste (Ministry for the Environment, 1997 forthcoming). These New Zealand-designed "Whirlstream" incinerators are located at Auckland, Wellington, Christchurch and Dunedin. They can run continuously, and their capacities vary from 500 to 900 kilograms per hour. The incinerated waste is reduced to only 5-10 percent of its original volume. Plans are underway in Auckland for the development of a much larger general waste incinerator, which would also be used to generate electricity (EECA and CAE, 1996).

Another form of incineration is provided by the cement industry which has recently begun adding used oil to one of its kilns. This is non-recyclable oil collected through the oil industry's Oil Recovery Programme. At temperatures as high as 2,000°C, the oil gives off no increased air emissions and leaves a non-toxic ash residue which is incorporated in the cement (Kingett Mitchell and Associates Ltd, 1994).

Experiments overseas have suggested that incineration for electricity production may be the most efficient way to dispose of plastic waste (Coghlan, 1994; EECA, 1996). Most plastic waste is not recyclable because of impurities, but tonne for tonne it has more energy than coal. Although it accounts for only 7 percent of landfill volume, it makes up 30 percent of a landfill's energy content. Even where the plastic is recyclable, the energy retrieval from burning is much higher than the materials retrieval from recycling. At present, plastics are not incinerated in New Zealand.

Another form of energy production from waste is becoming more widespread in New Zealand—the harnessing of landfill gas. Landfill gas typically contains 55 percent methane ($CH_4$) and 40 percent carbon dioxide ($CO_2$). This potentially explosive gas can be collected through a network of horizontal pipes and wells installed before and during the landfill's accretion. The gases are bottled and can be safely burnt to generate heat or electricity. Several landfills are producing gas, two in Auckland, and one in each of the Hutt Valley, Porirua and Dunedin. About 6 percent of the natural gas sold in the Wellington region is from landfills (EECA, 1996).

In summary, New Zealanders seem to be producing more solid waste than they were and the increases seem to be correlated with periods of economic growth. However, efforts are now underway to improve both our monitoring of the solid waste stream and our management of it. This has led to an increase in recycling and recovery programmes and in energy generation from landfill gas. It has also led some industries, organisations and households to adopt waste minimisation strategies. A positive sign of greater public awareness may be the decline in litter over the past decade. However, such trends are still at an early stage. The majority of households and businesses, and even waste managers and transporters, still seem quite indifferent to the problems caused by increasing volumes of waste, including hazardous waste.

## CONCLUSION

New Zealand's production and consumption patterns have resulted in a large ecological footprint based primarily on extensive land use, but also on the waste-absorbing properties of our water and air. As discussed in later chapters, land use pressures as well as absorption pressures from energy use and waste generation have had measurable impacts on the state of our air, water, soil and biodiversity (see Chapters 5 to 9).

So far, the small size of the New Zealand population and the relatively large land area and water resources at our disposal have allowed us to have our environmental cake and eat it too. In effect, the environment, particularly the indigenous wildlife (see Chapter 9), has partly subsidised our economic development by providing a succession of quarried resources and plentiful energy resources to use, and abundant land, water and fresh air to absorb our wastes. However, those subsidies cannot be sustained indefinitely and will eventually be reduced or withdrawn if we cannot manage our activities sustainably.

Given that our most important export-oriented industries (e.g. agriculture, forestry, fisheries and international tourism) rely heavily on the resources of land, water, and air, our stewardship of those resources will be critical to our ongoing economic development. Fortunately, New Zealand's environmental administration and law has been reformed within the past decade to give priority to the principle of sustainability (see Chapter 4). As a result, the nation is now well-placed to develop sustainable production and consumption patterns.

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THE STATE OF

NEW ZEALAND'S ENVIRONMENT

CHAPTER FOUR

# ENVIRONMENTAL MANAGEMENT

## CONTENTS

## ENVIRONMENTAL MANAGEMENT IN NEW ZEALAND

Environmental management in New Zealand was extensively reformed in the late 1980s and early 1990s. Today's environmental policies and laws reflect the concerns of both the New Zealand public and the global community. The public's concerns are expressed through the environmental planning processes, including the granting of resource consents in each region and district of New Zealand, through frequent consultation between environmental agencies and interest groups, and through issue-specific campaigns by New Zealand's many environmental lobby groups. Global concerns are expressed through international discussions which often result in treaties or other agreements requiring us to adopt or modify our policies or laws in some way.

Prior to the 1990s, New Zealand's approach to environmental management was piecemeal and incremental (OECD, 1981). From the 1940s on, as environmental awareness seeped slowly into the nation's consciousness, laws were passed, advisory bodies were set up, and management responsibilities were allocated to various government departments, local authorities or special purpose boards, councils or committees. The first attempt at coordinated environmental management was the Soil Conservation and Rivers Control Act 1941 which established local catchment boards to coordinate soil and water conservation across whole water catchments which spanned several towns, boroughs or counties. This approach of using natural boundaries as the management unit was a world first, and many nations are looking to implement this today. A supervisory national committee was also established, the National Water and Soil Conservation Organisation (NWASCO) which was serviced by the Soil and Water Division of the Ministry of Works and Development (MWD)—the government department in charge of public works, such as road, bridge and hydro dam construction. Government subsidies were supplied via MWD to the Catchment boards to assist local landowners to carry out flood protection works, river control work, drainage and soil conservation works. This division later had a special unit that carried out research into water and soil systems and management techniques.

In the 1950s and 1960s a number of new laws, organisations and responsibilities were introduced, beginning with the Wildlife Act 1953 and several new national parks. By the late 1960s and early 1970s, burgeoning public awareness of environmental issues was fuelling high profile campaigns against hydro development (i.e. the raising of Lake Manapouri), the clearfelling of indigenous forests, Christchurch's air pollution, water pollution of urban beaches and harbours, and international issues such as whaling and nuclear testing. The growing pressure for better environmental protection was reflected in a series of new laws, such as the Water and Soil Conservation Act 1967, the Clean Air Act 1972, the Town and Country Planning Act 1977(which reformed earlier Acts), the Marine Mammals Protection Act 1978, the Pesticides Act 1979, the Toxic Substances Act 1979 and the National Development Act 1979.

International influences were also becoming more important. In 1972, New Zealand attended the first Earth Summit in Stockholm—the United Nations Conference on the Human Environment. At the time, New Zealand was party to just nine international environmental agreements—up from one in 1960. The pace of international discussions on the environment picked up sharply after that conference and quickened again in the build-up to the Second Earth Summit at Rio de Janeiro in 1992 (see Figure 4.4). Today, New Zealand has signed nearly 50 international environmental agreements and a number of these are reflected in our domestic laws relating to such topics as marine pollution, ozone depletion, and traffic in endangered species (see Table 4.2).

The international influence is also felt through the Organisation for Economic Cooperation and Development (OECD), particularly its reviews of our environmental policies (OECD, 1981) and environmental performance (OECD, 1996). In its 1981 review the OECD identified three types of central government agency in New Zealand with environmental management roles:

- **advisory bodies and administrative agencies** whose sole or predominant concern was some aspect of environmental policy (e.g Commission for the Environment; Nature Conservation Council; Environmental Council; the Wildlife Division of Internal Affairs; National Parks Authority; Historic Places Trust; and the Queen Elizabeth II National Trust);

- **government departments and administrative agencies** whose environmental protection responsibilities were associated with responsibilities for managing or developing a particular sector of the economy (e.g. the Forest Service; Department of Lands and Survey; Ministry of Works and Development; Department of Health; National Chemicals Board; and the national Water and Soil Conservation Authority); and
- **government departments** and **administrative agencies** whose sole or predominant concern was the management and development of natural resources in a particular sector, thus pre-determining the framework in which environmental policies could operate (e.g. Ministry of Agriculture and Fisheries and the Ministry of Energy).

The OECD concluded that New Zealand's environmental policies needed to be better advised and better coordinated, and that a more integrated approach was necessary in dealing with the environmental concerns in energy, agriculture, forestry, mining and other economic development programmes (OECD, 1981). These recommendations influenced the new Labour Government's subsequent decisions to restructure central and local government and to overhaul and replace many of the nation's environmental laws.

As a consequence of the reforms, primary responsibility for environmental management was confirmed to rest with local authorities, subject to national legislation outlining the broad objectives and methods available to them for achieving sustainable management. Apart from some issues in which there is a clear national interest (e.g. nature conservation on public lands and endangered species protection, ozone layer protection, and the introduction of hazardous substances and new organisms) responsibility for dealing with most environmental impacts on air, land, water and ecosystems is now in the hands of catchment-based regional councils and the various territorial authorities within each region. Central government does, however, provide guidance on some matters, in some cases setting down national policies, standards or guidelines.

To fully appreciate the nature of New Zealand's approach to environmental management, it is useful to review the nature of government here, and the changes introduced by the reforms of the 1980s.

Her Majesty Queen Elizabeth II is New Zealand's Head of State. Her approval is required for new legislation and for the formation of new governments. This power to approve is routinely granted through her resident representative, the Governor-General. The people who actually create the new laws are the democratically elected members of the House of Representatives (Parliament, or the **legislature**). Once enacted, the laws are interpreted by judges acting through the law courts (the **judiciary**). The daily running of public institutions is in the hands of Government (the **executive**), which is made up of the majority faction(s) in Parliament.

The Government is headed by the Prime Minister , the leader of the dominant party or coalition in Parliament. The Government's major areas of responsibility are referred to as portfolios and are allocated to Cabinet Ministers selected from members of the ruling coaltion of parties that form the Government. Current portfolios with relevance to the environment include Environment, Conservation, Biosecurity, Agriculture, Forestry, Fisheries, Transport and Commerce (which deals with energy and tourism issues). Parliament's 120 members are elected through the recently introduced Mixed Member Proportional (MMP) system, with 60 members representing general electorates, 5 representing the Maori electorates (which overlap the general ones), and the remaining 55 representing political parties that received 5 percent or more of the total vote with the overall allocation to each party equal to its overall share of the total vote.

From 1984, in response to underlying deteriorating economic performance which led to severe borrowing difficulties, major reforms of the economy were undertaken. This included reforming government institutions. These reforms were guided by market-oriented principles that called for a reduction in the size and role of government, greater economic efficiency and public accountability within the state sector, and greater freedom for private enterprise and local communities in making development decisions. Nine State Owned Enterprises were formed to manage the government's commercially productive assets (e.g. coal mines, leasehold land, electricity stations and lines, forests, railways, the national airline and the telephone system). These corporations were defined as commercial operations and required to show profits and demonstrate efficiency in the same way as private companies.

The fragmented environmental responsibilities of the previous government departments were consolidated into three new agencies: the Department of Conservation, the Ministry for the Environment and the Parliamentary Commissioner for the Environment. Publicly owned assets were also re-allocated. Commercial resources (e.g. exotic plantation forests) were eventually sold (though the land itself remains in public ownership). Environmental assets, such as indigenous forests that had been managed by several different agencies (e.g. the Forest Service, the Wildlife Service and the Department of Lands and Survey) were all put in the care of the Department of Conservation.

Environmental legislation was also overhauled. A chaotic variety of issue-specific laws were reduced to a few more coherent laws that specified the objectives, responsibilities and general principles of environmental management and redefined the environmental roles and responsibilities of government agencies and local authorities.

### CENTRAL GOVERNMENT REFORM 1986 - 1988

Prior to 1986, environmental reponsibilities were scattered over of a variety of government institutions. Sometimes it was a case of the fox guarding the chickens with some departments having responsibility for both the protection and exploitation of the resources under their control. For instance the New Zealand Forest Service was responsible for protecting indigenous forest and also for converting native forest into commercial plantation forest. The Commission for the Environment had the role of advocating environmental protection, but it lacked influence or 'teeth'. Other agencies with environmental administration functions were the Department of Lands and Survey, the Ministry of Works and Development, and the Wildlife Service of the Department of Internal Affairs.

Today, the Department of Conservation has responsibility for giving policy advice on conservation matters to the Government and for managing all protected Crown land including protecting its indigenous biodiversity, and promoting nature and heritage protection on and off the conservation estate through public education. The Ministry for the Environment's role is to give policy advice to the Government on sustainable management of the environment, to provide guidance to local authorities and the private sector, and to promote sustainable management through public education. The Commissioner's role is to provide independent advice to Parliament on environmental matters and to provide an independent assessment of central and local government environmental agencies and their activities (Statistics New Zealand, 1996).

The overall reform process meant that by mid-1987 the following institutions were abolished (Buhrs and Bartlett, 1993):

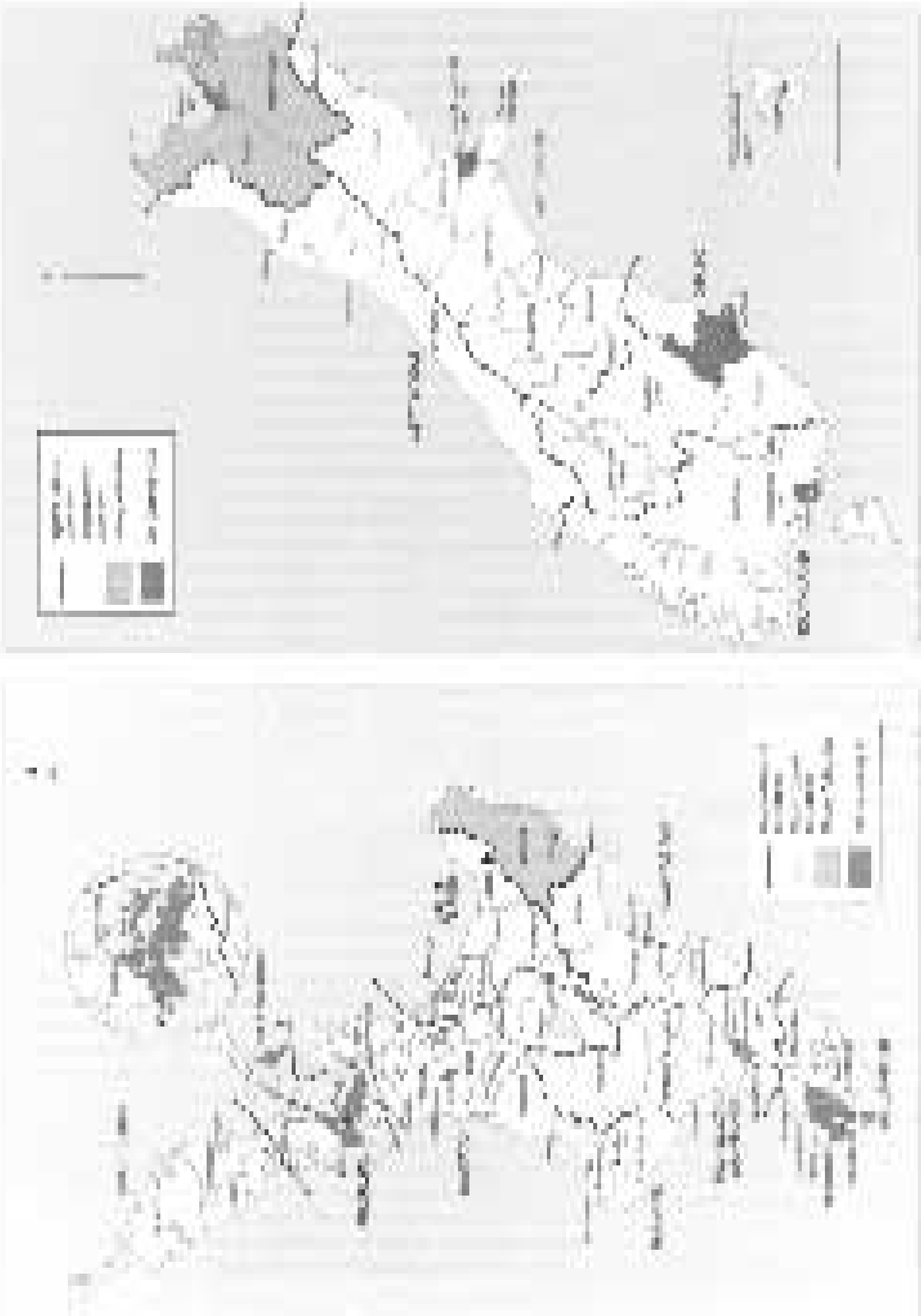
- New Zealand Forest Service
- Department of Lands and Survey
- Wildlife Service of the Department of Internal Affairs.
- Commission for the Environment.

In their place were created institutions with clearly defined commercial, regulatory, administrative, policy and environmental advocacy functions:

- ForestryCorp
- LandCorp
- Ministry of Forestry
- Department of Survey and Land Information
- Department of Conservation
- Ministry for the Environment
- Parliamentary Commissioner for the Environment.

The Ministry of Works and Development was abolished in April 1988, with its commercial functions allocated to the Works and Development Corporation and its resource management responsibilities transferred to the Ministry for the Environment. The Department of Survey and Land Information was restructured in 1996 to form Land Information New Zealand and TerraLink, separating land information policy functions from commercial activities.

**Figure 4.1**
**Local government in New Zealand.**



## LOCAL GOVERNMENT REFORM 1987 - 1989

The local government reforms of this period were made in close association with the reforms to environmental legislation, which ultimately led to the Resource Management Act 1991. The local government reforms used the principles of clear accountability and separation of roles, and culminated in the passing of the Local Government Act 1987. The Act reduced the number of local and regional units of government from more than 625 to 94 (Buhrs and Bartlett, 1993). The original units had included authorities, united councils, counties, municipalities, districts and special purpose boards, such as harbour boards, drainage boards and catchment boards.

The most important innovation under the new arrangements was the creation of 13 regional councils, whose geographical boundaries were based on natural river catchments. In 1996, there were 12 regional councils (the Nelson-Marlborough Regional Council was abolished in 1992 and its responsibilities transferred to three unitary authorities), 74 territorial authorities (including four unitary authorities), and six special purpose authorities (Statistics New Zealand, 1996) (see Figures 4.1 and 4.2). There were also 154 community boards primarily acting as community advocates for consultations with territorial authorities.

## ENVIRONMENTAL ADMINISTRATION TODAY

As a result of the reforms, the main players in today's system of environmental management are local authorities—regional councils and territorial authorities (including unitary authorities). Non-governmental organisations also play an important role (see Box 4.1) The hierarchy of central and local government responsibilities is set out below. Agencies' responsibility under the Resource Management Act are described in more detail later in this chapter (see Figure 4.2).

### Central Government

Ministers have responsibility under legislation:

- for the management of certain resources eg. fisheries management;
- for national responses to issues of concern that affect the nation as a whole eg. national pest management strategies under the Biosecurity Act, and the setting of national controls for hazardous substances and new organisms under the Hazardous Substances and New Organisms Act; and
- for overall administration of the various Acts to ensure appropriate actions are undertaken and that the legal provisions in those Acts do not create impediments to good environmental management.

### Regional Councils

Regional councils are elected local government bodies that coordinate, and set policy for, resource management, including water and soil conservation, and transport. They also have some residual responsibilities for civil defence, drainage, pest management and control.

### Territorial Authorities

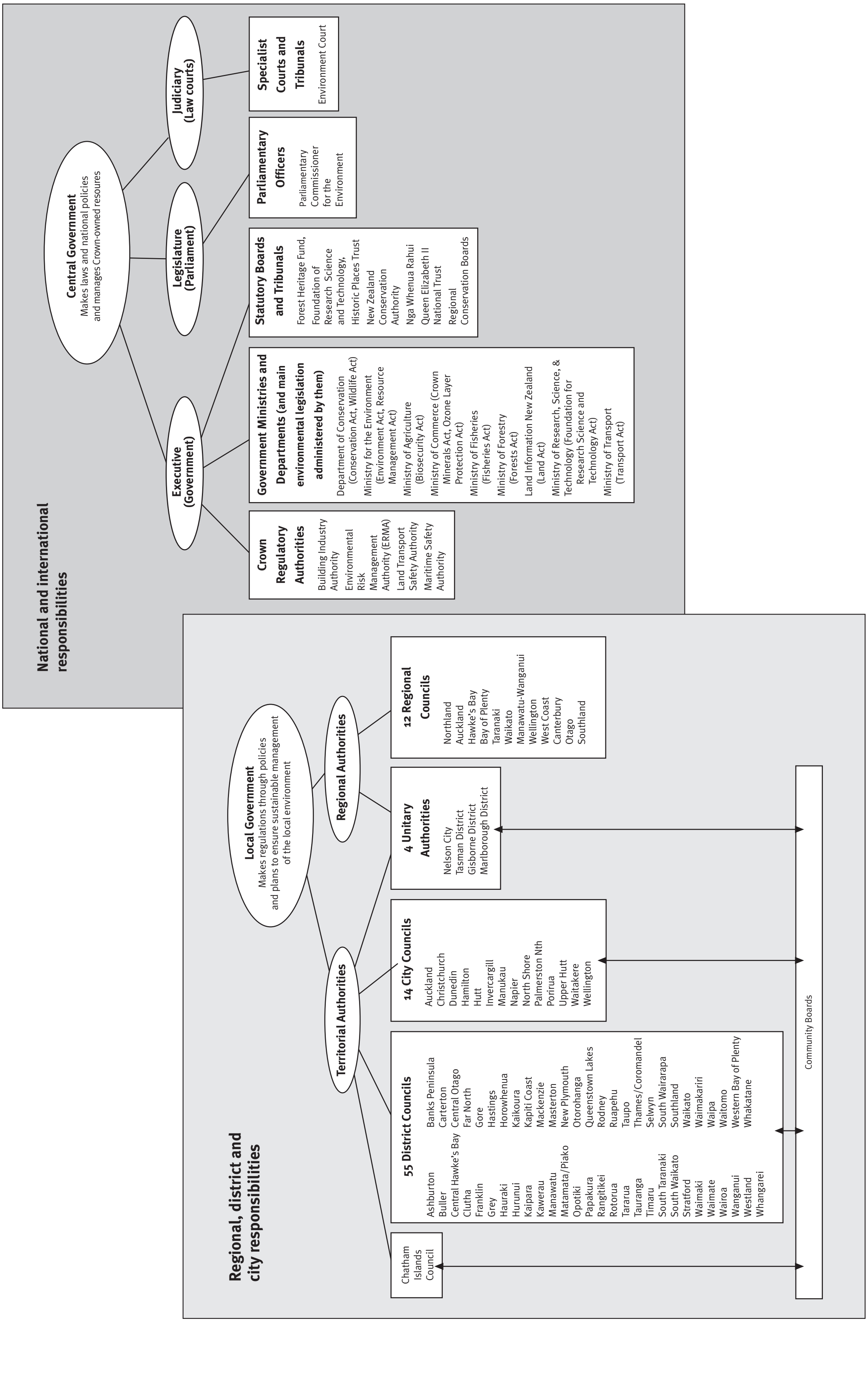
Territorial authorities are elected district or city councils. For the most part, functions of territorial authorities are complementary to those undertaken by regional councils, but focused on local service requirements. They cover water supply, control of land development, recreational facilities including parks and reserves, local roading and transport activities, sewerage and stormwater drainage, community development, and other public works.

### Unitary Authorities

There are four unitary authorities with combined responsibilities for resource management and service delivery. The Gisborne, Marlborough and Tasman District and Nelson City councils therefore have both regional and territorial authority functions under the Resource Management Act.

**Figure 4.2**

**The structure of government and environmental responsibilities**



**Box 4.1**

***The Role of Non-Governmental Organisations (NGOs)***

The impetus for environmental policies and laws in New Zealand has often come from the public through the lobbying of non-governmental organisations (NGOs) such as the Royal Forest and Bird Protection Society, Greenpeace, the Maruia Society, the Federated Mountain Clubs, and Environment and Conservation Organisations (ECO). Contributions are also made by the Royal Society of New Zealand. The ability of these organisations to reflect and mobilise public and expert opinion has often persuaded the government to develop new policies or reconsider existing ones.

Since the reforms of the late 1980s, and especially since the passing of the Resource Management Act, the public (including NGOs) have had better access to environmental decision-makers. The Act's consultation and public submission processes enable NGOs to have their views considered more easily. In fact, the Act tacitly assumes that the community can act as a watchdog in holding all decision makers under the Act accountable for the environmental effects of their decisions. This assumption applies not only to environmental organisations, but also to other groups such as industry groups, iwi, and neighbourhood organisations.

## RESOURCE MANAGEMENT LAW REFORM 1987 - 1991

By the end of the 1980s, New Zealand had a vast and cumbersome array of laws dealing with natural resources. Legislation had, until then, been designed in response to discrete environmental problems, but the responses were disconnected and inconsistent. No single principle or system for managing natural resources existed.

In December 1987, the Government announced a comprehensive reform of New Zealand's resource management law in conjunction with the local government reforms (Memon, 1993). As the first step in the reform, the existing legislation was reviewed and the following nine major problems identified (Palmer, 1991):

- there was no consistent set of resource management objectives;
- there were arbitrary differences in the management of land, air and water;
- there were too many agencies involved in resource management with overlapping responsibilities and insufficient accountability;
- consent procedures were unnecessarily complicated and costly, and there were undue delays;
- pollution laws were ad hoc and did not recognise the physical connections between land, air and water;
- in some aspects of resource management there was insufficient flexibility and too much prescription, with a focus on activities rather than end results;
- Maori interests and the Treaty of Waitangi were frequently overlooked;
- monitoring of the law was uneven; and
- enforcement was difficult.

The Resource Management Act and the Crown Minerals Act were passed in 1991. Together, these Acts form the basis for New Zealand's unique and pioneering resource management legislation. (See Milne, 1992 for a more detailed discussion of New Zealand's environmental legislation.)

### A principled approach to legislation

Since the reform process leading to the introduction of the Resource Management Act 1991, New Zealand's environmental legislation has contained a number of common themes. Chief among these is the principle of sustainability, which is now the umbrella principle for management of natural and physical resources, indigenous forests, and fisheries. This principle was endorsed internationally at the 1992 United Nations Conference on Environment and Development (UNCED) (see Box 4.4).

Other principles from this conference are evident in our national environmental laws. These include the precautionary principle, which was defined at UNCED to mean that: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". The corollary of this principle is that people proposing to undertake activities with potential effects on the environment should carry out environmental impact assessments. In this way, the nature and extent of any environmental risk is identified before action is taken. This approach is evident in laws governing the management of hazardous substances and new organisms, is inherent in the effects-based focus of the Resource Management Act (see below) and is contained in some form in most of our other environmental laws.

National environmental laws also endorse the principle of 'user pays'. People using resources that are managed at public costs are required to help pay for a share of the costs of that management. The Fisheries Act 1996, which uses an economic instrument in the form of a quota to manage fisheries resources, requires a substantial proportion of the costs of managing the fisheries resources to be met by the quota holders. The Resource Management Act also includes provisions for user charges.

Our laws also endorse the principle of 'polluter pays', requiring people conducting activities that damage the environment to account for the environmental costs of their activities, and to pay for measures to mitigate, remedy or avoid those effects. |The whole resource consent process under the Resource Management Act is an example of the practical application of this principle. This application of the principle may be used in future for resources causing climate change, perhaps in the form of a carbon tax or a tradeable permit.

As well as providing for sound environmental management on a national level, the incorporation of these principles into our national environmental laws helps give credence to New Zealand's 'green' reputation, and allows New Zealand to play a significant role in developing agreements to further environmental goals internationally.

## NEW ZEALAND'S ENVIRONMENTAL LEGISLATION

There remains a large number of laws that touch on resource management (see Table 4.1). An outline of the major pieces of environmental legislation is set out below.

### Resource Management Act 1991

By bringing together laws governing land, air and water resources, the Resource Management Act (RMA) introduces a totally new approach to environmental management. The Act's 'eco-system' approach recognises that elements of the environment do not stand alone, and that effects of human activities on the environment are not discrete.

*Sustainable management*

The Resource Management Act has a single, overarching purpose: to promote the sustainable management of natural and physical resources. In the Act, 'sustainable management' means managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural well-being and for their health and safety while:

- sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations;
- safeguarding the life-supporting capacity of air, water, soil and ecosystems; and
- avoiding, remedying, or mitigating any adverse effects on the environment.

This recognises that people need to use resources for their welfare, but that in doing so we must not, either singly or cumulatively, compromise the ability of the environment to continue to provide those resources, or other indirect services (such as erosion control) to the community.

The concept of sustainable management is derived from that of sustainable development. Sustainable development was coined in 1987 by the World Commission on Environment and Development (World Commission on Environment and Development, 1987), and developed at the 1992 Rio 'Earth Summit' (see Box 4.4). It is a widely embracing concept, requiring environmental sustainability as well as economic viability and social justice.

In comparison, the concept of sustainable management in the Resource Management Act leaves the pursuit of economic and social goals to other mechanisms available to government and the community, e.g. our taxation and welfare systems. While recognising that there are social and economic consequences from the use of resources, the Act attempts to ensure that the environment's sustainability is not compromised by the pursuit of those concerns.

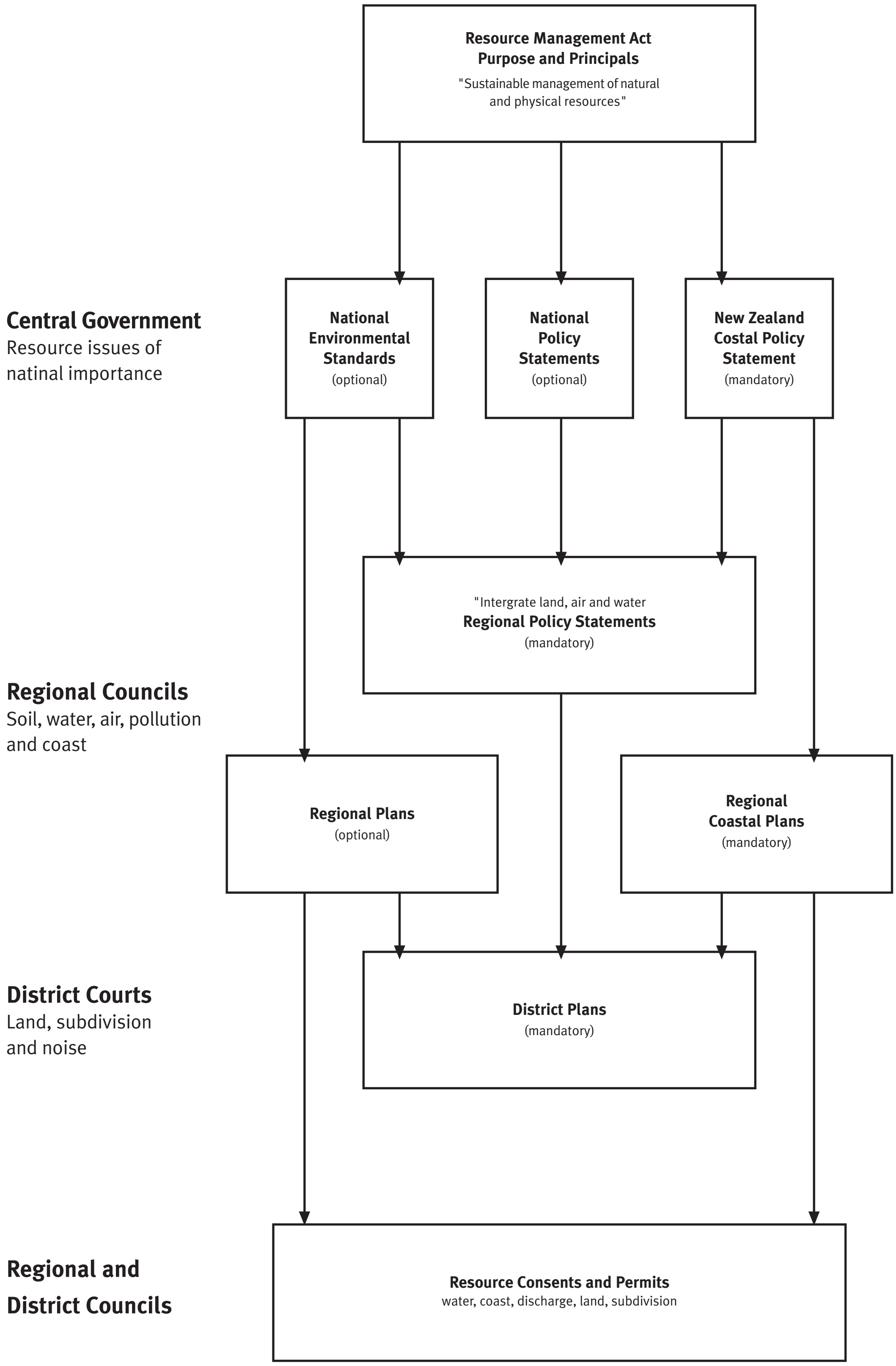
**Table 4.1**

**New Zealand's environmental and related legislation.**

| | |
|---|---|
| **Key laws relating to the environment** | *Import Control Act 1988* |
| *Biosecurity Act 1993* | *International Energy Agreement Act 1976* |
| *Conservation Act 1987* | *Irrigation Schemes Act 1990* |
| *Crown Minerals Act 1991* | *Lake Wanaka Preservation Act 1973* |
| *Environment Act 1986* | *Land Act 1948* |
| *Fisheries Act 1996* | *Land Drainage Act 1908* |
| *Forests Act 1949 (with 1993 amendment)* | *Land Transport Act 1993* |
| *Hazardous Substances and New Organisms Act 1996* | *Litter Act 1979* |
| *Ozone Layer Protection Act 1996* | *Local Government Act 1974* |
| *Resource Management Act 1991* | *Manapouri-Te Anau Development Act 1963* |
| *Wildlife Act 1953* | *Maori Fisheries Act 1989* |
| | *Maori Land Act/Te Ture Whenua Maori 1993* |
| **Other laws relating to the environment*** | *Maori Reserved Land Act 1955* |
| *Agricultural and Pastoral Societies Act 1908* | *Maori Vested Lands Administration Act 1954* |
| *Agriculture (Emergency Powers) Act 1934* | *Marine Farming Act 1971* |
| *Animal Control Products Ltd Act 1991* | *Marine Mammals Protection Act 1978* |
| *Animal Identification Act 1993* | *Marine Pollution Act 1974* |
| *Animal Remedies Act 1967* | *Marine Reserves Act 1971* |
| *Animals Act 1967* | *Maritime Transport Act 1994* |
| *Animals Protection Act 1960* | *National Parks Act 1980* |
| *Antarctic Marine Living Resources Act 1981* | *Native Plants Protection Act 1934* |
| *Antarctica Act 1960* | *New Zealand Nuclear Free Zone, Disarmament* |
| *Antarctica (Environmental Protection) Act 1994* | *and Arms Control Act 1987* |
| *Atomic Energy Act 1945* | *New Zealand Walkways Act 1990* |
| *Building Act 1991* | *Pesticides Act 1979* |
| *Continental Shelf Act 1964* | *Plant Variety Rights Act 1987* |
| *Crown Forest Assets Act 1989* | *Queen Elizabeth the Second National Trust Act 1977* |
| *Crown Grants Act 1908* | *Radiation Protection Act 1965* |
| *Crown Research Institutes Act 1992* | *Rangitaiki Land Drainage Act 1956* |
| *Customs Act 1966* | *Reserves Act 1977* |
| *Dangerous Goods Act 1974* | *Road User Charges Act 1977* |
| *Dog Control and Hydatids Act 1982* | *Scientific and Industrial Research Act 1974* |
| *Driftnet Prohibition Act 1991* | *Soil Conservation and Rivers Control Act 1941* |
| *Dumping and Countervailing Duties Act 1988* | *Southland Electricity Act 1993* |
| *Electricity Act 1992* | *Sugar Loaf Islands Marine Protected Area Act 1991* |
| *Energy Companies Act 1992* | *Synthetic Fuels Plant (Effluent Disposal) EMP Act* |
| *Energy Resources Levy Act 1976* | *Taranaki Harbours Act 1965* |
| *Explosives Act 1957* | *Tarawera Forest Act 1967* |
| *Fertilisers Acts 1960 and 1982* | *Territorial Sea and Exclusive Economic Zone Act 1977* |
| *Foreshore and Seabed Endowment Revesting Act 1991* | *Toxic Substances Act 1979* |
| *Forest and Rural Fires Act 1977* | *Trade in Endangered Species Act 1989* |
| *Foundation for Research, Science and Technology Act 1990* | *Transit New Zealand Act 1989* |
| *Franklin-Manukau Pests Destruction Act 1971* | *Transport Act 1962* |
| *Gas Act 1992* | *Treaty of Waitangi Act 1975* |
| *Harbour Boards Dry Land Endowment Revesting Act 1991* | *Treaty of Waitangi (Fisheries Claims) Settlement Act 1992* |
| *Harbours Act 1950* | *Waikato Raupatu Claims Settlement Act 1995* |
| *Historic Places Act 1993* | *Wild Animal Control Act 1977* |

* *A further 18 laws (along with their 40 amending acts) were repealed by the Resource Management Act in 1991.*

**Figure 4.3**
**Resource Management Act**



### Effects-based approach

The RMA's approach differs from the approach of previous legislation by concentrating on the environmental effects of human activities, rather than on the activities themselves. This means that, regardless of who carries out an activity, it is the environmental effects that result from the activity that are the determining factor as to whether the activity is permitted in any particular location. It also means that, if a particular industrial activity can meet a community's environmental standards, that business should be able to operate in the area. Resource users must consider how their activity will affect the environment.

Focusing on environmental outcomes rather than activities also provides incentives for resource users to come up with efficient and creative ways to achieve good environmental results. People can be rewarded for devising new ways to use resources while promoting environmental sustainability.

#### *Management controls*

The Resource Management Act embodies three conceptually separate but related functions:

- it allocates access to, and use of,common property natural resources (fresh, coastal and ground water, geothermal energy and water, the surface of lakes and rivers, riverbeds, the foreshore and the seabed);
- it controls the discharge of contaminants (pollutants) to air, land and all water including ground, fresh and coastal water; and
- it manages the adverse affects of all activities using land, air, or water.

The RMA sets out a series of duties and restrictions. Under the Act, everyone has a duty to avoid, remedy, or mitigate adverse effects on the environment, notwithstanding the requirements of consent permits. The duties and restrictions also mean that nobody can use natural resources such as water, air or the coast unless the RMA or a consent under it says so.

No-one may discharge any contaminant to water or onto land in a way which might enter water. In the case of air and land discharges, any person operating industrial or trade premises is prohibited from discharging any contaminant without a consent (permit).

Although the presumption for the use of natural common property resources is very strict, the ropposite applies to the use of private land. Here, activities such as the right to erect a building, are deemed to be permitted unless constrained by provisions in statutory plans under the Act.

#### Responsibilities

Responsibilities for environmental decision making under the Act are allocated to the community most closely affected by the use of that resource. A decision is therefore made by the community that will deal with the effects and that can best understand the environmental issues at stake. This means that the government, and district and regional authorities, are required to identify the environmental risks in their area, and develop policy statements and plans containing ways to regulate activities in response to those threats. These plans and policies are constructed in a hierarchy, depending on the degree of action needed to address the perceived threat. (see Figure 4.3) Regional councils and territorial authorities use a common process for developing all plans and policy statements.

**Central government** can develop national policy statements and environmental standards to address environmental issues affecting the whole nation (such as management of the coastal zone or minimum ambient air quality to protect health -see Box 4.2). The government's statements and standards set policy boundaries from which local authorities develop their own policies and regulations.

Under the Act, **Regional councils** are charged with achieving 'integrated management of the natural and physical resources of the region'. Each council is required to draft a Regional Policy Statement identifying environmental issues and responses of significance for its region. It must also draft and administer a Regional Coastal Plan and may draft and administer other regional plans. All regional policy statements and plans must be drafted so they 'are not inconsistent' with any national policy statements or environmental standards in place at the time.

Regional councils also have responsibility for granting resource consents to occupy the coast; to carry out activities in river beds; to use natural water including underground, geothermal and coastal waters; to discharge contaminants to air, water or land; and to control certain activities on land for the purposes of soil conservation, hazard mitigation, and to protect the quantity and quality of natural water in accordance with the provisions of the Act, the Regional Policy Statement, and any regional plans.

Under the Resource Management Act, **territorial authorities** are charged with achieving "integrated management of the *effects of the use, development, or protection* of land and associated natural and physical resources of the district" (emphasis added). Territorial authorities must draft district plans identifying environmental issues of significance relating to land use for the district, and setting down any restrictions and controls on land use and subdivision taking into account the issues identified in the Regional Policy Statements and any regional plans that affect that area, and in national policy statements or environmental standards.

The territorial authorities also grant resource consents for subdivision of land and for activities on land where these have been determined as necessary in the district plan in accordance with the provisions of the Act and the district plan.

#### Analysis of alternative mechanisms

The Resource Management Act does not presume regulation is the only, or necessarily the best, way of dealing with environmental problems. Built into it is a requirement for decision-makers to carry out an appropriate assessment of alternative mechanisms. These include providing information, undertaking works and services, providing subsidies and the use of economic instruments—for example, tradeable water permits.

The Act sets a strict requirement that, before adopting a policy statement or plan or national environmental standard, decision-makers under the Act must analyse the alternative means of achieving the environmental outcomes sought, and choose the most cost effective one (or combination) in the circumstances.

#### Consents

The RMA has a common process for all consents, whether for land, subdivision, water, the coast, or the discharge of contaminants.

Rules in plans also provide for the degree and type of scrutiny of proposals for resource consents (permits). There are five levels of consents: permitted, controlled, discretionary, non-complying and prohibited. Anyone proposing an action requiring a consent must carry out an impact assessment of the effects of that proposal. Plans can set out the particular impacts that the community wishes to examine and control. If there is no plan, or if the plan does not contain environmental criteria, the applicant must ensure that all adverse impacts on the environment are identified and measures to avoid, remedy or mitigate them are identified and developed.

Where a proposal needs more than one consent, these will be dealt with concurrently and by a joint hearing where necessary. This mechanism applies within and between agencies also.

#### Monitoring

The RMA requires local authorities to monitor:

- the state of the environment in their jurisdiction or area;
- whether their policy statements or plans are working as intended;
- whether resource consents and their related conditions are being properly carried out.

Where this monitoring indicates a discrepancy from the original target, the local authority must act to resolve this—either by changing the target or the measures needed to achieve compliance.

For further information about the RMA, see Ministry for the Environment, 1994b, 1994c, 1994d, 1994e.

**Box 4.2**

### *Environmental standards and guidelines*

**The Ministry for the Environment** coordinates development of environmental standards and guidelines to help local authorities and resource users implement their responsibilities under the Resource Management Act (RMA). Standards and guidelines help define the 'environmental bottom line' of sustainable management described by the Act by setting values and targets for environmental quality.

Guidelines contain recommendations for the attainment of certain aspects of environmental quality. They can identify specific targets for environmental outcomes, incentives for resource managers to work towards those outcomes, different means for achieving them, and ways of measuring progress towards them. They are not legally enforceable in themselves, but provide a useful means for standardising practice. They can be incorporated into local authorities' policies and plans (and then become legally enforceable), and some can be translated into codes of practice for industry groups.

Standards differ from guidelines in that they are legally enforceable and apply nation-wide. The RMA provides for national environmental standards to be enacted in the form of regulations. Standards for the use, development and protection of natural and physical resources can relate to:

- noise
- contaminants
- water quality, level, or flow
- air quality
- soil quality in relation to the discharge of contaminants.

In October 1995, the Ministry for the Environment published a paper detailing the principles and processes for developing standards and guidelines (Ministry for the Environment, 1995c). These include the principle that standards and guidelines should prescribe the minimum amount of regulation to best achieve the desired environmental outcome, that they should consider impacts on other parts of the ecosystem, and that they should employ a precautionary approach which takes account of the uncertainty in the measures prescribing environmental quality. The paper also states that standards should be developed only where the advantages of protecting national values or providing national consistency outweigh the advantages of regional resource management.

The process for developing standards and guidelines aims to ensure widespread public consultation and peer review. Several drafts, and submissions on them, are called for at several stages in the development process. A significant element of the process for developing standards is a formal 'section 32' report, which is an evaluation of the alternatives to, benefits and costs of, adoption of the proposed standard.

To date, no national environmental standards have been enacted. However, several guidelines have been developed, some of which may be enacted as standards in future.
To date, guidelines developed by the Ministry for the Environment are:

- *Guidelines for Subdivision,* October 1991
- *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites,* January 1992
- *Ambient Air Quality Guidelines,* June 1994
- *Water Quality Guidelines No 1,* June 1994: control of undesirable biological growths in water
- *Water Quality Guidelines No 2,* June 1994: water colour and clarity
- *Above-Ground Bulk Storage Containment Systems Guide,* July 1995
- *Odour Management Under the Resource Management Act,* June 1995
- *Cleaner Production Guidelines,* May 1994: an update of case studies was published in October 1995
- *Landfill Full Costing Guide,* June 1996.

The Ministry for the Environment is also coordinating development of guidelines on coastal and fresh water bathing quality, toxic contaminants in water, stock drinking water, instream flows, organochlorines management, air emissions source testing, and marine pollution.

**The Ministry of Health** also develops guidelines, especially where use of resources can have effects on human health. Guidelines published by the Ministry of Health to date include:

- *Draft Health and Environmental Guidelines for Selected Timber Treatment Chemicals* Ministry for the Environment and Ministry of Health, 1993
- *Air Pollution Monitoring in New Zealand 1960 - 1992* Institute of Environmental Science and Research Limited, 1994
- *Energy Efficiency Opportunities from PCB Phase-Out* Energy Efficiency and Conservation Authority and Ministry of Health, 1994
- *Microbiological Methods for Monitoring Saline Recreational Waters,* 1994
- *Drinking Water Standards for New Zealand,* 1995
- *A Guide to Health Impact Assessment: Guidelines for public health services and resource management consent agencies and consent applicants* Public Health Commission, 1995
- *Guidelines for Drinking-Water Quality Management,* 1995

- *Guidelines on the Management of Leadbased Paint* Joint Public Health Commission and Occupational Safety and Health Service, 1995
- *Risk Assessment: a 'user friendly' guide: Guidelines for public health services and resource management agencies and consent applicants* Public Health Commission, 1995
- *Interim National Quality Standards,* 1995
- *Guidelines for Management of Asbestos in the Non-occupational Environment,* 1996
- *Information about Selling, Packing, Handling and Storing Poisons,* 1996
- *Priorities and Procedures for Contaminated Site Investigation* Version 1, Institute of Environmental Science and Research Limited, 1996
- *Protocol for Drinking Water Monitoring Programmes Based on Rapid Test Systems such as Colilert/Colisure*, 1996.

***Crown Minerals Act 1991***

The Crown Minerals Act controls mining rights to Crown-owned minerals. It deals with the allocation of property rights. It establishes minerals programmes and sets royalty regimes for the various mineral ores. Permits are granted for prospecting, exploring and mining in accordance with these programmes and subject to the royalty regimes and appropriate conditions.

Three permissions are required before mining can start:

- a right to the mineral resource
- a right to access to the land on which or under which the mining will take place
- environmental consents to carry out the activity.

A mining permit does not confer any right to access—this must be negotiated between the permit holder and the landowner. In the case of Crown land, access conditions are determined in accordance with the legislation under which the land is being managed.

The Resource Management Act controls the environmental effects resulting from the use of those rights. Mineral depletion is therefore exempt from the sustainability provisions of the RMA, but the environmental impacts of the mining and use of minerals on other resources may be addressed under the RMA.

***Environment Act 1986***

The Environment Act 1986 established the Ministry for the Environment and authorised appointment of the Parliamentary Commissioner for the Environment. In addition to establishing these new administrative agencies, it entrenched the Government's commitment to include environmental issues as a key element in its policy-making formula. One of its objectives is to ensure that, in the management of natural and physical resources, full and balanced account is taken of:

- the intrinsic values of ecosystems
- all values which are placed by individuals and groups on the quality of the environment
- the principles of the Treaty of Waitangi
- the sustainability of natural and physical resources
- the needs of future generations.

***Hazardous Substances and New Organisms Act 1996***

The passing of the Hazardous Substances and New Organisms Act in June 1996 represents one of the most significant reforms of environmental legislation since the Resource Management Act. The Act has a strong focus on environmental protection, although the actual level of environmental and human health protection will be set through regulations yet to be developed. The Act establishes the Environmental Risk Management Authority (ERMA) to assess and decide on applications to introduce hazardous substances or new organisms into New Zealand.

***Biosecurity Act 1993***

The Biosecurity Act was introduced in 1993 to restate and reform the laws relating to pests and unwanted organisms. It covers the quarantine, importation and monitoring of pests and unwanted organisms, and provides for pest management through regional or national pest management strategies. Any minister can recommend development of a national pest management strategy for an organism that is a pest 'of national importance', and regional councils can propose a strategy for controlling pests 'of regional importance'.

Criteria for identifying the need for a strategy are not just environmental; they include considerations of economic well-being, cultural concerns, as well as the viability of rare or endangered species, soil structure and water quality. The Act provides for cost-benefit analyses to be made of the pest's potential impacts before strategies are implemented. The roles and responsibilities of land-owners, regional councils and others and the cost-sharing for the management of the pest are then allocated on the basis of the nature and extent of the threats posed by the pest.

***Conservation Act 1987***

The Conservation Act 1987 establishes the Department of Conservation, and defines its mandate for managing and promoting the conservation of New Zealand's natural and historic resources on Crown-owned land. These resources include plants and animals; the air, water and soil they live upon or within; landscapes and landforms; and historic resources as defined under the Historic Places Act 1980. The Act sets up a system of land protection, and describes the variety of lands held for conservation purposes. These include ecological, sanctuary or wilderness areas and conservation parks. The Act also makes the Department of Conservation responsible for managing the recreational and tourist use of natural and historic resources within the protected estate.

***Fisheries Act 1996***

The Fisheries Act 1996 implements a system for ensuring sustainability of New Zealand's fishing resources. The Act aims to provide for the use, conservation, enhancement and development of fisheries resources so that people can provide for their social, economic and cultural well-being while:

- ensuring that the potential of those resources to meet the foreseeable needs of future generations is maintained; and
- avoiding, remedying or mitigating any adverse effects of fishing on the aquatic environment.

The Act therefore incorporates sustainability as its underlying principle. This means that the long-term viability of stocks for each species, the biological diversity of the aquatic environment, and human interests in using fishing resources are all considerations under the management system. A Quota Management System provides for the sustainability of fisheries resources. Under this system, the Minister of Fisheries can put in place fishing quotas for specific stock.

Under the Act, a Total Allowable Catch is set for species managed under the Quota Management System (covering commercial, recreational and traditional Maori fishing activity). This is reviewed annually for each species covered by the system. From this, a Total Allowable Commercial Catch (TACC) is established and commercial fishers acquire rights to harvest fish by purchasing or leasing Individual Transferable Quotas (ITQs). ITQs are expressed as a proportion of the TACC for each fishery, and therefore change as the TACC increases or decreases in response to the assessed health of the fishery.

***Forests Amendment Act 1993***

The 1993 amendments to the Forests Act 1949 affected the management of natural forests. The Amendment does not apply to land controlled by the Department of Conservation, but applies to most other private and public natural forests. Its purpose is to promote the sustainable forestry management of indigenous forest land. The Act defines sustainable forestry management as "the management of an area of indigenous forest land in a way that maintains the ability of the forest growing on that land to continue to provide a full range of products and amenities in perpetuity while retaining the forest's natural values". It requires areas of natural forest available for timber production to be managed under sustainable management plans defining, among other things, rates of harvest calculated on the forest's capacity for regeneration. It also provided for unsustainable logging in natural forests to be phased out by July 1996.

***Wildlife Act 1953***

This is the main law protecting wildlife on land and in New Zealand's territorial waters. It provides that wildlife sanctuaries, management reserves and refuges can be established for the protection of wildlife and their habitats. Species are classed under schedules to the Act according to their need for protection.

***Ozone Layer Protection Amendment Act 1996***

The 1990 Ozone Layer Protection Act was amended in June 1996 to bring New Zealand's ozone laws up to date with changes to the Montreal Protocol. Instead of specifying particular controls, the new Act enables controls to be imposed through regulations. This means that it is now easier to meet changing obligations under the Protocol. The new Act also sets up a system for accreditation of workers dealing with ozone-depleting substances. This will require these workers to have sufficient technical knowledge to comply with their obligations under the new Act.

## SCIENCE REFORMS

As part of the reform of central government agencies, science institutions were restructured to separate policy and ownership, funding, and operational functions. The Crown Institutes Act 1992 abolished the Department of Scientific and Industrial Research, the technology division of the Ministry of Agriculture and Fisheries, the Meteorological Service, the Forest Research Institute and the Department of Health's communicable diseases centre, and replaced them with ten Crown Research Institutes.

These institutes bid for funding from a variety of sources, but primarily from the Foundation for Research, Science and Technology's Public Good Science Fund. Today (following the closure of the Institute for Social Research and Development in 1994) there are nine crown research institutes administered under the Act (see Box 4.3). The Ministry of Research, Science and Technology was created in 1989 to advise the government on the overall policy framework, priorities and funding for research, science and technology, and to provide contract management services to the Minister for the implementation of funding.

The Ministry works closely with the Foundation for Research, Science and Technology, which is a statutory body responsible for allocating government funds to specific science activities. It administers the Public Good Science Fund—a contestable pool of funds for research in science and technology. The Foundation was also responsible for establishing the Marsden Fund. This Fund is administered by the Royal Society of New Zealand, and supports ingenuity and excellence in scientific research.

**Box 4. 3**

### *Crown Research Institutes*

The crown research institutes were established under the 1992 Crown Research Institutes Act 1992. Establishment of the Crown Research Institutes was guided by principles underlying other economic and institutional reforms of the 1980s. By subjecting science and research to market controls, the government looked to achieve three principal objectives: accountability, enhanced economic growth, and improved decision-making. The institutes are registered as companies, have boards of directors appointed by the government, and manage their own resources. Currently there are nine Crown Research Institutes (Statistics New Zealand 1996):

**NZ Forest Research Institute Ltd**: research on profitable and environmentally sound forest and wood products and production processes;

**AgResearch (New Zealand Pastoral Agriculture Research Institute Ltd)**: research on innovative solutions and opportunities for the food, fibre and biotechnology-related industries based on pastoral agriculture;

**Horticulture and Food Research Institute of New Zealand Ltd**: research to help New Zealand's horticulture and food organisations develop and enhance their competitive advantage within New Zealand and overseas;

**New Zealand Institute for Crop and Food Research Ltd:** research on the production and processing of crops and foods for local and overseas processing and manufacturing companies, farmers and growers;

**Landcare Research New Zealand Ltd**: environmental research on management of land resources for conservation and primary production, to benefit land users, resource managers and policy makers;

**Institute of Geological and Nuclear Sciences Ltd**: geo-science and nuclear science expertise to government and industrial organisations involved in geothermal, oil and gas exploration and development, and environmental studies throughout the Asia-Pacific region;

**Industrial Research Ltd**: scientific and technological research and development in the processing, manufacturing and energy industries, in partnership with the government;

**National Institute of Water and Atmospheric Research Ltd**: research for the sustainable management of New Zealand's atmospheric, marine and freshwater systems and associated resources; environmental consultancy work on a global scale;

**Institute of Environmental Science and Research Ltd:** science-related research, analytical and consulting services in public health, environmental health and forensics within New Zealand and the Asia-Pacific region.

A tenth Crown Research Institute, responsible for social research, was also set up in 1992, but was subsequently disbanded. The Crown Research Institutes obtain their money from contract research and by bidding for project grants from various funds, the largest of which is the Government's Public Good Science Fund. The Public Good Science Fund supports research on topics that the Government, acting on advice from the Ministry of Research Science and Technology, considers as high priorities. Bids for Public Good Science Fund support are evaluated by the Foundation for Research Science and Technology.

This system means that the institutes are required to do significant amounts of work outlining their proposals for funding. They must focus their projects on the priorities identified by the Government. As suppliers of services, they must also manage their projects according to their clients' needs. One criticism of the scheme is that it results in research constricted in the first place to the Government's priorities, and in the second place to other clients' priorities. This means that research is often directed to scientific 'outputs' that are driven by short-term rather than long-term goals, often focused on economic production. Scientists are also concerned by the lack of any provision for more 'pure' science on longer-term projects which are not driven by client interests, but rather by wider social and economic interests.

The advantages of the system, however, are that it provides for closer scrutiny of projects being funded by the government. The institutes have more clearly delineated functions, and work more closely with industry. In the area of environmental management, this means that research responds to priorities identified by those implementing policies developed through public consultation processes, and in response to regional environmental issues. This leads to an integrated approach in the development of efficient and effective environmental solutions.

In addition to the Crown Research Institutes, the Ministry of Foreign Affairs and Trade administers the New Zealand Antarctic Institute, a separate crown entity based in Christchurch. The Institute was set up to address a perceived lack of coordination in Antarctic activities, and to promote research in the area. It manages New Zealand's operational and research interests in Antarctica.

## TOWARDS SUSTAINABILITY: ENVIRONMENT 2010 AND THE GREEN PACKAGE

As can be seen from the above, there is a multitude of activities underway to address many environmental issues. Although this is to be encouraged, there is a need to co-ordinate efforts and direct activities for maximum effect, and to ensure effort is being applied to the issues of most concern. The ***Environment 2010 Strategy*** (*E2010*) is the first comprehensive statement of environmental priorities and strategies ever developed by a New Zealand government. The Strategy was released as a discussion document in October 1994, and, after many rounds of consultation, was published in September 1995 (Ministry for the Environment, 1995a). It is an overarching umbrella for resource management that does not change responsibilities, but will help focus priority effort. It aims to guide the development of environmental policies and priorities of Government, local authorities, resource users and community groups up to the year 2010. The *E2010* **vision** is of: *a clean, healthy and unique environment, sustaining nature and people's needs and aspirations*. The goals and action agenda focus on eleven **priority issues***:*

- **managing our land resources**—maintaining and enhancing our soils, so that they can support a variety of land-use options;
- **managing our water resources**—managing the quality and quantity of all types of water to meet the needs of people and ecological systems;
- **maintaining clear, clean, breatheable air**—maintaining clean air in parts of New Zealand where it is already clean, and improving its quality elsewhere;
- **protecting indigenous habitats and biological diversity**—maintaining and enhancing New Zealand's remaining indigenous forests, and other indigenous ecosystems; and promoting the conservation and sustainable management of the diversity of plants and animals;
- **managing pests, weeds, and diseases**—to protect the diversity of plants and animals in ecosystems, to protect human health, and reduce risks to the economy;
- **sustainable fisheries**—for the benefit of the fisheries resources and all New Zealanders, including for commercial, recreational and customary use;
- **managing the environmental impacts of energy services**—to manage sustainably the environmental effects of producing and using energy services;
- **managing the environmental effects of transport services**—to provide for transport services while protecting the health of the environment and humans;
- **managing waste, contaminated sites and hazardous substances**—managing waste and hazardous substances, and cleaning up contaminated sites, to reduce risks to environmental and human health;
- **reducing the risk of climate change**—to help address levels of greenhouse gases in the atmosphere, and to meet New Zealand's international obligations under the Framework Convention on Climate Change;
- **restoring the ozone layer**—to help achieve its full recovery, and constrain peak levels of ozone destruction, by phasing out imports of ozone depleting substances and limiting emissions of imported substances.

*E2010* was developed to complement the Government's economic growth strategy which was released in June 1993 as *Path to 2010*. *Path to 2010* and its updates, *The Next Three Years* (June 1994) and *New Opportunities* (1996), identify the Government's two key strategic priorities as maintaining strong economic growth and building strong communities and a cohesive society. *E2010*'s vision is placed firmly within this wider strategic context. Its effective implementation is dependent on four key conditions: a competitive enterprise economy', effective laws and policies, information, and social participation.

*E2010*'s agenda for action requires the integration of environmental, economic, and social policy (to address all aspects of sustainability), making sure laws are effective for achieving sustainable management, developing codes of practice, guidelines and standards, promoting environmental education, and developing the means to monitor and assess decisions on resource use. It also aims to ensure that people have the opportunity to participate, individually and collectively, in making decisions that affect the environment.

Although *E2010* provides an initial strategic framework for addressing sustainability issues, it does not presume to set priorities among the eleven areas of environmental action described above. **Evaluation and monitoring** of the strategy are necessary precursors to identifying future priorities for action. Monitoring is important to ensure that *E2010* goals for environmental improvement are being met, to judge the effectiveness of actions chosen in response to those goals, and to provide for consistency in reaching those goals.

The Ministry for the Environment's *National Environmental Indicators Programme* plays a significant role in this respect. The programme will identify and develop environmental indicators which will be used to assess the 'health' of the environment in the same way as blood pressure or pulse rate can be indicators of human health. This first State of the Environment Report also plays an important role in the monitoring process. It formally reports on characteristics and trends in the New Zealand environment, collating information collected throughout New Zealand. The Minister for the Environment intends to revise the Report every four years, so that it will help highlight trends for use in developing and refining environmental policies beyond 2010.

In addition to measures at the domestic level, international organisations monitor New Zealand's environmental performance. New Zealand submits reports to the United Nations Commission on Sustainable Development on measures that implement Agenda 21 (see Box 4.3)—many of which are identified in *E2010*. It also provides information and support for the Organisation for Economic Cooperation and Development's regular reviews of the country's environmental performance—the latest of which was released by the Minister for the Environment in November 1996. Monitoring by international bodies helps place *E2010* goals and actions in an international environmental context.Their feedback helps the Government review the Strategy and adjust priorities.

Local government has the opportunity to build *E2010* into their annual planning processes, and into their plans and policies on the environment. Chief executives of central government departments have been asked to take into account relevant goals of *E2010* in their annual planning. In addition, the annual Government budget cycle provides an opportunity to consider environmental strategy in the broader context of the Government's overall strategy and priorities. One of the Strategy's architects, Environment Minister Simon Upton, has stressed that *E2010* can be put into operation only as central government, local government, Maori, industry, non-government organisations, communities and individuals translate the vision, principles, and goals into specific policies and action plans.

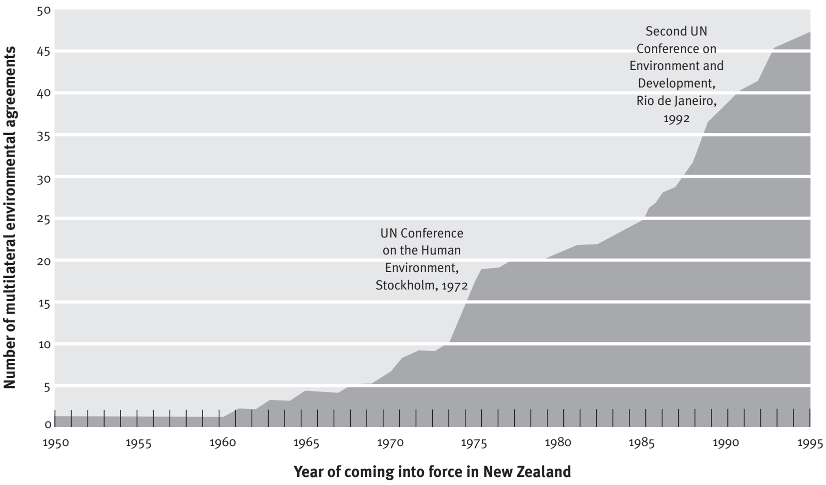
While the *Environment 2010 Strategy* gives the longer term direction and context for environmental policies, the particular focus at any time will reflect short and medium term priorities that are identified as critical steps in achieving the overall agenda. The ***Green Package*** announced in the 1996 Budget represented the first attempt at Government level to prioritise actions the Government needed to take in the medium term to implement *E2010* goals. It provided $110m additional funding over three years for addressing aspects of the eleven priority issues in *E2010*. From the many competing interests for funding under the Package, Ministers chose those that will have the most wide-reaching effects on different sectors, and that address the most pressing problems most efficiently. The Package focuses on four broad strands:

- better environmental information;
- more sustainable resource use—especially to implement the Government's Sustainable Land Management Strategy, and to ensure sustainable management of fisheries resources;
- less pollution;
- reducing the risks to plants and animals posed by pests and diseases.

In early March 1997, the Coalition Government committed itself to fund a 'Green Package 1997' under the 1997 Budget. This will allow the Coalition Government to put in place further measures to achieve key

**Figure 4.4**

**New Zealand's increasing international commitments on the environment**




priorities for environmental protection identified in its Coalition Agreement of December 1996. The Green Package money helps to ensure that *E2010*'s vision can facilitate ongoing, effective and informed environmental decision making.

## NEW ZEALAND'S INTERNATIONAL OBLIGATIONS

Obligations under international law are mainly aimed at preserving nations' rights over their own territory. However, a new ethic of environmental responsibility is emerging as awareness grows that some environmental problems cross national boundaries, and that some forms of international trade have environmental implications.

The main method available under international law for combined state action on is the multi-lateral environmental agreement, or MEA (See Guruswamy *et al.*, 1994). MEAs may take the form of 'soft-law', which sets out the environmental principles that parties will respect when considering actions affecting a particular issue, or 'hard-law', which specifies particular actions that must be taken to achieve a given environmental objective. In the past two decades, New Zealand has entered many multi-lateral environmental agreements (see Figure 4.4).

A number of important agreements were entered into at the 1992 United Nations Conference on Environment and Development (UNCED, or 'The Earth Summit'), which was held in Rio de Janeiro, Brazil (see Box 4.4). The 'Earth Summit' produced five key documents on sustainable development issues, all of which New Zealand has endorsed. Of these, two are 'hard law' – the Convention on Biological Diversity and the Framework Convention on Climate Change; and three are 'soft law' – the Rio Declaration on Environment and Development, Agenda 21, and the Forest Principles.

**Box 4.4**

### *The 'Earth Summit' and Agenda 21*

The United Nations Conference on Environment and Development (UNCED, also known as the **'Earth Summit'**) was held in Rio de Janeiro, Brazil in 1992. The Summit brought together representatives of 180 countries to discuss the many environmental and developmental problems facing the world. Discussions were guided by the principle of **sustainable development**, defined as: **development that meets the needs of the present without compromising the ability of future generations to meet their needs.** The aim of sustainable development is nothing less than to ensure the well-being of all people and of nature. It is a broad concept that encompasses integration of economic objectives, such as efficiency and prosperity; social objectives, such as equity and social justice; and environmental objectives, such as conservation, protection, and sustainable management of the environment. The enormous challenge in meeting this objective is the cold, hard fact that most modern methods of improving human well-being are destructive of nature.

The 'Earth Summit' produced five key documents on sustainable development issues: two legally binding conventions—the Biodiversity Convention and the Framework Convention on Climate Change; and three non-binding, but morally suasive, agreements—the Forest Principles, the Rio Declaration, and Agenda 21 (Ministry for the Environment, 1993). The Forest Principles address the management, conservation and sustainable development of all types of forests. The **Rio Declaration on Environment and Development** identifies 27 guiding principles on sustainable development, including:

- intergenerational equity—that there should be equity between the rights and needs of the current generation and generations to come;
- the precautionary approach—that lack of full scientific certainty should not be a reason for delaying action to prevent damage to the environment;
- polluter pays—that polluters should bear the cost of pollution;
- fairly sharing responsibilities—that all nations share responsibility for protecting the global environment, but countries that pollute more should do more for environmental protection than countries that pollute less.

**Agenda 21** is a 40-chapter plan for use by governments, local authorities and individuals to implement the principle of sustainable development. Some of its main themes include:

- reforming policies—for bringing together environmental and economic issues. It calls for environmental considerations to be built into policy-making from the start rather than being added as an afterthought;
- controlling wasteful consumption and production—Agenda 21 pinpoints the wasteful consumption and production associated with industrialisation and wealth acquisition as the most serious current cause of global degradation of the environment;
- improving technologies—promoting greater use of environmentally sound technologies that use resources more efficiently and generate minimal levels of waste;
- integrating trade and environment—to make environment and trade mutually supportive. This recognises that, while unjustifiable environmental controls can impede free trade, trade based on unsustainable production or unsustainable resource use can harm the environment.

Governments can implement aspects of the Agenda in many different ways—through legislation, through consultation processes they use to develop policy, by ratifying multilateral agreements, by designing policies which influence the effects of other countries' policies, and so on. The economic, social and environmental elements of sustainable development are reflected in Government strategy documents such as *Path to 2010* and the *Environment 2010 Strategy*. 'Sustainable management' of the environment is one strand of sustainable development and the foundation for most of New Zealand's environmental legislation (including the Resource Management Act, the Fisheries Act, the Forests Amendment Act, and the Biosecurity Act).

The extent to which Agenda 21 is being turned into practical actions varies from nation to nation and community to community. The United Nations Commission on Sustainable Development (CSD) meets annually to consider progress made by governments. Non-government organisations play an important role in these evaluations, contributing to the debate and helping to monitor the activities of countries and multilateral agencies in implementing sustainable development. In New Zealand, the UNCED Implementation Officials Group oversees implementation of Agenda 21. This Group comprises government representatives from agencies with portfolios of high relevance to Agenda 21 issues. It offers advice for local authorities to implement 'local Agenda 21s', as a framework for both their annual, and longer-term strategic plans.

In 1994, the Local Government Association and Ministry for the Environment published a guide for local authorities on implementing Agenda 21 entitled *Taking up the Challenge of Agenda 21* (Ministry for the Environment, 1994a). This offers ideas to help local authorities integrate planning processes for wideranging community and environmental interests such as business development and employment; unique qualities and resources; managing ecosystems, waste, stormwater and transport systems; housing; recreational pursuits; tourism; health services, etc. The Guide provides case studies of local Agenda 21s, and helps identify a number of useful ingredients for new agendas.

Several local authorities have already designed local Agenda 21s; others implement Agenda 21 principles on a less formal basis. Many of the functions and activities that local authorities already carry out (for instance, under legislation such as the Resource Management Act and Local Government Act) contribute to achieving the objectives of Agenda 21. However, authorities can use Agenda 21 as both a checklist and a catalyst for implementing actions towards sustainable development. Whether designed by international agencies, the Government, or local authorities, the most important ingredient of any plan to implement Agenda 21 and its wider principle of sustainable development is commitment.

One of the conventions agreed at the 1992 'Earth Summit', the **Framework Convention on Climate Change (FCCC),** develops a global response to managing climate change. Its primary objective is "to achieve stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".

FCCC commitments made by New Zealand along with other developed countries (referred to as Annex I Parties) include:

- adopt national policies to mitigate climate change through limiting anthropogenic (human-induced) emissions of greenhouse gases and protecting and enhancing our greenhouse gas sinks and reservoirs;
- report detailed information on greenhouse gas inventories, national actions and projected human-induced greenhouse gas emissions and removal by sinks;
- take climate change considerations into account, to the extent that it is feasible, in relevant social, economic and environmental policies and actions;
- promote, and cooperate in, relevant scientific and technological research and exchange information in such areas (including technology transfer to developing countries);
- provide new and additional financial resources to meet the agreed full costs incurred by developing countries in complying with their obligations under the FCCC;
- promote and cooperate in education, training and public awareness related to climate change and encourage the widest participation in this process.

The **Convention on Biological Diversity (CBD)** is another product of the Rio Conference (ratified by New Zealand on 29 December 1993). Biological diversity is the variety of all life-forms, the genes they contain, and the ecosystems in which they exist (see Chapter 9). The CBD aims to conserve biological diversity for its intrinsic value, for our sustainable use of it and for the fair and equitable sharing of the benefits from the use of genetic resources. In response to its obligations under the CBD, New Zealand is developing a National Strategy on Biological Diversity, and participates in the work of the meetings of the parties to the Convention. We also contribute to the work of the Subsidiary Body on Scientific, Technical and Technological Advice—an advisory body to the Parties, and participate in the negotiation of the Bio-safety Protocol to the CBD.

New Zealand is also committed to biodiversity and species conservation under several other MEAs. These include the **International Convention on Trade in Endangered Species (CITES)** and the **Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention)**.

CITES is an attempt to reconcile competing international trade and species conservation issues. It is an international framework for regulating and restricting trade in certain wild animals and plants. Trade obligations for any particular species depend on evaluations of that species' ecological significance and its effect on other species, as well as the levels of exploitation and the effects of harvesting techniques. These obligations range from total trade bans to 'quota' restrictions and other measures (such as registration requirements, tagging systems, microchip implants in live animals, and so on).

New Zealand's obligations under CITES are implemented through the Trade in Endangered Species Act 1989. This Act prohibits trade in specimens violating the Convention, and imposes penalties for such violations.

The Ramsar Convention was initiated by the International Union for the Conservation of Nature and Natural Resources (IUCN) in 1971 to stem the loss of wetlands worldwide. It promotes the conservation of wetlands, and their use, so that these areas continue to operate as functioning ecosystems.

New Zealand has five sites listed as wetlands of importance under the Convention:

- Firth of Thames;
- Whangamarino Wetland;
- Kopuatai Peat Dome;
- Farewell Spit; and
- Waituna Wetlands Scenic Reserve.

New Zealand is also a party to the **International Convention for the Regulation of Whaling** and takes a strong conservationist stance at the International Whaling Commission (IWC) which meets regularly to assess the status of whale stocks and to regulate whale hunting. A worldwide ban on commercial whaling (but not customary and scientific whaling) was introduced in 1986, and a southern hemisphere whale sanctuary was declared in 1995.

New Zealand played a key role in negotiating the **Convention for the Prohibition of Fishing with Long Drift Nets in the South Pacific** in 1989. The Pacific's fisheries resources (and in particular, its limited southern albacore resource) had been placed under severe strain by extensive (and unsustainable) fishing by Korean and Japanese fishing industries in the region, often with little or no regard for the region's indigenous peoples. This convention banned the use of driftnets over 2.5 metres long in the South Pacific, and paved the way for a global moratorium on drift-net fishing on the high seas to be agreed by the United Nations in 1991.

**Table 4.2**

**New Zealand's Multilateral Environmental Agreements (November 1996)**

| | year treaty entered into force | date of NZ's signature (S) ratification(R) or accession (A) | date NZ's S/R/A came into effect[1] | date treaty came into effect in NZ[2] |
|---|---|---|---|---|
| **Antarctica** | | | | |
| *The Antarctic Treaty 1959* | **1961** | R 1.11.60 | 1.11.60 | 23.6.61 |
| *Convention on the Conservation of Antarctic Marine Living Resources 1980 [CCAMLR]* | **1982** | R 8.3.82 | 8.3.82 | 7.4.82 |
| **Atmosphere and Space** | | | | |
| *Vienna Convention for the Protection of the Ozone Layer 1985* | **1988** | R 2.6.87 | 2.6.87 | 22.9.88 |
| *Montreal Protocol on Substances that deplete the Ozone Layer 1987 [Montreal Protocol]* | **1989** | R 21.7.88 | 21.7.88 | 1.1.89 |
| *London Amendment to the Montreal Protocol on Substances that deplete the Ozone Layer 1990* | **1992** | R 1.10.90 | 1.10.90 | 10.8.92 |
| *Copenhagen Amendment to the Montreal Protocol 1992* | **1994** | R 4.6.93 | 4.6.93 | 14.6.94 |
| *United Nations Framework Convention on Climate Change [FCCC] 1992* | **1994** | R 16.9.93 | 16.9.93 | 21.3.94 |
| *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies 1967* | **1967** | R 3.5.68 | 31.5.68 | 31.5.68 |
| **Protection of the Marine Environment and Resources** | | | | |
| *United Nations Convention on the Law of the Sea [UNCLOS] 1982* | **1994** | R 19.7.96 | 18.8.96 | 18.8.96 |
| *International Convention relating to Intervention on the High Seas in cases of Oil Pollution Casualties 1969* | **1975** | A 26.3.75 | 26.3.75 | 6.5.75 |
| *International Convention on Civil Liability for Oil Pollution Damage (as amended) 1969* | **1975** | A 27.4.76 | 26.7.76 | 26.7.76 |
| *International Convention for the Prevention of Pollution of the Sea by Oil 1954 [OILPOL]* | **1958** | R 1.6.71 | 1.9.71 | 1.9.71 |
| *Amendments to the International Convention for the Prevention of Pollution of the Sea by Oil 1962* | **1967** | R 1.6.71 | 1.9.71 | 1.9.71 |
| *Amendments to the International Convention for the Prevention of Pollution of the Sea by Oil 1969* | **1978** | R 27.4.76 | 27.4.76 | 20.1.78 |
| *Convention on the Continental Shelf 1958* | **1964** | R 18.1.65 | 17.2.65 | 17.2.65 |
| *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 [London Convention]* | **1975** | R 30.4.75 | 30.4.75 | 30.8.75 |
| **Fishing** | | | | |
| *Convention for the Prohibition of Fishing with Long Driftnets in the South Pacific 1989 [Wellington Convention]* | **1991** | R 17.5.91 | 17.5.91 | 17.5.91 |
| *Convention for the Conservation of Southern Bluefin Tuna 1993* | **1994** | R 9.5.94 | 9.5.94 | 20.5.94 |
| **Whaling** | | | | |
| *International Convention for the Regulation of Whaling 1946* | **1948** | R 2.8.49[3] | 15.6.76 | 15.6.76 |
| *Protocol to the International Convention for the Regulation of Whaling 1956* | **1959** | R 21.6.57[4] | 15.6.76 | 15.6.76 |
| **Hazardous Substances** | | | | |
| *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal 1989* | **1992** | R 20.12.94 | 20.3.95 | 20.3.95 |
| **Conservation of Natural Resources** | | | | |
| *Statutes of the International Union for the Conservation of Nature and Natural Resources 1948 (IUCN Convention)* | **1948** | R 6.5.74 | 6.5.74 | 6.5.74 |
| *International Plant Protection Convention 1951* | **1952** | R16.9.52 | 16.9.52 | 16.9.52 |
| *Amendments to the International Plant Protection Convention 1979* | **1991** | R 10.4.90 | 10.4.90 | 4.4.91 |
| *Plant Protection Agreement for the South East Asia and Pacific Region 1956* | **1956** | A 17.12.75 | 17.12.75 | 17.12.75 |
| *Amendment to Article I(A) of the Plant Protection Agreement for the South East Asia and Pacific Region 1967* | **1969** | A 17.12.75 | 17.12.75 | 17.12.75 |
| *Amendments to the Plant Protection Agreement for the South East Asia and Pacific Region 1979* | **1983** | R 10.4.90 | 10.4.90 | 10.4.90 |
| *Amendments to the Plant Protection Agreement for the South East Asia and Pacific Region 1983* | **1990** | R 10.4.90 | 10.4.90 | 23.5.90 |
| *Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES] 1973* | **1975** | A 10.5.89 | 8.8.89 | 8.8.89 |
| *Amendment to the Convention on International Trade in Endangered Species of Wild Fauna and Fauna (Art XI) 1979* | **1987** | A 10.5.89 | 8.8.89 | 8.8.89 |
| *UNESCO Convention concerning the Protection of the World Cultural and Natural Heritage 1972* | **1975** | R 22.11.84 | 22.2.85 | 22.2.85 |
| *Convention on Wetlands of International Importance especially as Waterfowl Habitat 1971 [Ramsar Convention]* | **1975** | S 13.8.76 | 13.12.76 | 13.12.76 |
| *Protocol to the Convention on Wetlands of International Importance... 1982* | **1986** | S 9.2.87 | 9.2.87 | 9.2.87 |
| *Amendments to Art.s 6 & 7 of the Convention on Wetlands of International Importance especially... 1987* | **1994** | R 7.7.93 | 7.7.93 | 1.5.94 |
| *Convention for the Protection of the Natural Resources and Environment of the South Pacific Region 1986 [SPREP]* | **1990** | R 3.5.90 | 3.5.90 | 22.8.90 |
| *Protocol [to SPREP*] for the Prevention of Pollution of the South Pacific Region by Dumping 1986* | **1990** | R 3.5.90 | 3.5.90 | 22.8.90 |

| | year treaty entered into force | date of NZ's signature (S) ratification(R) or accession (A) | date NZ's S/R/A came into effect[1] | date treaty came into effect in NZ[2] |
|---|---|---|---|---|
| *Protocol [to SPREP*] concerning Cooperation in Combating Pollution Emergencies in the South Pacific Region 1986* | ***1990*** | *R 3.5.90* | *3.5.90* | *22.8.90* |
| *Convention on Biological Diversity 1992 [CBD]* | ***1993*** | *R 16.9.93* | *16.9.93* | *29.12.93* |
| *International Convention for the Protection of New Varieties of Plants (as amended) 1978* | ***1978*** | *R 3.11.80* | *8.11.81* | *8.11.81* |
| *International Tropical Timber Agreement 1983* | ***1985*** | *A 5.8.92* | *5.8.92* | *5.8.92* |
| **Arms Control and Nuclear Pollution** | | | | |
| *Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water 1963* | ***1963*** | *R 10.10.63* | *10.10.63* | *10.10.63* |
| *Treaty on the Non-Proliferation of Nuclear Weapons 1968* | ***1970*** | *R 10.9.69* | *10.9.69* | *5.3.70* |
| *Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction 1972* | ***1975*** | *R 13.12.72* | *13.12.72* | *26.3.75* |
| *Convention on Early Notification of a Nuclear Accident 1986* | ***1986*** | *A 11.3.87* | *11.4.87* | *11.4.87* |
| *Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency 1986* | ***1987*** | *A 11.3.87* | *11.4.87* | *11.4.87* |
| *South Pacific Nuclear Free Zone Treaty and Protocols 1985 [SPNFZ]* | ***1986*** | *R 13.11.86* | *13.11.86* | *11.12.86* |
| *Convention on the Prohibition of Military or any other Hostile use of Environmental Modification Techniques 1976* | ***1978*** | *A 7.9.84* | *7.9.84* | *7.9.84* |
| *Treaty on the Prohibition of the Emplacement of Nuclear Weapons and other Weapons of Mass Destruction on the Sea Bed and the Ocean Floor and in the Subsoil Thereof 1971* | ***1972*** | *R 24.2.72* | *24.2.72* | *18.5.72* |

*Source: Updated from Gurswamy et al, 1994 and Ministry of Foreign Affairs and Trade, 1994.*

1 *This was usually the date of ratification. In many cases, the Treaty did not come into effect until a defined period after the ratification or signing. In some cases, signing had the effect of ratification.*

2 *This was the later of either the date the Treaty came into force, or the date it came into effect in New Zealand.*

* *the Convention for the Protection of the Natural Resources and Environment of the South Pacific Region – see* ***Conservation of Natural Resources*** *heading.*

3 *ratified 2.8.49, withdrew 3.10.68, then rejoined 15.6.76*

4 *ratified 21.6.57, withdrew 30.6.69, then rejoined 15.6.76*

New Zealand is also a party to the **Convention for the Conservation of Southern Bluefin Tuna** 1994, and has contributed to negotiations for the 1995 United Nations Convention on Straddling Fish Stocks and Highly Migratory Fish Stocks.

New Zealand's environmental interests in Antarctica have a long history. The **Antarctic Treaty** 1959 (ratified by New Zealand in 1961) was, to a large extent, borne of a mutual desire to preserve Antarctica for the benefit of countries with competing interests and claims over Antarctica's natural resources. The Treaty's only environmental provisions are those that prohibit nuclear explosions and the disposal of nuclear waste in Antarctic waters, and require consultative meeting recommendations for measures directed at (among other things) the preservation and conservation of living resources in Antarctica. The reality of environmental protection has not always corresponded with the claim of the Antarctic Treaty partners (New Zealand among them) that the protection of Antarctica's environment is their foremost concern.

The first real attempt to introduce environmental protection resulted in the adoption of the 1964 **Agreed Measures for the Conservation of Antarctic Fauna and Flora** (although these did not take effect until November 1982 as they were not ratified by some adopting states, including New Zealand). These measures denote the Antarctic as a 'Special Conservation Area'.

In 1982, parties adopted the **Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR)**. This Treaty (ratified by New Zealand in March 1982) is a model for other treaty regimes aimed at protecting marine and other living resources.

Parties to the Antarctic Treaty have been especially concerned to secure agreements over the regulation of mineral activities on the continent. Negotiations on the proposed **Convention for the Regulation of Antarctic Mineral Resource Activities (CRAMRA)** began in 1982. After increasing pressure from environmentalists objecting to any form of exploitation of Antarctica's minerals, the agreement was abandoned in 1988.

Following this collapse, a Special Consultative Meeting was called to discuss measures for preservation of Antarctica's resources in the interests of protecting the Antarctic Treaty system as a whole. The resulting agreement is the **Protocol to the Antarctic Treaty on Environmental Protection** 1991 (the Madrid Protocol, signed and ratified by New Zealand but not yet in force). This Protocol is an historic agreement establishing a comprehensive framework for protecting the Antarctic environment and its ecosystems. It currently contains four annexes dealing with:

- environmental impact assessment;
- conservation of flora and fauna;
- waste disposal; and
- marine pollution.

New Zealand's Antarctic (Environmental Protection) Act came into effect in February 1995, and means that provisions in the Protocol can now be given effect in New Zealand law.

New Zealand is a world-leader in implementing measures for the protection of the ozone layer. It is party to both the **Vienna Convention** and the **Montreal Protocol**. The Convention establishes principles for regulating substances that harm the ozone layer. The Protocol (as amended in London in 1990, and Copenhagen in 1992) sets targets for reducing the production and consumption of ozone-depleting substances. New Zealand's obligations under the Montreal Protocol are implemented through the Ozone Layer Protection Act 1996 (passed in June 1996 to replace the original 1990 Act and all subsequent amendments to it). This Act contains more stringent measures than are required under the Protocol in respect of timetables and quantities for phase-out of ozone-depleting substances. It also contains a system for accreditation of workers dealing with ozone-depleting substances.

New Zealand's coastal and marine resources are at risk from a variety of factors, including land-based sources of marine pollution, ocean dumping and oil spills. A number of international conventions relate to the regulation of activities with potential for these environmental effects. These include the **International Convention for the Prevention of Pollution from Ships (MARPOL**—not yet ratified by New Zealand) and the **London Dumping Convention** (which New Zealand ratified in April 1975).

MARPOL aims to eliminate pollution of the sea by oil and other toxic substances which might be discharged operationally or released accidentally as a result of collisions or stranding of ships. The London Dumping Convention regulates the dumping at sea of wastes and other matter.

Regulations recently prepared under the Resource Management Act to help control marine pollution from ships will allow New Zealand to:

- better control polluting emissions from foreign ships;
- join MARPOL's international system of controlling pollution from ships;
- exercise more consistent and better integrated coastal management; and
- begin preparation of a guideline document for shipping and boating operators on implications of the new regulations.

The **United Nations Convention on the Law of the Sea (UNCLOS)** is the most recent addition to the list of international environmental conventions to which New Zealand is a party. New Zealand ratified UNCLOS in July 1996 after the passage of enabling legislation. UNCLOS codifies customary international law concerning the sea and sets out states' varying obligations and rights in respect of the sea. It declares that the sea-bed, ocean floor and subsoil are beyond the limits of national jurisdiction, but that their exploitation shall be carried out for the benefit of mankind as a whole. The Convention outlines states' obligations and responsibilities in relation to different areas such as: territorial sea and the contiguous zone; straits used for international navigation; archipelagic states; the exclusive economic zone; the continental shelf; the high seas; islands; enclosed or semi-enclosed seas; rights of land-locked states; and the area (the seabed, ocean floor and subsoil beyond the limits of national jurisdiction).

A significant aspect of UNCLOS is its incorporation of the principle of 'common heritage of mankind'. This is similar to the 'intergenerational equity' and 'global responsibility' principles contained in the Rio Declaration.

New Zealand ratified the **Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal** 1989 in March 1995. This Convention aims to both reduce the amount of waste being produced by signatories, and regulate the international traffic in hazardous wastes (especially to developing countries). The Convention emphasises the principle of 'generator responsibility' for disposal of wastes, and requires parties to minimise the environmental effects of the movement and disposal of hazardous waste. Ratification of the Convention required consideration of its implications under various aspects of New Zealand's domestic law, including the new Hazardous Substances and New Organisms Act 1996.

New Zealand has been a staunch campaigner against the testing of nuclear weapons and the disposal of nuclear wastes in this part of the world. The **South Pacific Nuclear Free Zone Treaty** (negotiated by members of the South Pacific Forum) is one result of this campaign. Its objective is to establish a nuclear free zone in the region and to keep the region free of environmental pollution by radioactive wastes. New Zealand is party to several other regional and international agreements concerning the use of radioactive materials and weapons.

***From principle to performance***

The preceding chapters have looked at the context for our environmental management and the arrangements for that management. As our core legislation, the Resource Management Act, recognises in its purpose, use of resources by the community to provide for their economic and social welfare is legitimate—we must ensure, however, that the way and the rate at which we use those resources does not cumulatively become unsustainable for the environment, on which all this activity depends.

We need to take the next step, and ask how New Zealand's arrangements for environmental management are performing. These arrangements are only valuable if they enhance our environment both at home and on the global scale.

So far the report card is blank. Environmental information is a prerequisite for identifying areas where we 'must try harder', and areas where we can afford to maintain (or even slow) our efforts. The next chapters take a look at some of our 'environmental realities'. Only by analysing the real state of our environment, and determining trends in its quality over time, can we enter into a meaningful dialogue for ways to improve our world.

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THE STATE OF

NEW ZEALAND'S

ENVIRONMENT

CHAPTER FIVE

# THE STATE OF OUR ATMOSPHERE

## CONTENTS

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **$^0$C** | Temperature in degrees Celsius |
| **$CCL_4$** | Carbon tetrachloride |
| **CFC** | Chlorofluorocarbon |
| **$CH_4$** | Methane |
| **CO** | Carbon monoxide |
| **$CO_2$** | Carbon dioxide |
| **DU** | Dobson Unit-used to describe the amount of ozone above a particular location |
| **EECA** | Energy Efficiency and Conservation Authority |
| **ENSO** | El Niño/Southern Oscillation (i.e. a recurrent weather pattern triggered by air pressure changes in the Pacific). |
| **FCCC** | The United Nations Framework Convention on Climate Change |
| **GCM** | General Circulation Model (i.e. a computer model of the world's climate) |
| **Gg** | Gigagrams (i.e. a billion grams or a million tonnes) |
| **GWP** | Global Warming Potential (i.e. a measure of the potency of each greenhouse gas) |
| **$H_2$** | Hydrogen |
| **HBFC** | Hydrobromofluorocarbon |
| **HCFC** | Hydrochlorofluorocarbon |
| **HFC** | Hydrofluorocarbon |
| **$H_2O$** | Water |
| **INC** | Intergovernmental Negotiating Committee of the Framework Convention on Climate Change |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IRL** | Industrial Research Limited |
| **MED** | Minimum erythemal dose (the minimum amount of radiation that causes reddening of the skin) |
| **mb** | Millibars (a measure of atmospheric pressure) |
| **nm** | nanometres - a wavelength measurement |
| **NIWA** | National Institute of Water and Atmospheric Research Ltd |
| **NMVOC** | Non-methane volatile organic compounds (i.e. carbon-based gases other than methane) |
| **NO** | Nitric oxide |
| **$NO^2$** | Nitrogen dioxide |
| **NOx** | Oxides of nitrogen (i.e. NO and NO2) |
| **$N_2O$** | Nitrous oxide |
| **$O_2$** | Molecular or common oxygen |
| **$O_3$** | Ozone |
| **ODP** | Ozone Depleting Potential |
| **OECD** | Organisation for Economic Cooperation and Development |
| **PFC** | Perfluorocarbon |
| **ppb** | parts per billion (i.e. the concentration of a substance in air or water) |
| **ppbv** | parts per billion by volume |
| **ppm** | parts per million |
| **ppt** | parts per trillion |
| **PFC** | Perfluorocarbon |
| **PSC** | Polar stratospheric cloud |
| **QBO** | Quasi-Biennial Oscillation (a global atmospheric circulation effect) |
| **QPS** | Quarantine and pre-shipment |
| **R-B** | Robertson-Berger Meter (an instrument for measuring ultraviolet radiation) |
| **SF6** | Sulphur hexafluoride |
| **SOI** | Southern Oscillation Index (i.e. a scale showing the presence and intensity of the ENSO) |
| **TOMS** | Total Ozone Mapping Spectrometer - a satellite instrument to measure ozone |
| **UNEP** | United Nations Environment Programme |
| **UV-A** | Ultraviolet- A radiation (320-400 nanometres) |
| **UV-B** | Ultraviolet-B radiation (290-320 nanometres) |
| **UV-C** | Ultraviolet-C radiation (200-290 nanometres) |
| **WMO** | World Meteorological Organisation |

**KEY POINTS**

- *Life on Earth depends on the protective properties of the ozone layer and the 'greenhouse' gases in the upper atmosphere (water vapour, carbon dioxide, methane, and nitrous oxide). The ozone layer filters harmful ultraviolet radiation while the greenhouse gases keep global temperatures within a liveable range. Recently, ozone levels have fallen while greenhouse gases have increased.*

- *Potential problems arising from ozone depletion include the increased risk of impaired growth and reproduction in some plants, including crop plants, and of eye and skin problems in some humans and other animals as a result of more intense ultraviolet-B radiation.*

- *Scientists working with the Intergovernmental Panel on Climate Change (IPCC) now believe that the release of greenhouse gases from human activities is causing global temperatures to rise and weather patterns to change. Potential problems arising from this are more frequent floods and droughts, land encroachment and coastal erosion from rising seas, more frequent invasions by tropical pests, weeds and infectious diseases, and the disappearance of some types of ecosystems. In New Zealand, patterns of agriculture may be changed and some fisheries may be affected.*

- *Ozone concentrations in the upper atmosphere have been significantly depleted over the past 20 years by manufactured gases that contain chlorine (such as chlorofluorocarbons, known as CFCs). The total concentration of chlorine in the atmosphere has grown by more than 600 percent from its natural level of around 0.6 parts per billion to an unprecedented 4.0 parts per billion.*

- *At mid latitudes, total ozone has declined by an average 4–5 percent over the past 20 years. Above the Antarctic, a 'hole' in the ozone layer has occurred every spring since the 1980s. By 1995, it had expanded to its maximum possible area but had not yet reached its lowest possible ozone concentrations. The hole (which does not directly affect New Zealand) is likely to keep reappearing until the middle of the next century, until atmospheric chlorine levels have been brought back down to about 2 parts per billion.*

- *Coinciding with the depletion of the ozone layer, the levels of solar ultraviolet (UV) radiation in New Zealand have been increasing. Monitoring is relatively recent, and only limited data are available, but it is estimated that a 5–7 percent decrease in ozone since the mid 1970s has been accompanied by a 6–9 percent increase in ultraviolet-B (UV-B) radiation.*

- *Greenhouse gases other than water vapour have increased worldwide in the past several hundred years, as a result of increased industrial and agricultural production, and motor vehicle use. Water vapour is also expected to increase as global temperatures rise, causing more evaporation.*

- *Carbon dioxide ($CO_2$) concentrations have increased by about 30 percent since pre-industrial times with Southern Hemisphere concentrations lagging slightly behind the Northern Hemisphere.*

- *On a per capita basis, New Zealand emissions of human-induced carbon dioxide are 25 percent lower than the OECD average, but about 50 percent higher than the global average. At present, about half of these emissions are absorbed by forest growth which acts as a 'carbon sink'. The area of commercial pine forests is increasing at present, but in the long-term the forests will not be able to maintain the 50 percent absorption ratio unless reductions are made in actual carbon dioxide emissions.*

- *Globally, atmospheric methane ($CH_4$) concentrations have more than doubled in the past 400 years. Methane is produced by biological processes (e.g. sheep and cattle digestion, rice growing, and the breakdown of waste) and fossil fuel production and use. The global rate of methane increase slowed during the 1980s and early 1990s, but has been rising again since 1993.*

- *New Zealand's per capita emissions of methane are almost six times the OECD average, and almost ten times the global average. Although cattle and deer numbers are increasing, the recent fall in sheep numbers caused a reduction in livestock methane emissions of 3.5 percent between 1990 and 1995.*

- *Nitrous oxide ($N_2O$) concentrations are increasing globally but the sources are dispersed and not well understood.*

- *The atmospheric changes of the past century have coincided with small changes in average global temperature and sea level. Surface temperatures have increased by between 0.3°C and 0.6°C since 1900, and by between 0.2°C and 0.3°C in the last 40 years. Global sea level has risen by between 10 and 25 cm over the past 100 years, and much of that rise may be related to the increase in global mean temperature.*

- *Scientists increasingly suspect that the two trends are linked, and have attempted to disentangle the climatic effects of human-induced atmospheric change from those of natural factors (e.g. the short-term effects of sunspot cycles and sulphate particles emitted by industry, volcanoes and marine algae, and the long-term effects of fluctuations in the Earth's axis and orbit).*

- *Although there are still scientific uncertainties, and although recent global warming still falls within the range of natural variability, the Intergovernmental Panel on Climate Change (IPCC) has concluded that 'the balance of evidence suggests that there is a discernible human influence on global climate'. The latest IPCC report predicts global warming in the range of 1°C–3.5°C over the next century and a sea level increase of about 50 centimetres.*

- *New Zealand's climate has warmed faster than the global average, gaining 1. 1°C since 1860, compared to the world's 0.7°C. Most of this warming has occurred in the last 50 years. Prior to 1940, there was little discernible trend. Our sea level has risen by 15 centimetres in the past century.*

- *Scientists are uncertain about the potential interaction of climate warming with the El Niño–Southern Oscillation (ENSO). This recurrent climatic pattern periodically makes New Zealand cooler, drier, and more prone to cyclones. It is triggered by changes in surface air pressure over the Pacific Ocean and alters ocean currents, rainfall, winds and temperatures around the world. Some scientists suspect that ENSO events may increase in frequency or duration as the climate warms.*

- *New Zealand's general response to human-induced pressures on the atmosphere has been to participate in international efforts to reduce damaging emissions and to contribute to international research on the problems (e.g. through regular monitoring of the atmosphere at Baring Head in Wellington, Lauder in Central Otago, and Scott Base in Antarctica).*

- *In particular, New Zealand has responded to the ozone threat by agreeing to the restrictions on ozone-depleting substances set down in the international convention known as the Montreal Protocol, and has set even more stringent domestic goals for phasing out the use of chlorofluorocarbons (CFCs) and several other harmful substances.*

- *CFC use is declining, both here and overseas. New Zealand's use per person in 1993 was half that of the OECD, but still twice the global average. Our national use of CFCs had always been below the internationally-agreed limits set by the Montreal Protocol, but in accordance with the Protocol, consumption (imports) ceased on 1 January 1996.*

- *Ozone is a naturally occurring greenhouse gas and has always been part of the natural greenhouse effect. What effect the restoration of ozone to pre-CFC levels will have on global warming is unclear. This is because of the uncertainties relating to future levels of greenhouse gas emissions from human activities; the fact that although the substances replacing CFCs are not ozone-depleters, many of them are powerful greenhouse gases, and because of the overall complexities of atmospheric physics.*

- *New Zealand has responded to the greenhouse threat by signing the Framework Convention on Climate Change (FCCC) and setting the domestic goals of reducing net carbon dioxide emissions to their 1990 levels by the year 2000 and stabilising them from then on.*

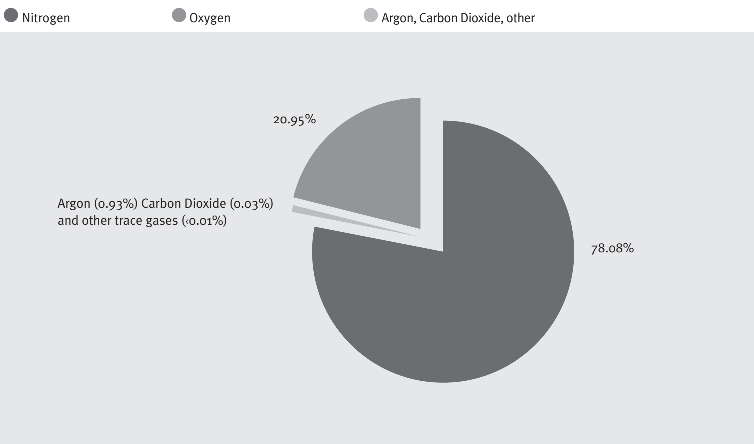
- *Since 1990 our net carbon dioxide emissions have actually risen, despite increases in forest planting. The main causes have been increasing fossil fuel use associated with economic growth, and changing forest growth rates associated with age structure. Current projections indicate that, in the absence of further policy measures, our net* $CO_2$ *emissions will be more than double 1990 levels by the year 2000.*

## INTRODUCTION

The atmosphere is a thin shroud of gas surrounding our planet. By day it shields us from the worst of the Sun's rays. By night it acts as a blanket, keeping temperatures on Earth relatively stable. As they swirl above us, the atmospheric gases create the world's weather patterns, and at ground level they make up the air we inhale ten to twenty times every minute. This chapter is about the atmosphere in general, but concentrates more on the non-breathable but highly-protective part which begins several hundred metres above us and extends far out to space. We discuss its nature, the pressures on it, its current state, and the responses New Zealand is making to those pressures. Chapter 6 focuses more narrowly on the ambient atmosphere, the air we breathe.

Within our solar system, Earth's atmosphere is unique and comparatively recent. Unlike our neighbouring planets, Venus and Mars, Earth has an atmosphere that includes water vapour ($H_2O$), and free oxygen ($O_2$ and $O_3$). Molecular oxygen ($O_2$) and ozone ($O_3$) are absent from the other planets, but make up one-fifth (21 percent) of Earth's atmosphere. Oxygen is a highly reactive gas. It readily couples up with other molecules to form new compounds, a process known as oxidation (see Chapter 6, Box 6.5). For free oxygen to occur on such a scale, something has to be decoupling (or, in chemical terminology, reducing) it from other compounds faster than it can oxidise them.

**Figure 5.1**
**The composition of dry air on Earth**[1]




[1] *Earth's air is never totally dry. Its water vapour content varies from 0.01% to around 3%.*

That something is life—specifically, photosynthesis, the process in which plants, algae and cyanobacteria use sunlight to break down carbon dioxide ($CO_2$) so that they can 'eat' the carbon while releasing the unwanted oxygen into the environment. Life is what makes Earth's atmosphere so dramatically different from its sibling planets. Whereas the atmospheres on Venus and Mars are composed of about 95 percent carbon dioxide ($CO_2$) and 3 percent nitrogen ($N_2$), on Earth nitrogen is the dominant gas, making up more than three-quarters (78 percent) of the atmosphere, and carbon dioxide is a mere trace gas comprising less than 1 percent. (see Figure 5.1).

In recent decades, scientists have discovered that the composition of the Earth's atmosphere, which has remained quite stable for the past 10,000 years or more, is being altered by human activities. Mass-produced chemicals containing chlorine and bromine are eating away at the ozone layer, and widespread fossil fuel use, rice growing, waste disposal, deforestation, and livestock belching are pumping increasing amounts of greenhouse gases, particularly carbon dioxide and methane ($CH_4$), into the atmosphere. At the same time, solar radiation has increased and global temperatures have risen slightly. Scientists suspect that these atmospheric and climatic trends are linked, and this has led to growing concern that humans are triggering worldwide climate change (Wratt *et al.*, 1991; Houghton *et al.*, 1996).

At present, scientists are intensively studying the links between atmosphere and climate to see how serious the risk might be. Much of their work is aimed at disentangling the effects of atmospheric change from the many other factors that influence climate. These other factors include:

- *Milankovitch cycles*—small but regular fluctuations in the Earth's orbit and rotational axis which have the potential to trigger ice ages every 100,000 years or so by reducing the amount of sunlight that reaches temperate zones;
- *Sunspot cycles*—regular variations of about 0.1 percent in the intensity of solar radiation which recur every 11 years and may influence climate by altering the amount of ozone; and

- *The El Niño–Southern Oscillation* (ENSO)—a climate pattern with global impacts that is triggered every 2–10 years by fluctuations in surface air pressure over the Pacific and Indian Oceans.

The scientists are also discovering things in the atmosphere other than gases which appear to influence climate. These are airborne particles or aerosols of solid matter, particularly sulphates, which arise from both human activities (e.g. the burning of coal, oil and diesel and the manufacture of fertilisers) and natural sources (e.g. volcanoes and sulphate emissions from marine algae). They form a light haze which has an anti-greenhouse effect by scattering solar radiation before it can reach the Earth's surface.

The most recent and comprehensive studies of the global atmosphere are those conducted by the Intergovernmental Panel on Climate Change (IPCC) in 1990, 1992, and 1995. The IPCC scientists compiled data on the known atmospheric changes caused by gas and particle emissions and made a detailed study of past climate records. This information was fed into a series of computer models of the Earth's climate. These 'general circulation models' (GCMs), as they are called, attempt to simulate the world's climate by combining data on atmospheric gases, aerosols, weather patterns and ocean currents.

Although individual GCMs vary in detail, and many have trouble simulating prehistoric climatic conditions on Earth, they are in broad agreement on recent climate patterns and likely future changes. Drawing on a number of different models, the IPCC scientists have concluded that, in the past century, humans have increased the level of greenhouse gases and ozone-destroying chemicals in the atmosphere to their highest levels in 10,000 years (Houghton *et al.*, 1996).

The scientists have estimated that, during the next century, the global average temperature is likely to rise by between 1°C and 3.5°C and the average sea level is likely to rise by about 50 centimetres. These changes are unlikely to occur uniformly and may result in greater weather variability, wind turbulence, and temperature extremes in some areas. Some parts of the Earth may even become a little cooler as a result of changed wind currents and evaporation and rainfall patterns. The IPCC acknowledges the scientific uncertainties in these predictions, and the need for further research to refine them (Houghton *et al.*, 1996).

An important finding of the IPCC studies is that the predicted climate changes, and the atmospheric changes driving them, are not limited to one particular part of the globe. Unlike nations, and even continents, the atmosphere has no borders. New Zealand's geographical isolation, therefore, affords no sanctuary. In fact, the rate of temperature increase has been greater in New Zealand than for the planet in general. Nor does our isolation protect other countries from the changes that we New Zealanders are causing to the atmosphere's trace gases (Bouma *et al.*, 1996).

Faced with this information, and expecting others to play their part in reducing emissions of possibly harmful gases into the atmosphere, New Zealand, as a party to the Montreal Protocol on Substances that Deplete the Ozone Layer, is committed, with other countries, to phasing out the production and use of ozone-depleting substances. New Zealand has stopped the importation of the main ozone-depleting chemicals, halons on 3 October 1990 and chlorofluorocarbons (CFCs) on 1 January 1996, and is in the process of phasing out less damaging CFC replacements. Industries using CFCs and other ozone-depleting chemicals have taken a positive approach to the use of new technology and chemicals, and New Zealand has kept well ahead of the phase-out deadlines.

New Zealand has also started to address the issues of greenhouse gas emissions, and the prospect of climate change. It has ratified the United Nations Framework Convention on Climate Change (FCCC), which aims to stabilise greenhouse gas levels before they trigger dangerous climatic effects. New Zealand has set itself the domestic objective of reducing net carbon dioxide emissions to 1990 levels by the year 2000, and maintaining them at that level from then on. Objectives for beyond the turn of the century are currently being negotiated. Net emissions are those emissions that remain in the atmosphere after the amount of $CO_2$ absorbed by forests has been taken into account. On current trends, there is no sign of this objective being achieved without further policy measures being taken.

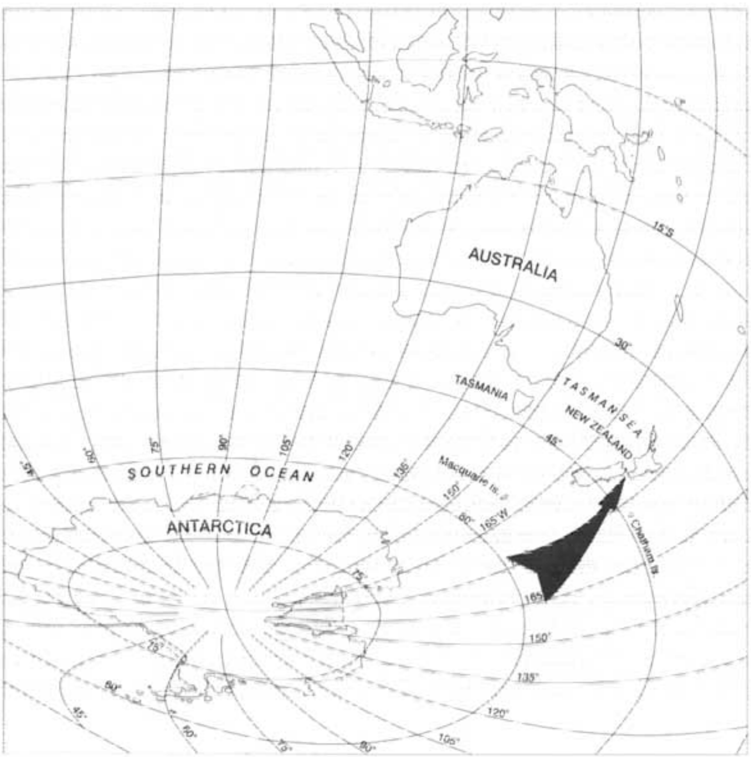
## THE STATE OF THE DATA

The atmosphere is a shared resource and some of our information on it comes from international sources, such as NASA's Total Ozone Mapping Spectrometer (TOMS) and other satellite monitoring programmes operated by many countries, especially the European Community, the USA, and Japan. However, much of our data are also homegrown.

Records of temperature, rainfall, air pressure, and wind speeds have been kept at some sites in New Zealand for around 150 years. However, the technology for the routine measuring of trace gases has been developed only in the past few decades, spurred on by the increasing recognition of the need for such data. The early work was produced largely through the foresight and persistence of atmospheric scientists such as Edith Farkas, who meticulously monitored ozone from the 1950s until her retirement in 1986.

Further back than 150 years, New Zealand is fortunate in having considerable geological evidence of past atmospheric conditions and climate. These include sediment layers, fossilised pollen showing past vegetation patterns, geological evidence of glacier movements, tree rings, and bubbles trapped in ice. These have enabled scientists to reconstruct the Ice Age climate with a high degree of confidence.

**Figure 5.2**
**Typical southerly air flow to the Baring Head Clean Air Sampling Station, Wellington**




### Data on atmospheric gas levels

Today, trace gases in the atmosphere can be detected with a range of instruments so sophisticated that they make measurements in terms of parts per billion (ppb). Precise information on the concentrations of each gas can be gathered almost instantly. The National Institute of Water and Atmospheric Research (NIWA) does most of the measuring work on the stratospheric trace gases above New Zealand.

The carbon dioxide record established by Martin Manning and Peter Pohl began only in 1970, first at Makara near Wellington, then at the superior site at Baring Head, also near Wellington, in 1973. These data are representative of atmospheric carbon dioxide concentrations over a wide region of the ocean to the south of New Zealand. (See Figure 5.2).

Other tropospheric trace gases, such as **methane**, are also measured at the Baring Head Clean Air Sampling Station.

**Total ozone** is the amount of ozone contained in a vertical column of atmosphere up to 50 or 60 kilometres above a defined part of the Earth. It is most frequently measured in milli-atmosphere centimetres, or **Dobson Units** (DU). These take their name from the Oxford scientist G.M.B. Dobson, who, in 1920, also invented the instrument routinely used for today's ground-based monitoring of total ozone, the Dobson Ozone Spectrophotometer. New Zealand's ozone levels are monitored daily with one of these from the NIWA research station at Lauder, in Central Otago. A similar instrument at Scott Base measures ozone over Antarctica and plays an important role in the detection of the 'ozone hole' each spring. Since 1979, these ground-based measurements have been complemented by the satellite-borne Total Ozone Mapping Spectrometer (TOMS). Data from this, and other satellite instruments, are made available to scientists around the world.

**CFCs, halons** and other ozone-depleting chemicals in the atmosphere are not monitored in New Zealand. However, data on these chemicals are regularly obtained from overseas sources.

**Data on weather and climate patterns**

Weather statistics are collected and maintained by both NIWA and MetService (the national meteorological organisation) from a network of monitoring stations around the country. They include data on **rainfall**, **temperatures** and **sunshine hours**. Prior to the 1980s, no data on **ultraviolet (UV) radiation levels** were available in New Zealand. In addition to the Robertson-Berger (R-B meter) which has been operating at Invercargill since the early 1980s, NIWA now operates three new-generation broadband filter R-B meters—two at Lauder, in central Otago, and one at Leigh, in Northland—as well as two spectroradiometers at Lauder. To provide data on daily ultraviolet levels and make forecasts for public health purposes, Industrial Research Limited (IRL) has established a network of portable meters in main population centres.

**Data on gas and particle emissions**

Unfortunately, data on the quantity of emissions that we put into the atmosphere are not gathered as quickly or easily as data on atmospheric gas levels. Because there are many different sources of carbon dioxide, methane, CFCs, and other atmospheric contaminants, it is not possible to monitor them all. Instead total emissions must be estimated from other data on such things as the amount of fossil fuel produced or purchased (and presumably burnt, thereby emitting carbon dioxide), the amount of CFCs imported (and presumably used, thereby leading to emissions), and the number of ruminant animals (i.e. cattle, sheep, goats, deer) that are presumably burping methane into the atmosphere. Key emitters are usually sampled to assess the relationship between, for example, fuel use and the amount of pollution generated. Without this, accurate estimates could not be made, and even with this sampling the estimates still have a large degree of uncertainty. For carbon dioxide emissions from energy sources and industrial processes, however, emissions can be predicted to within about 6 percent.

Following this procedure, the Ministry of Agriculture provides annual calculations of methane and nitrous oxide emissions from agricultural sources. The Ministry of Commerce uses fossil fuel data to calculate greenhouse gas emissions from the energy sector (which includes electricity generation and transport, and $CO_2$ from industrial processes).

Using forest planting data from the Ministry of Forestry, the New Zealand Forest Research Institute calculates the amount of atmospheric carbon which is absorbed by planted commercial forests. Each year, these calculations are combined by the Ministry for the Environment to reach an annual estimate of greenhouse gas emissions, including 'net' carbon dioxide emissions (that is, actual emissions minus the amount absorbed by forests).

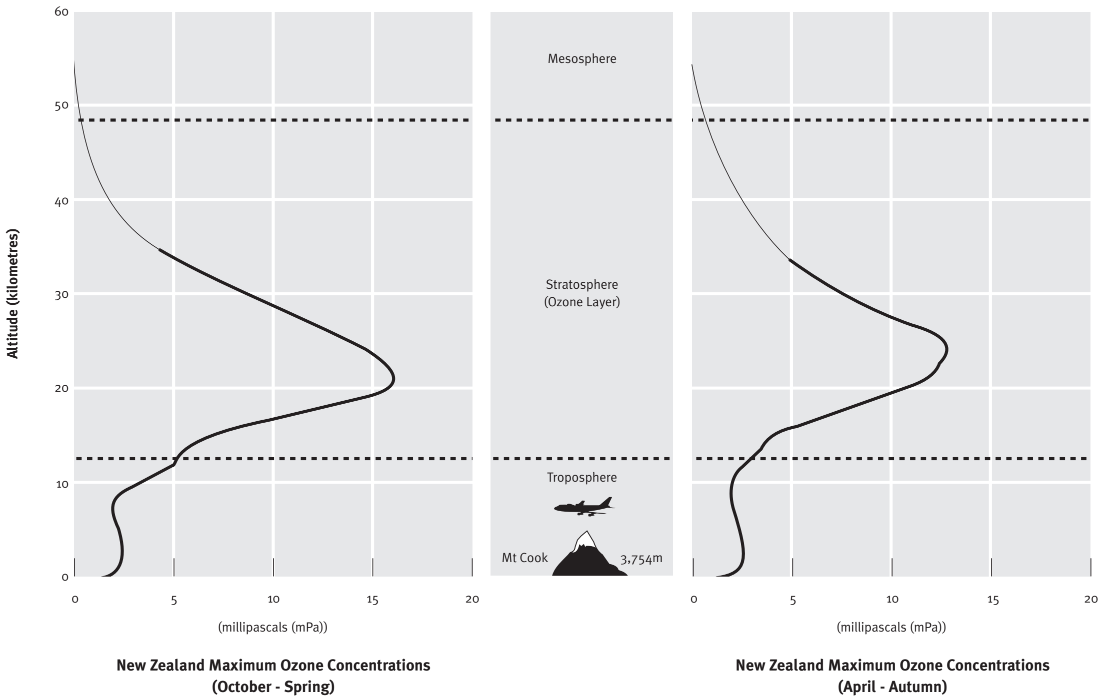
## THE NATURE OF NEW ZEALAND'S ATMOSPHERE AND CLIMATE

New Zealand's atmosphere is most tangible to us in the air we breathe and in the weather patterns we experience near the ground—the sunshine, wind, cloud, and rain. But this is a highly selective view. It only applies to the lowest reaches of the atmosphere, a zone of just a few kilometres where oxygen is dense and water vapour is abundant. The atmosphere actually extends for more than 1,000 kilometres out into space, gradually becoming thinner and thinner until it merges with the solar wind. It is layered into a series of discrete zones where gases of different densities tend to cluster (See Figure 5.3).

Two zones of prime importance to life on Earth are the *troposphere* and the *stratosphere*. Together they wrap the Earth in a protective cloak less than 80 km thick. Without them, the Earth would be a sterile ball of ice and rock bombarded by killer radiation. These zones contain tiny amounts of trace gases which have a powerful effect on the amount of solar radiation reaching the Earth and the amount of heat leaving it. These, in turn, influence ocean currents, climate patterns, plant growth and the health of humans and other animals.

The troposphere is the atmospheric zone that is closest to Earth. It is the zone in which our weather occurs and where atmospheric gases are densest. It is bun-shaped, extending out about 18 kilometres at the equator and about 6 kilometres at the poles. Above New Zealand, it is about 12 kilometres thick. Within it, greenhouse gases form an insulating blanket and contribute to the Earth's climate patterns. Outside it, the stratosphere forms a larger protective shell which rises to about 50 kilometres and has much lower concentrations of gases. The stratosphere's main significance lies in the fact that it contains the ozone layer—Earth's thin but effective bullet-proof vest which shields us from harmful solar radiation.

**Figure 5.3**
**Layers of the atmosphere, and ozone concentrations measured over Lauder (Central Otago) during Spring and Autumn.**




*(Profiles up to 35 km have been plotted from NIWA balloon sonde data and extrapolated above that point from data from other sources.)*

**Box 5.1**

### *Out of thin air—the evolution of life and the atmosphere*

Clues to the history of our atmosphere are scattered throughout the Earth's crust, in fossil and mineral deposits, in ancient ice layers, in the air around us, and even on neighbouring planets. Scientists are ingeniously sifting these clues in an effort to understand how the atmosphere has changed and how it might change in the future. The picture is becoming clearer every year, though much remains tentative, theoretical, and hotly debated, particularly for the earliest periods. However, there is broad agreement on the following scenario. Earth's original atmosphere of hydrogen and helium was stripped away shortly after the planet's birth 4.6 billion years ago. A secondary atmosphere arose from volcanic eruptions. It was dominated by carbon dioxide and prevailed for some 2–3 billion years. Today's atmosphere was created within the last 1–2 billion years by photosynthesising organisms. It is characterised by abundant nitrogen and free oxygen, an ozone layer, and comparatively low levels of carbon dioxide which maintain a moderate greenhouse effect that keeps Earth about 33°C warmer than it would be if it had no atmosphere.

At first, the Earth was all atmosphere and nothing else. The nine planets of the Solar System started out 4.6 billion years ago as a vast cloud (or nebula) of particles and gases orbiting the Sun (Harper and Jacobsen, 1996; Hecht, 1996; Hunten, 1993). This cloud, like the Sun itself, was composed mostly of the two lightest elements in the Universe—hydrogen and helium—with a small sprinkling of the 91 other natural elements (most notably, carbon, nitrogen, oxygen, iron and sulphur). Within the first 10 million years or so, these gases and particles condensed into hundreds of spinning lumps which, in turn, aggregated into planets. The four inner planets became small compact balls of dense rock and ice surrounded by hydrogen and helium gas (Mercury, Venus, Earth, and Mars). The five outer planets, formed much larger spheres known as gas giants (Jupiter, Saturn, Uranus, Neptune and Pluto).

In those early days, the Sun radiated about 30 percent less heat than it does today. However, for a relatively brief period of several million years the faint young Sun became a raging fireball which blasted vast amounts of ultraviolet radiation and extreme solar winds into space. This solar holocaust, which scientists call the Sun's T-Tauri phase, stripped the inner planets of their gas shrouds. In its wake came a sustained series of asteroid storms that rained on the planets for 700 million years, from around 4.5 to 3.8 billion years ago. Our Moon is believed to have formed at this time from an impact between Earth and a Mars-sized asteroid. Smaller asteroids with diameters as large as 100 kilometres were commonplace. Their impacts still scar the waterless surfaces of Mars and the Moon.

Volcanoes were also more active on the young planets than they are today. Soon new atmospheres were forming from the erupting clouds of volcanic steam and gas. These 'steam atmospheres' were dominated by water vapour ($H_2O$) and carbon dioxide ($CO_2$), but also included nitrogen ($N_2$), carbon monoxide (CO), hydrogen sulphide ($H_2S$), and a number of trace gases (Kasting, 1993; de Duve, 1995). Whenever temperatures dropped below 100°C on Earth or Mars the steam condensed into rain, and oceans formed—only to be vaporised by the next asteroid impact. When the asteroid storms finally abated, most of the atmosphere on Mars had been blasted into deep space, well beyond the pull of the planet's weak gravity. With the faint sunlight and very little greenhouse gas to trap heat, temperatures on Mars fell to below freezing point, and its remaining water turned to ice.

In contrast, the atmosphere on Venus survived the asteroids but was so dense that a runaway greenhouse effect took over, keeping temperatures forever above boiling point. The planet's water vapour was driven outward and upward by the intense heat until eventually the water molecules were split by solar radiation and dissipated into space. Only on Earth did temperatures settle at a level that allowed permanent oceans to form—about 85°C initially (Kasting, 1993). Apart from water, the atmospheres of all three planets had a fairly standard assortment of gases: about 95 percent carbon dioxide, 3 percent nitrogen, and a sprinkling of trace gases. On Venus and Mars, it is still like that. But on Earth, all that was to change.

Because it is further from the Sun, Earth was spared the runaway greenhouse effect that enveloped Venus. However, in the first few hundred million years, its dense concentrations of carbon dioxide and carbon monoxide may have produced an atmospheric pressure as high has 11,000 millibars (or hectopascals), compared to today's 1,000, and an average temperature of around 85°C (Kasting, 1993). When the first bacteria appeared more than 3.5 billion years ago, the atmosphere was probably still heavier and warmer than it is now. Earth's ancient atmosphere still had no free oxygen ($O_2$) and no ozone layer ($O_3$), and populations of bacteria were confined to the radiation-safe zone on the sea-floor, several metres below the surface (de Duve, 1995). The high carbon dioxide levels, perhaps 300 times current levels, would have ensured a mild greenhouse climate during this era of faint sunlight.

The atmosphere did not start changing until one group of bacteria (the cyanobacteria) developed the ability to 'eat' sunlight and carbon dioxide in the process called photosynthesis (see Chapter 9). In effect, they used the Sun's energy to separate the carbon from the oxygen. While the carbon was 'welded' into big useful molecules, energy-rich carbohydrates (e.g. oils, starches, sugars), the unwanted oxygen was simply released to the environment. In fact, the free oxygen was not merely unwanted, it was toxic. Being so chemically reactive, it was a danger inside living cells, and still is—a fact now borne out by medical researchers who are finding that oxidation of body tissues by molecules called free radicals (OH) is related to ageing, heart disease and cancer, while antioxidants (e.g. vitamins E and C) appear to delay these processes (Nesse and Williams, 1995).

It is not known when photosynthesis started. Although fossil bacteria resembling cyanobacteria are known from nearly 3.5 billion years ago (Schopf, 1993), recent genetic research suggests that cyanobacteria actually arose only about 1.5 billion years ago (Doolittle *et al.*, 1996; Morell, 1996). Geological evidence from iron deposits and ancient soils indicates that free oxygen started coupling up with other substances to form oxides around 2 billion years ago, and that carbon dioxide began to be extracted from the air and buried in sediments with dead organisms about 2.5 billion years ago (Kasting, 1993). On this basis we can only say that photosynthesis probably began between 1.5 and 2.5 billion years ago.

As oxygen accumulated in the atmosphere, its uppermost layer was bombarded by ultraviolet radiation which transformed a small but significant proportion of the oxygen molecules ($O_2$) into ozone ($O_3$). By perhaps 1.5 billion years ago total oxygen ($O_2$ plus $O_3$) still made up less than 1 percent of the atmosphere's volume—well below today's 21 percent—but this was sufficient to form an effective ozone layer which allowed life to come out of the shadows and evolve into more genetically complex forms (Kasting, 1993). An entire new group of hybrid organisms now began to appear: the algae. Part protozoan and part cyanobacteria, algae became floating oxygen factories on the ocean surface. Their vast blooms caused global oxygen levels to surge upward as $CO_2$ fell (Kasting, 1993). Between 1 billion and 600 million years ago, there was a pronounced oxygen increase and the stage was set for oxygen breathing animals to evolve (Canfield and Teske, 1996; Knoll, 1996). This momentous stage was reached only in the last 12–20 percent of Earth time.

By the time the world's earliest animals began to proliferate in the sea 530–570 million years ago (an event known as the Cambrian Explosion) oxygen probably comprised some 15 percent of the atmosphere (Graham *et al.*, 1995). A further oxygen boost came about 70 million years later, when green algae colonised the land and gave rise to the plant kingdom. Oxygen levels soared even more when trees appeared about 100 million years after the first plants. The trees could make a new kind of carbohydrate—wood—and on such a scale that, by 300 million years ago, forests were everywhere and oxygen made up 35 percent of the atmosphere, an all-time high (Graham *et al.*, 1995). At the same time, carbon dioxide levels had plummeted to an all-time low as the trees voraciously sucked the carbon from the air. Over tens of million of years, the $CO_2$ had been reduced from concentrations perhaps ten times higher than today, to levels below ours (Appenzeller, 1993a; Kaiser, 1996). This appears to have coincided with a shift in the Earth's orbit and axis, plunging the planet into an ice age.

Then came a spectacular, and drastic, atmospheric reversal. Continuous volcanic eruptions clouded the skies above the supercontinent of Pangea, $CO_2$ levels rose, and oxygen began to decline (Renne *et al.,* 1995). The ocean became anoxic and stagnant (Wignall and Twitchett, 1996). A vast upwelling of $CO_2$ from layers of dead sea organisms belched from the sea depths, killing marine life and adding to the clouds of greenhouse gas (Knoll *et al.,* 1996). By 250 million years ago, oxygen levels had fallen by two-thirds (Graham *et al.,* 1995) and life was nearly annihilated in Earth's greatest ever mass extinction (Kerr, 1995d and 1995e). From the ashes eventually arose the dinosaurs whose reign lasted until the next great extinction, 65 million years ago. Atmospheric oxygen levels slowly climbed back from their 12 percent low, and have fluctuated between 15 percent and 25 percent throughout the past 200 million years. Today's level of 21 percent is part of a small declining trend that began 50 million years ago (Graham *et al.,* 1995).

Today's $CO_2$ levels are also part of a declining trend that began about 100 million years ago (Appenzeller, 1993a). In the past few million years, these levels have stabilised at around 200 parts per million during ice ages, and about 280 ppm in the warm interglacial periods between. Earth has been in an interglacial period for the past 12,000 years or so, with $CO_2$ levels remaining at around 280 ppm—until the present century. While some scientists have taken comfort from the fact that ancient carbon dioxide levels were once much higher than they are now without any apparent devastating effects (Emsley, 1994), others note that the Sun was weaker for much of that time and also that the speed of atmospheric change was much slower, giving living things much more time to adapt. While much remains to be learned, it is clear that our oxygenated atmosphere was a late development in Earth's history, built by living things whose fate is now closely tied to its state. Awareness of this fact is what underlies the current concern about rapid atmospheric change.

**Box 5.2**

## *The natural formation and destruction of ozone*

The Natural Formation of Ozone

| | | | |
|---|---|---|---|
| 1 | $O_2$ + UV light | → | O + O |
| 2 | O + $O_2$ + M | → | $O_3$ (ozone) + M |

*M = any other molecule.*
*(The reaction in step 2 will not proceed without a third molecule.)*

*The net result from the 2 steps is that two oxygen molecules are converted to an ozone molecule and an oxygen atom.*

| | | | |
|---|---|---|---|
| 3 | $O_2$ + $O_2$ | → | $O_3$ (ozone) + O |

Oxygen is a versatile atom which can combine with many others to form a bewildering variety of different molecules. When oxygen atoms combine with each other though, they take only two forms: 'molecular' oxygen, which has two atoms ($O_2$); or ozone, which has three ($O_3$). When either of these is broken apart, the separated oxygen atoms quickly latch onto the first things they meet—usually other oxygen atoms—to form new molecules. In some cases, however, they join up with non-oxygens to form oxides or other compounds.

The Natural Destruction of Ozone

| | | | |
|---|---|---|---|
| 1 | $O_3$ (ozone) + UV light | → | O + $O_2$ |
| 2 | $O_3$ (ozone) + O | → | $O_2$ + $O_2$ |

**OR**

| | | | |
|---|---|---|---|
| 1 | $O_3$ (ozone) + UV light | → | O + $O_2$ |
| 2 | $O_3$ (ozone) + Y | → | YO + $O_2$ |
| 3 | YO + O | → | Y + $O_2$ |

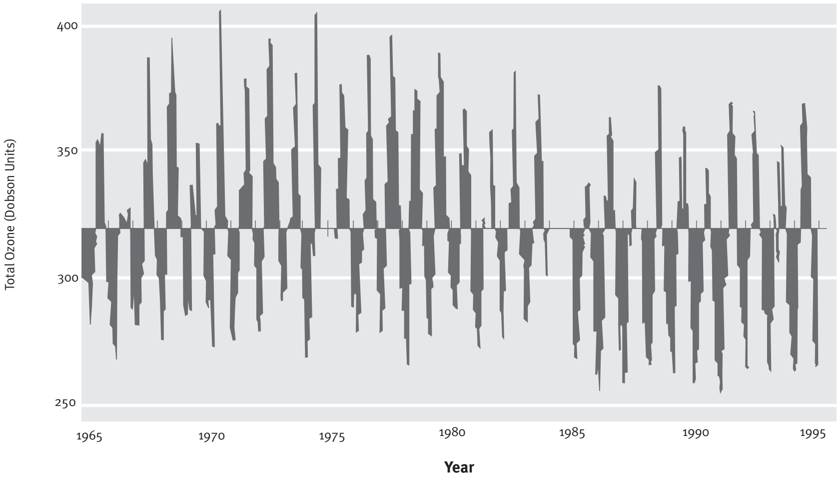
*Y = atoms and molecules that can combine with oxygen, such as chlorine atoms (Cl), nitric oxides (NO), or hydroxyl radicals (OH).*

*The result from each of these processes is that an ozone molecule ($O_3$) is converted into common oxygen ($O_2$). In the second process, however, the destructive 'Y' molecule is set free to break down more ozone.*

In the stratosphere, a delicate but stable balance exists between the destruction and formation of ozone. The Sun's ultraviolet rays constantly smash the oxygen and ozone molecules into separate atoms which then career wildly into each other. If a free atom happens to join another free atom, molecular oxygen is formed ($O+O=O_2$). If the free atom collides with molecular oxygen, the duo becomes a trio and a new ozone molecule is born ($O + O_2 = O_3$). However, if the free atom hits an ozone molecule, the ozone's third atom breaks off to join it and two molecular oxygens ($O + O_3 = O_2 + O_2$) result.

As the concentration of chlorine (Cl) increases through the breakdown of chlorofluorocarbons, the natural balance is upset. Chlorine atoms are extremely effective at snatching oxygen atoms away from ozone molecules and then losing them to free oxygen atoms which couple up to form molecular oxygen rather than ozone (see Box 5.4). The net result is that ozone is now being destroyed at a faster rate than it is being created (QBO).

**Figure 5.4**
**New Zealand total ozone, 1965-95.**




*Source: Nichol and Coulmann (1990); NIWA unpublished data.*

### Ozone and the ozone layer

Ozone is a pale blue gas which is toxic to humans and other animals, yet crucial to our existence. Ninety percent of it is concentrated in the stratosphere where it is under constant bombardment from the sun's radiation. Fortunately, by being such an easy target for the damaging ultraviolet-B (UV-B) rays, it stops many of them reaching Earth. However, at ground level, ozone is not so benign. It still absorbs ultraviolet light, but it is also a pollutant, being a key ingredient of big city smog (see Chapter 6).

In the stratosphere, ozone is constantly being broken down and reconstituted by the incessant radiation barrage (see Box 5.2). Under natural conditions it can sustain this pressure indefinitely, but, in recent years, it has also had to cope with a new enemy attacking from below—human-made chemicals, such as CFCs and halons. When these chemicals are hit by radiation, they lose chlorine and bromine atoms which dart wildly through the stratosphere, destroying ozone molecules. The main battle zone is in the 'ozone layer' at an altitude of 15–25 kilometres above the poles and 25–35 kilometres above the equator. This is where the ozone molecules are most densely concentrated (see Figure 5.3).

Even here, though, ozone is still a relatively rare commodity whose natural density never exceeds about 10 parts per million (ppm). In fact, typical ozone levels around the world range from 230 to 500 Dobson Units (DU), with a world average of about 300 DU. If all this ozone were brought down to sea level, it would automatically compress into a very thin gas layer of only 3 millimetres at standard pressure and temperature, one millimetre for every 100 DU—about the same thickness as an average pane of glass. This is the 'thin blue line of defence' that stands between us and the Sun.

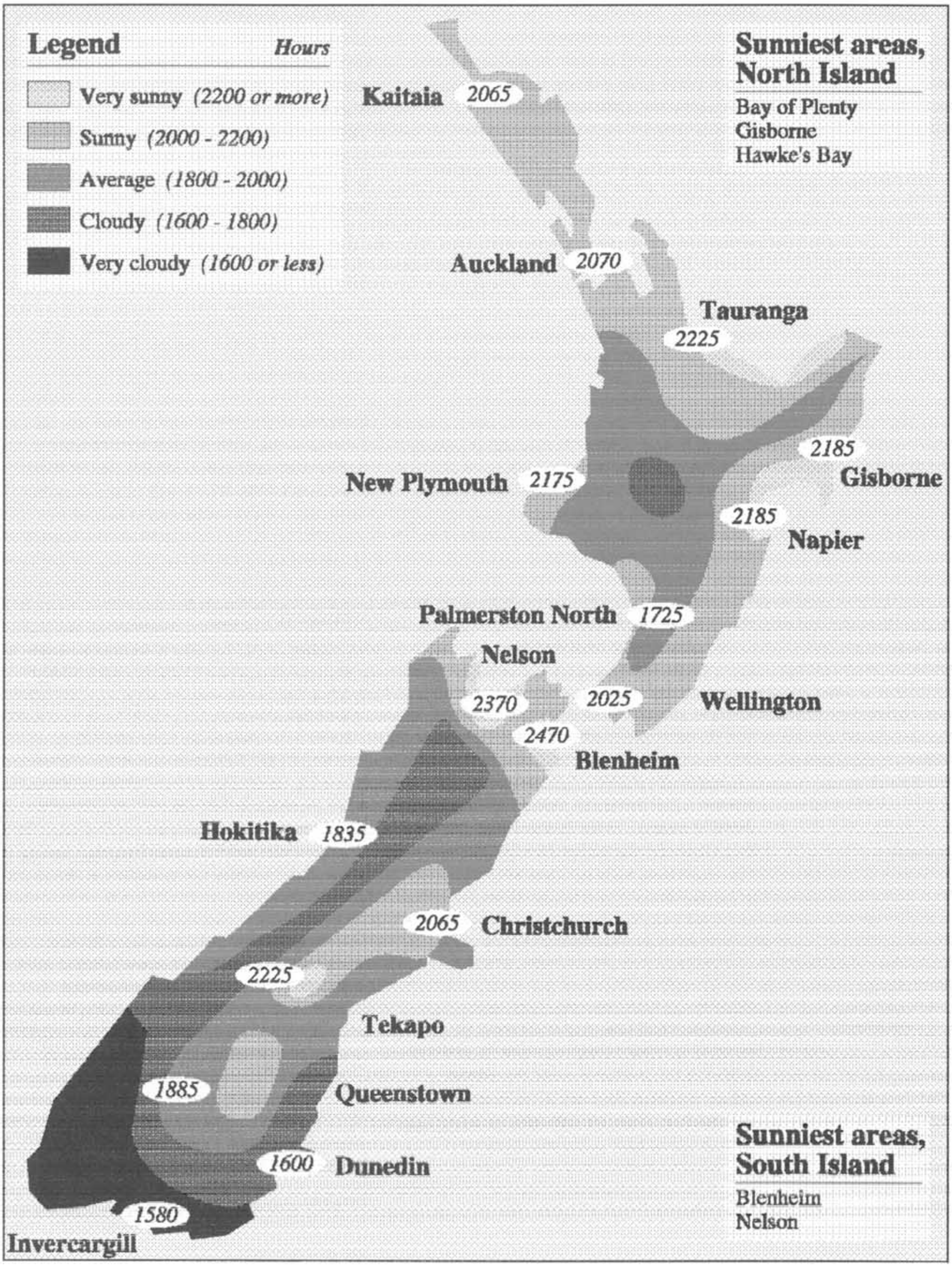
The amount of ozone over any one place varies considerably in response to stratospheric winds. These fluctuate from day to day, week to week, and season to season. They also vary on a two-yearly cycle called the Quasi-Biennial Oscillation (QBO) in response to regular global circulation patterns. On average, the total ozone concentrations over New Zealand are highest in late winter and spring, when they often exceed 350 DU, and lowest in late summer and autumn when they fall well below 300 DU. The season of thinnest ozone also corresponds to New Zealand's season of skimpiest clothing. (See Figure 5.4).

### Solar ultraviolet (UV) radiation

The Sun is a natural nuclear reactor emitting radioactive rays into space. This radiation travels to Earth in waves of varying length. The rays fall into three broad bands or spectra: long wavelength *infrared* radiation; medium wavelength *visible* light, and short wavelength *ultraviolet* light. Infrared radiation is sensed by us as heat. It is strongly absorbed by the atmosphere and, without it, Earth would freeze. Visible light passes virtually unimpeded through the Earth's atmosphere until it encounters clouds or solid objects. In some cases, the light is absorbed by these objects and converted to heat energy. In others it bounces back. Different objects absorb specific wavelengths of light and reflect others. Much of this reflected light is visible to us as colours.

It is the radiation with the shortest wavelengths—ultraviolet (UV) radiation—that has captured the headlines over the past decade. Depletion of the ozone layer allows more of this radiation to reach Earth with

**Figure 5.5**
**Average annual sunshine hours in New Zealand.**




*Source: NIWA and Statistics New Zealand (1996)* possible harmful impacts on plants, animals and human health (see Box 5.6). Ultraviolet radiation spans wavelengths from 200 nanometres (nm) to 400 nm and is of three types: UV-A (320–400 nm); UV-B (290–320 nm); and UV-C (200–290 nm).

**UV-A radiation** is relatively harmless and reaches the Earth largely unobstructed by the ozone layer. **UV-B radiation** can be more of a problem. Although the ozone layer filters out most of it, UV-B can cause eye and skin damage to humans and other animals and can retard plant and algal growth. On the positive side, it is used in water treatment to kill bacteria. **UV-C radiation** is lethal to plants and animals but, fortunately, oxygen and ozone almost completely remove it from the atmosphere.

Solar radiation in New Zealand is 50 percent more intense than at comparable latitudes in Europe. This is partly because we are closer to the Sun during summer and partly because we have less air pollution and so less tropospheric ozone. Besides being more intense, direct sunshine is also more frequent in many parts of New Zealand than at comparable European latitudes.

Most of our sunlight shines on the east and north of both islands (Statistics New Zealand, 1996). The highest sunshine levels in the South Island are in Nelson-Marlborough and the inland Mackenzie country (averaging around 2,300 hours per year, or about half the daylight hours). In the North Island, Hawke's Bay, Gisborne, the Bay of Plenty and New Plymouth have high amounts of sunshine, averaging about 2,200 hours. In contrast, the cloudiest areas, averaging less than 1,800 hours of sunshine are in Southland, Otago, the Southern Alps and the North Island's central plateau. Clouds can both block solar radiation and reflect it. Continuous cloud layers may reduce solar radiation by as much as half in the course of a day, but patchy clouds on sunny days can actually intensify radiation exposure by reflecting escaping light back down to land and water surfaces.

**New Zealand's climate**

The influence of solar radiation on New Zealand is not just confined to the amount of sunshine and cloud directly overhead. The Sun's energy drives the Earth's climate patterns, causing the fluctuations which give us our daily weather. It does this by heating the air, water and land each day, causing temperatures to rise and fall and air and water pressure to change. Changes in temperature affect evaporation rates and hence cloud formation and rainfall patterns. Variations in air and water pressure create the wind and ocean currents which redistribute heat and moisture around the planet.

Most of the sunlight that stirs up Earth's climate lands in the tropics. From there, its heat is dispersed on winds and ocean currents toward the poles. These currents form weather belts around the globe. New Zealand, with its elongated shape and north-south axis, straddles two of these (Salinger, 1988). The north of the country protrudes into the subtropical belt of anticyclones, receiving relatively dry settled weather with average temperatures of around 16°C. Its coastline is bathed with warm subtropical currents.

The south of the country is washed by cold sub-polar waters and lies in the path of the westerly wind belt. These winds travel over vast areas of ocean accumulating large amounts of moisture which is released as rain when the clouds roll over the high country. A series of westerly-flowing anticyclones and low pressure troughs give an alternating cycle of settled and unsettled weather, each lasting a few days. Average temperatures in the south are around 10°C.

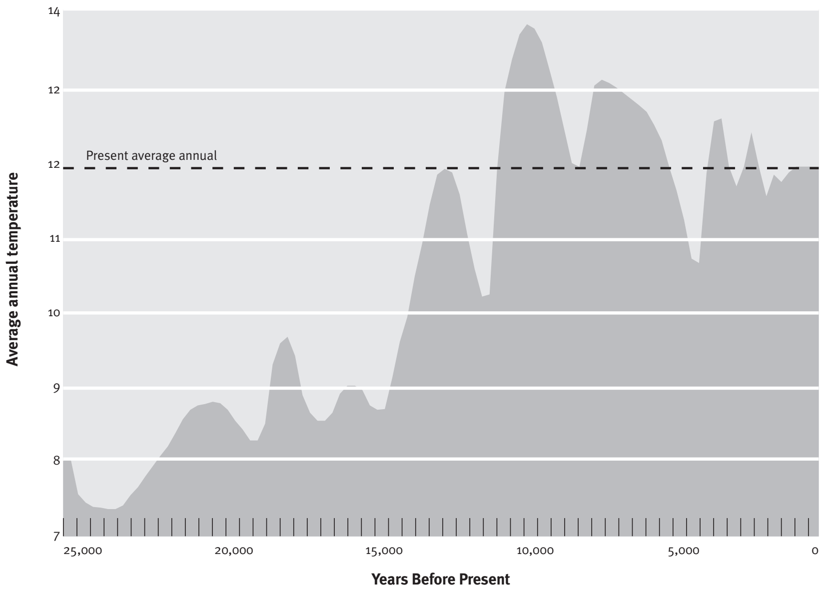
Occasionally the westerly pattern breaks down with southerly 'cold snaps' bringing snow to low levels in winter—and sometimes spring—or tropical depressions moving down from the north bringing warm, moist air into the New Zealand region. The surrounding ocean means that New Zealand generally has a 'marine' climate, except in central Otago where the climate is more 'continental' with hot, dry summers and cold, dry winters.

Besides the north-south climate division, there is also an east-west division, defined by the long mountain ranges which run up the centre of the islands. These intercept the prevailing westerly winds, causing them to release more rain in the west and south than in the east and north. This division is particularly marked in the South Island where the mountains are higher. Temperature extremes also tend to occur in the drier areas east of the main ranges. The result is a tendency towards drought, or severe dry spells, in the east and a widespread vulnerability to flash floods (see Chapter 7).

Evidence from sediments, pollen and ice suggests that, for the past 14,000 years, New Zealand's climate has fluctuated between 10°C and 14°C (Salinger, 1988). Prior to that, the world was in a long Ice Age, during which New Zealand's average temperature is estimated to have been about 7°C. That Ice Age was the latest of about a dozen which have occurred over the past 1.2 million years. Each has lasted about 100,000 years, punctuated by a 10–20,000 year warmer interglacial period.

The current interglacial period, the Holocene, started about 14,000 years ago in New Zealand and a little later in the Northern Hemisphere. Temperatures doubled over about 4,000 years to reach a peak average of 14°C by 10,000 years ago (see Figure 5.6). This warmer climate was mild, with light winds and lush forests. However, temperatures fell sharply to average under 11°C about 5,000 years ago before climbing back up to where it is today. By 3,000 years ago, New Zealand's modern climate was established. Glacial advances and natural forest fires began to occur, indicating that winds from the west and southwest had strengthened, and that the east was periodically subject to extreme temperatures and dryness. These trends probably received periodic assistance from the El Niño–Southern Oscillation which continues to exert a strong impact on New Zealand's weather (see Box 5.3). The average temperature in the past 3,000 years has remained within 1°C of today's average temperature (12°C) which, in turn, is about 3°C below the global average.

**Figure 5.6**
**New Zealand's estimated yearly temperatures since the last Ice Age.**




*Source: Salinger (1988)*

**Box 5.3**

### *El Niño and the Southern Oscillation*

The El Niño–Southern Oscillation (ENSO) climate pattern has a marked effect on New Zealand. The term El Niño was originally coined by Spanish-speaking Peruvians to describe an unusually warm current that periodically appears off the coast of Peru. Because it tends to show up around Christmas time, the current was dubbed 'the Boy Child', which, at that time of year corresponds to 'the Baby Jesus'. This warm current is caused by low air pressure settling over the eastern equatorial Pacific and preventing food-rich cold water welling up to the surface. In 1972, El Niño caused havoc in the Peruvian anchovy fisheries. It was the research into this event that linked the warm South American current to air pressure changes.

These changes, known as the Southern Oscillation, turned out to be a Pacific-wide phenomenon, in which low surface air pressures in the east are mirrored by high pressures in the west. Every few years the pattern reverses in see-saw fashion as pressures rise in the central and eastern Pacific and fall over the Indian Ocean, Western Australia, and Indonesia. These switches recur every 2 to 10 years. The Southern Oscillation Index (SOI) measures the ENSO effect by calculating the monthly air pressure difference between Darwin and Tahiti. When air pressure is high over Darwin and low over Tahiti, the SOI is negative and is said to be in the El Niño phase. At other times, when the pressure systems are reversed and the SOI is positive, the climate pattern is referred to as a La Niña event. These oscillations affect weather patterns around the world (see Figure 5.7).

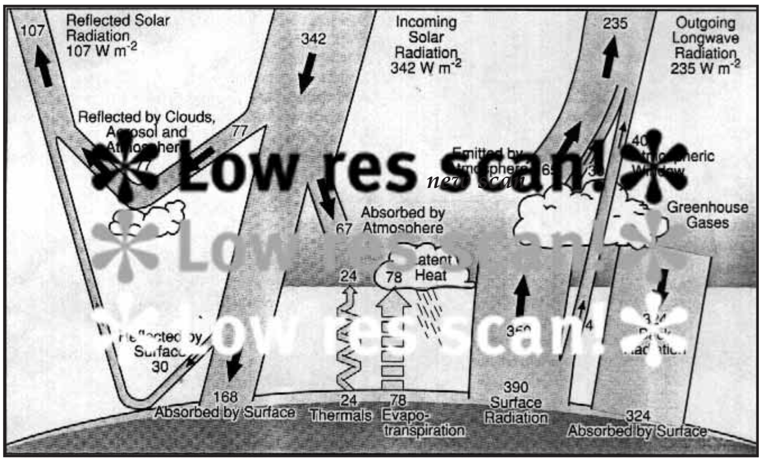
During a strong El Niño event, New Zealand tends to be cooler and windier than at other times, with more droughts in the east and north of both islands and more rain in the south and west. The effects vary with the season. Winter has more frequent southerly winds, autumn and spring have more frequent south-westerlies, and summer experiences more westerlies. Temperatures over the country are cooled by the southerly airflow. The most recent El Niño event, from autumn 1991 to autumn 1995, contributed to: low rainfall in the South Island lakes during the autumn and winter of 1991; particularly severe South Island snowstorms in the winter of 1992; much cooler than average temperatures in 1992 and 1993; and extremely low rainfall in the north and east of the North Island in 1994. During a La Niña event, westerly winds are dominant, with fewer southerlies and more north-easterlies. Rain is also more widespread, and temperatures are warmer. The 1988–89 La Niña contributed to one of the warmest periods on record and brought high summer rainfall to Northland and Auckland, a pattern which was also forecast for 1996–97.

Recent research indicates that the ENSO climatic fluctuations began around 5,000 years ago, at a time when the world's climate entered a slight cooling phase (Sandweiss *et al*., 1996). Climate researchers are now trying to assess whether there is any link between recent climate warming and the ENSO phenomenon (Kerr, 1994; Wuethrich, 1995). In its summary of recent climate anomalies that may be associated with human-induced global warming, the IPCC's scientific working group noted that: "The 1990 to mid-1995 persistent warm phase of the El Niño–Southern Oscillation (which causes floods and droughts in many areas) was unusual in the context of the last 120 years" (Houghton *et al*, 1996).

A number of computer models have suggested that there is a connection.
One recent computer 'experiment' investigated the impacts of rising carbon dioxide levels on Pacific sea surface temperatures and cloud cover (Meehl and Washington, 1996). The resulting climate pattern resembled some aspects of an El Niño event, pointing to "the possibility that $CO_2$-induced climate change in the Pacific could have this signature." The researchers also noted that El Niño-associated droughts in the Australasia/western Pacific region could intensify with climate warming, disrupting water resources on small islands dependent on rainfall for fresh water, and contributing to long-term depletion of freshwater resources. This concern could also apply to some parts of New Zealand (see Chapter 7).

**Figure 5.7**
**The Southern Oscillation during an El Niño Event.**
*Adapted from Trenberth and Shea (1987)*


**Figure 5.8**
**The Greenhouse Effect.**




*Source: Houghton et al. (1996)*

## Greenhouse gases and the 'greenhouse effect'

The idea that carbon dioxide helps warm the planet was very controversial when first put forward last century (Tyndall, 1861; Idso, 1984). It is now known that this and several other 'greenhouse gases' provide the necessary insulation to maintain Earth's climate within a relatively stable temperature range. Without these gases, the heat which beams down each day would evaporate back into space by night, causing huge fluctuations. Temperatures on the moon, for example, can vary from -150°C to +200°C in a single lunar day (Lowe *et al.*, 1988).

The most important greenhouse gases are water vapour ($H_2O$) first, followed by carbon dioxide ($CO_2$), and methane ($CH_4$). In natural concentrations these gases trap just enough heat from the Sun to keep Earth about 33°C warmer than it would be without them (15°C instead of -18°C). This is the 'natural greenhouse effect' (see Figure 5.8). In the 600 million years since animal life evolved, carbon dioxide levels have fluctuated considerably, but the general trend has been a decline from levels that were sometimes 10–20 times higher than today (Appenzeller, 1993a; Mora *et al.*, 1996). The lows generally coincided with ice ages and the highs with warm periods, but the relationship is not a straightforward one (Barron, 1994; Culotta, 1993; Kerr, 1993b; Emsley, 1994; Sellwood *et al.*, 1994).

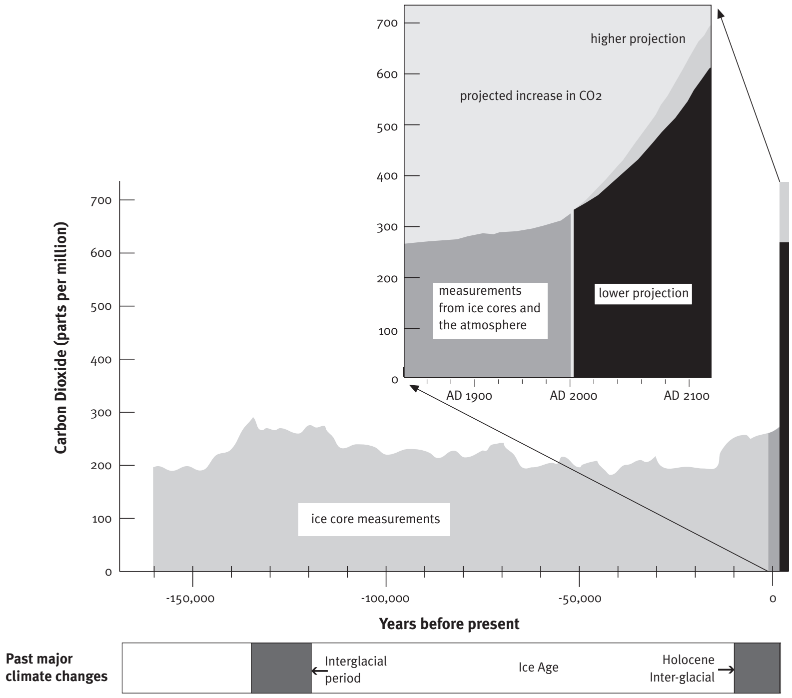
In nature, carbon dioxide is absorbed from the atmosphere by photosynthesising organisms, particularly trees, other vegetation, and marine algae, and by the ocean. Things that remove carbon dioxide from the atmosphere are referred to as 'carbon sinks'. Things which emit carbon dioxide into the atmosphere are referred to as 'carbon sources'. Natural sources include living things (when they decay, or when animals exhale), the ocean, volcanoes, soils and natural forest fires.

Vast quantities of carbon which were absorbed by forests and animals millions of years ago, were removed from the atmosphere when these organisms were buried in sediments. Today, these fossil deposits have been dug up and their carbon is familiar to us as the fossil fuels, coal, petrol and oil, and the sedimentary rock, limestone (calcium carbonate, $CaCo_3$). Human use of fossil fuels and the burning of limestone in cement manufacture are now the major sources of carbon dioxide emissions into the atmosphere. As a result, $CO_2$ levels are now higher than they have been for millions of years.

The widespread deforestation that has accompanied the rise of modern agriculture is the other main source of today's $CO_2$ build-up, not just because carbon dioxide escapes when trees are burnt, but also because a significant carbon sink has been removed. New Zealand was once a wall-to-wall carbon reservoir, with about 85 percent of its surface covered in native forest. Today, only about 28 percent of the country is forested, including both native forests and planted exotic forests (see Chapter 8).

**Figure 5.9**

**Carbon dioxide concentrations past, present, and future.**




*Source: M. Manning, NIWA*

Like carbon dioxide, methane is emitted by biological processes. Before A.D. 1800, the dominant methane source was decaying organic matter in wetlands. Other sources included termites, the belching of ruminant animals (e.g. buffalo, bison, cattle, sheep, deer, goats), wildfires and oceans (Brook *et al.*, 1996). The major sink is oxidation in the air, which converts the methane to other gases. In the past century, natural sources of methane (e.g. wetlands) have declined markedly. New Zealand's wetland area has been reduced by about 85 percent (see Chapter 7). All things being equal, this should have reduced methane emissions, but, in fact, methane levels have risen because human-induced sources of methane are more prolific than the natural sources were. They include livestock, waste disposal, and fossil fuels.

Carbon dioxide and methane are not the only greenhouse gases however. Nitrous oxide is released from many small natural and human-induced sources. These are difficult to quantify but levels are rising (Houghton *et al.*, 1996). The halocarbons, such as CFCs, simply did not exist before this century, but they too, are rising. Halocarbons are manufactured chemicals that combine carbon atoms with atoms of the halogen group (i.e. fluorine, chlorine, bromine or iodine). Besides being potent greenhouse gases, many halocarbons are also potent destroyers of the ozone layer.

Today, all the greenhouse gases other than water vapour are more abundant in the atmosphere than they have been for at least 200,000 years (Raynaud *et al.*, 1993). Even water vapour is predicted to become more abundant as temperatures rise and evaporation rates increase. Pre-industrial levels of carbon dioxide were around 280 parts per million by volume (ppmv)(see Figure 5.9). Today they are over 360 ppmv. In the next century, the total amount of $CO_2$ discharged into the atmosphere by human activity will exceed the amount released from the deep ocean over a period of 7,000 years at the end of the last Ice Age (Sundquist, 1993). Methane concentrations were once about 700 parts per billion by volume (ppbv). Now they stand at around 1,720 ppbv. Nitrous oxide has risen from around 275 ppbv to about 312 ppbv, and the halocarbons have risen from nothing at all to levels in excess of 600 parts per trillion by volume (pptv) (Houghton *et al.*, 1996).

## PRESSURES ON THE ATMOSPHERE

Although New Zealand has a relatively small population, we, like the people in other developed countries, make a disproportionate contribution to greenhouse gas emissions. At the peak of its consumption in 1986, New Zealand was also a major user of ozone-depleting substances on a per capita basis. In 1993, New Zealand's 3.5 million people represented only 0.06 percent of the world's population, but our contribution to all human-related carbon dioxide emissions was closer to 0.10 percent and our per capita share of methane emissions was ten times the global average (see Table 5.1).

The reasons for this are emissions from livestock and fossil fuel use.

Although CFCs and halons are potent greenhouse gases, they are much better known for their impact on the ozone layer. New Zealand had made extensive use of halons in fire extinguishers up until 1990 when it became the first country to eliminate their consumption by banning imports. In 1986, New Zealand's share of global CFC use stood at 0.20 percent, but by 1992 it had fallen to 0.10 percent. This was significantly faster than the global reduction over that period. New Zealand's 1986 per capita consumption of CFCs was very high at 700 grams per person compared to the global average of 210 g/person. However, by 1992, New Zealand had reduced its consumption rate by nearly 70 percent to 200 g/person. This was still nearly twice the global average, which, by then, had fallen to 120 g/person, but around half the 1992 OECD average of 400 g/person. Since 1 January 1996, there have been no more CFC imports into New Zealand, though products containing CFCs (e.g. refrigerators) are still imported.

### Pressures from ozone-depleting substances

Over the past five decades the ozone layer has been under attack from manufactured chemicals used in such diverse areas as refrigeration and air-conditioning, packaging, fire fighting, market gardening and industrial cleaning. For 20–30 years the chemical attack on ozone was silent, unseen, and unrecognised. The world only learned of the extraordinary longevity of CFCs in 1971 when Dr Jim Lovelock studied their global distribution to see if they would be useful marker chemicals for tracking air movements (Gribbin, 1988). Lovelock later became famous as the co-author of the Gaia hypothesis (the idea that Earth's atmosphere acts like a self-regulating organism).

Other scientists quickly seized on the fact that these apparently indestructible chemicals must eventually float up to the stratosphere and the fragile ozone layer. The suggestion that CFCs may be destroying the ozone layer was published the following year by two University of California scientists, Sherwood Rowland and his Ph.D. student, Mario Molina (Molina and Rowland, 1974). Controversial at the time, the idea was soon tested and confirmed.

It turned out that CFCs were not alone. A number of other halocarbons have the same destructive properties, though their Ozone Depleting Potential (ODP) varies according to chemical structure and longevity (see Table 5.2). A chemical's ODP is calculated by measuring it against CFC-11 which has been assigned an ODP of '1'. A chemical with an ODP of 2, for example, would mean it is twice as destructive as CFC-11. What these chemicals have in common are highly reactive atoms, particularly chlorine and bromine, which remain rigidly attached to the parent molecule as it floats up through the troposphere, but then become detached under the impact of ultraviolet radiation in the stratosphere. At this point, the free molecules began attacking ozone molecules (see Box 5.4).

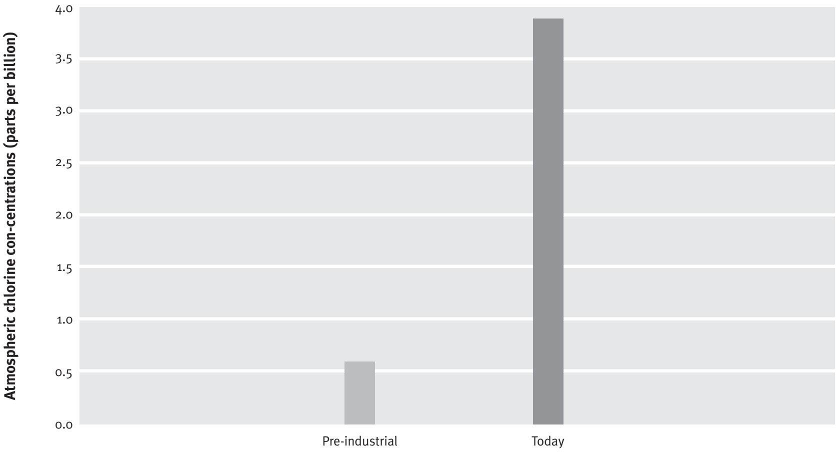
**Table 5.1**
**Major greenhouse gas emissions from the world, the OECD and New Zealand, 1993.**

| Greenhouse Gases | Total emissions (millions of tonnes) | | | | Per capita emissions (kilograms per person) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | World | OECD nations | New Zealand | NZ's share[1] | World | OECD nations | New Zealand | NZ: World ratio | NZ: OECD ratio |
| Carbon dioxide | 21,826 | 10,944 | 27.3 | 0.1 | 3,940 | 11,350 | 8,680 | 2.2:1 | 0.8:1 |
| *100-year GWP*[2] | *21,826* | *10,944* | *27* | | *3,940* | *11,350* | *8,680* | | |
| Methane | 261 | 67.8 | 1.6 | 0.6 | 47 | 71 | 455 | 9.7:1 | 6.4:1 |
| *100-year GWP*[2] | *5,481* | *1,424* | *133* | | *987* | *1,491* | *9,555* | | |
| Nitrous oxide[3] | 4 | unknown | 0.05 | 1.2 | 0.7 | unknown | 13 | 18.6:1 | unknown |
| *100-year GWP*[2] | *1,240* | | *15* | | *226* | | *4,030* | | |

*Sources: Ministry for the Environment (1997); OECD (1995); Sherlock et al. (1996); World Resources Institute (1996).*

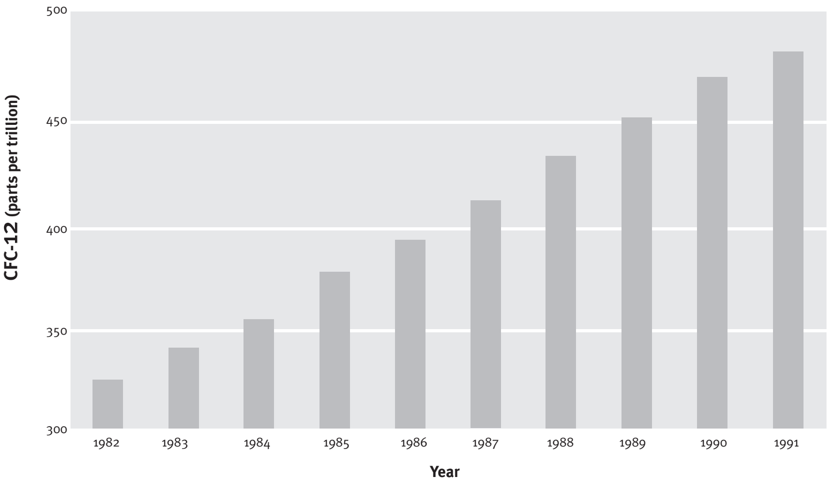
*[1] New Zealand's emissions as a percentage of the world total (New Zealand had 0.06 percent of the world population in 1993)*
*[2] GWP=Global Warming Potential in $CO_2$ equivalents (see Table 5.3)*
*[3] Nitrous oxide emissions from soil etc. are very difficult to estimate from current data and have a very wide margin of error.*

**Figure 5.10**
**The global increase in atmospheric chlorine.**




*Source: Houghton et al. (1996).*

**Figure 5.11**
**CFC-12 concentrations over Tasmania, 1982-91.**




*Source: Fraser and Derek (1994)*

Before these chemicals were invented the chlorine level in the atmosphere was 0.6 parts per billion (ppb). The natural chlorine was mostly in molecules, such as methyl chloride, which caused no damage to the ozone layer. Today, chlorine levels have risen to almost 4.0 ppb—a six-fold increase (see Figure 5.10). Eighty percent of the chlorine in the stratosphere is now directly attributable to human activities (World Meteorological Organisation, 1995).

The ban on the manufacture and importation of ozone-depleting chemicals (with the exception of hydrochlorofluorocarbons and methyl bromide) took effect on (and in some cases before) 1 January 1996. However, their past use and continued presence in manufactured products means that their impact on the atmosphere will continue for several decades.(See Figure 5.18).

### *Chlorofluorocarbons*

Chlorofluorocarbons (CFCs) were invented in 1928. At the time they seemed like magic molecules. They are colourless, odourless, and non-toxic. They do not burn or explode and they do not break down this side of the stratosphere. They vaporise easily at low temperatures, making them ideal coolants in refrigerators and air-conditioners, and ideal propellants in spray cans. However, the 80 grams of CFC-12 in one refrigerator can destroy three tonnes of ozone.

Throughout the 1980s, the atmospheric concentrations of the principal chlorofluoro-carbons, CFC-11 and CFC-12, increased by as much as 5 percent per year. The annual increase through 1990–1992 was more modest: about 0.9 percent for CFC-11 and 2.6 percent for CFC-12 (World Meteorological Organisation, 1995). CFC monitoring at Cape Grim in Tasmania shows a steady rise in the concentrations of these compounds in the Southern Hemisphere (see Figure 5.11). In 1986, New Zealand's estimated consumption of CFCs was 2,300 tonnes. By 1989, this had fallen to around 1,211 tonnes. The reduction was largely due to New Zealand phasing out the use of CFCs in spray cans (other than those used for medical purposes). Consumption dropped to under 375 tonnes in 1994 and the importation of new CFCs ceased altogether at the end of 1995.

**Box 5.4**

### *Ozone destruction by CFCs*

Ozone depletion is caused mainly by synthetic chemicals containing chlorine and bromine, particularly chlorofluorocarbons (CFCs) and halons. The key to their destructiveness is their long atmospheric lifetimes. Most chemicals break down in the lower atmosphere, but CFC and halon molecules are so stable that they hold together long enough to reach the upper atmosphere. This can take up to 100 years. Once there, individual chlorine atoms are torn from the parent molecule by the strong ultraviolet radiation. They then become free to bond with other molecules. They can destroy thousands of ozone molecules before eventually finding a more stable chemical to bond with.

**Destruction of Ozone by Chlorine Atoms (eg.CFCs)**

| | | | |
|---|---|---|---|
| 1 | $Cl + O_3$ *(ozone)* | → | $ClO + O_2$ |
| 2 | $ClO + O$ | → | $Cl + O_2$ |

The process of ozone destruction is as follows. Ultraviolet radiation splits individual chlorine (Cl) atoms away from the CFC molecule.. The freed chlorine atom (Cl) encounters an ozone molecule ($O_3$) (step 1 in the diagram), 'steals' one oxygen atom (O) to form chlorine monoxide (ClO), and leaves behind a common oxygen molecule ($O_2$).

As explained in Box 5.2, ultraviolet radiation also breaks down ozone molecules, creating free oxygen atoms. When a free oxygen atom (O) encounters the chlorine monoxide molecule (ClO), it seizes the already 'stolen' oxygen atom (O) and forms molecular oxygen ($O_2$) (step 2). At the same time, the chlorine atom is set free to restart the whole process, breaking down molecule after molecule of ozone and converting it to molecular oxygen.

This example is only one of several chemical processes involving chlorine and/or bromine that are now known to catalytically destroy ozone. The reason chlorine atoms in bleach or swimming pool chemicals don't destroy ozone is because the molecules in these compounds are less stable and never reach the ozone layer. They quickly dissolve in the lower atmosphere, and get washed back to Earth when it rains. The same applies to most chlorine released from volcanoes and sea salt.

### *Halons*

Halons are similar to CFCs but contain bromine (and sometimes chlorine as well). Bromine also destroys ozone. Halons were developed during World War II to put out fires in tanks and submarines. They became more widely used from the mid-1970s and are commonly found in yellow fire extinguishers. They have not been used as extensively as CFCs, but are much more destructive (see Table 5.2). In fact, Halon 1301, with an ODP of 12, is more lethal to ozone than any other pollutant. Halon imports in 1986 were 142 tonnes. This rose to 264 tonnes in 1989. Imports were prohibited from 3 October 1990.

**Table 5.2**

**Ozone-depleting Potential (ODP) measured against CFC-11.**

| Species | Chemical Formula | Atmospheric Lifetime (years) | Ozone-depleting Potential (ODP) |
|---|---|---|---|
| *CFC-11* | $CFCl_3$ | 50±5 | 1.0 |
| *CFC-12* | $CF_2Cl_2$ | 102 | 0.82 |
| *CFC-115* | $C_2F_2Cl$ | 1,700 | 0.40 |
| *Carbon tetrachloride* | $CCl_4$ | 42 | 1.2 |
| *HCFC-22* | $CF_2HCl$ | 13.3 | 0.04 |
| *HFC-134a* | $CH_2FCF_3$ | 14 | $<1.5x10^{-5}$ |
| *Halon 1211 (BFC)* | $CF_2ClBr$ | 20 | 5.1 |
| *Halon 1301* | $CF_3Br$ | 65 | 12.0 |
| *Methyl bromide* | $CH_3Br$ | 1.3 | 0.64 |
| *Methyl chloroform* | $CH_3CCl_3$ | 5.4±0.4 | 0.12 |

*Source: World Meteorological Organisation (1995)*

### *Hydrochlorofluorocarbons and hydrobromofluorocarbons*

Hydrochlorofluorocarbon (HCFC) and Hydrobromofluorocarbon (HBFC) have similar properties to halons and CFCs, but they are not as damaging to the ozone layer. They are being used by some industries as transitional substances to ease the difficulties caused by phasing out CFCs. In 1989, the base year used for Montreal Protocol phase-out calculations, 416 tonnes of HCFCs were imported. This rose to 472 tonnes in 1993, and 695 tonnes in 1995, as more of the chemical was used to make the transition from ozone-depleting CFCs to ozone-benign substances. A minimal amount (2 tonnes or less) of HBFCs may have been brought into the country before 1992 when imports were banned, but there are no official data.

#### *Carbon tetrachloride*

Carbon tetrachloride is a solvent once used by dry-cleaners, but now used mainly in chemistry laboratories. It is toxic and causes cancer. It has an ozone-depleting potential slightly greater than that of CFC-11, and an atmospheric lifetime of 42 years. Between 1989 and 1 January 1996, when imports ceased, less than one tonne was imported annually.

#### *Methyl chloroform*

Methyl chloroform is an industrial solvent used to degrease metal. It is also used as a solvent in white-out correction fluids for typing. It has an ozone-depleting potential roughly one-tenth that of CFC-11, and an atmospheric lifetime of 5–6 years. In 1989, the base year for the Montreal Protocol phase-out calculations, 982 tonnes were imported. By 1994 this figure had dropped to 101 tonnes. Imports ceased on 1 January 1996.

#### *Methyl bromide*

Methyl bromide kills all pests from microbes to insects and weeds and is used by horticulturalists to fumigate soil (often for crops such as strawberries and tomatoes). It is also used to fumigate imported goods being held in quarantine, and some export products, such as logs and fruit. Since CFC imports stopped in 1996, methyl bromide and HCFCs are the only ozone-depleting substances still imported into New Zealand. Of these, methyl bromide is the most significant because its ozone-depleting potential is only slightly less than CFC-11 (see Table 5.2).

In 1991, the official estimate for methyl bromide imports was 165 tonnes. Of this, 15 tonnes were used for quarantine and pre-shipment (QPS) purposes and the remaining 150 tonnes for all other non-QPS purposes (primarily horticulture). Those figures are estimated to have remained constant through until 1994, when a total 186 tonnes were imported, with 38.5 tonnes of that used for quarantine and pre-shipment purposes. In 1995, New Zealand capped its imports for non-QPS uses at 1991 levels (150 tonnes) as required under the Montreal Protocol. In the event, only 129 tonnes were imported for non-QPS uses in 1995, but 56 tonnes were imported for quarantine and pre-shipment use. This pushed the total for the year to 185 tonnes.

### Pressures from greenhouse gases

It is well established that the concentrations of some greenhouse gases are increasing as a result of human activities (e.g. Wratt *et al.*, 1991; Houghton *et al.*, 1996; Battle *et al.*, 1996). Many of the world's climate scientists are concerned that an 'enhanced greenhouse effect' could lead to a temperature increase for the surface of the Earth, changes in other aspects of climate (such as rainfall) in some regions, and rises in sea level.

Scientists cannot yet say with certainty whether the observed global and regional temperature trends are caused by natural climate phenomena, by enhanced emissions of greenhouse gases produced by human activity, or by a combination of the two. However, in its most recent report, the Science Working Group of the IPCC concluded that "the balance of evidence suggests a discernible human influence on global climate" (Houghton *et al.*, 1996; Kerr, 1995b). This conclusion has received added support from the latest study of recent temperature trends, which found a close relationship between actual temperature rises and those predicted by state-of-the-art computer models (Santer *et al.*, 1996; Kerr, 1996c; Nicholls, 1996).

The rise is not predicted to be at a steady rate, because natural fluctuations in climate will be superimposed on this change. However, the predicted warming and sea level changes summed up over time intervals of 30–100 years are much greater than corresponding natural rates of change, and are four to five times those experienced during the last century.

In the past 100 years the average temperature of the Earth has risen by 0.5°C. Even small temperature variations can produce large changes in climate. The temperature during the last Ice Age (which ended about 14,000 years ago) was only 3–5°C colder on average than it is now. Many scientists expect temperature increases of between 1°C and 3°C by the year 2050, and the IPCC, in its 1996 report, concludes that global temperatures are likely to increase by between 1°C and 3.5°C over the next 100 years (see Box 5.5).

The pattern of temperature change in New Zealand has been similar to the global pattern over the past 140 years, but recent evidence suggests that New Zealand's temperature is rising at a rate 50 percent higher than the global average. Global mean surface temperatures for the land and sea have increased by 0.45°C over the past 100 years, but New Zealand's temperature in the same period has risen by 0.7°C (Salinger, 1995). However, there is no firm scientific basis for predicting future rates of temperature increase based on past trends.

The warmest decade in New Zealand was the 1980s (see Figure 5.21). The very much cooler years of 1991 and 1992 are directly attributable to the effects of the eruption of Mount Pinatubo, in the Philippines, in June 1991 (see Figure 5.22).

Although the temperature changes for both New Zealand and the globe still fall within the ambit of natural variation, IPCC scientists now say evidence of the human influence on global climate is starting to emerge from the 'noise' of natural variability (Houghton, 1996).

**Box 5.5**

***The scientific assessment of climate change***

In the 1980s, several major conferences around the world revealed that many scientists were concerned about the possible influence of air pollution on the climate. The idea of such an effect had been around for more than a century, but rising world temperatures were now persuading more scientists to take it seriously. By 1988, temperatures and concern had grown sufficiently for the United Nations to set up the Intergovernmental Panel on Climate Change (IPCC). The IPCC's role is to examine the best evidence available, draw scientifically-based conclusions, and develop suitable research and policy responses.

The IPCC's Scientific Assessment Group (known as Working Group 1) involves about 170 scientists from 25 countries. Its first report, *Climate Change - The IPCC Scientific Assessment* (Houghton *et al.,* 1990; IPCC, 1990), was followed in 1992 and 1994 by updates incorporating the latest scientific knowledge (Houghton *et al.,* 1992 and 1994). In 1996 the Working Group released its second assessment (Houghton *et al.,* 1996).

In the original 1990 assessment, the Scientific Working Group scientists concluded that human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluorocarbons (CFCs), and nitrous oxide. They were also certain that those increases would enhance the greenhouse effect, making average temperatures warmer than they would otherwise have been at the Earth's surface. Furthermore, as temperatures increased, more water would evaporate from the oceans, thereby increasing the main greenhouse gas, water vapour (i.e. clouds), which would further enhance the greenhouse effect in a process referred to as *positive feedback*.

The 1992 Supplementary Report again predicted a warming rate of 0.2˚C to 0.5˚C per decade arising from human-induced greenhouse gases, but suggested this would be masked to some extent by the cooling effects of industrial emissions of sulphate aerosols and by ozone depletion in the upper atmosphere. Aerosols decrease temperature by forming cloud cover (if water vapour is present) or a whitish haze which blocks or scatters light, thereby reducing the amount of solar radiation that reaches the Earth's surface (Taylor and Penner, 1994; Jones *et al.,* 1994; Stephens, 1994; Kerr 1995a, 1995f) . The extent of this cooling effect is highly uncertain, making climate change predictions also uncertain (Houghton *et al.,* 1996; Schwartz and Andreae, 1996). One estimate suggested that aerosols may reduce temperature rises by 20 percent, and sea level rises by 25 percent (Wigley and Raper, 1992). More recent assessments by the IPCC and the US National Research Council indicate a level of uncertainty ranging from a very minor effect to a very strong one (Houghton *et al.,* 1996; Seinfeld, 1996).

In its second assessment the IPCC Working Group concluded, among other things, that "most ... studies have detected a significant change [in the global mean surface air temperature over the last century] and show that the observed warming trend is unlikely to be entirely natural in origin" (Houghton *et al.,* 1996). The Working Group further concluded that, despite the uncertainties, "the balance of evidence suggests that there is a discernible human influence on global climate." The Working Group said that "the increasing realism of computer simulations of current and past climate has increased our confidence in their use for projection of future climate change. Important uncertainties remain, but these have been taken into account in the full range of projections of global mean temperature and sea level change" (Houghton *et al.,* 1996).

Based on this, the Working Group predicted an increase in average global temperature of between 1˚C and 3.5˚C by the year 2100, and an increase in average sea level of about 50 cm. This is slightly lower than earlier estimates, mainly because of lower estimates of future greenhouse gas emissions and an increased awareness of the potential cooling effect of sulphate aerosols. Six different projections were made of future temperature and sea levels, and the middle ones were taken as best estimates (see Figures 5.12 and 5.13).

**Figure 5.12**

**IPCC projections of possible increases in global average temperatures**

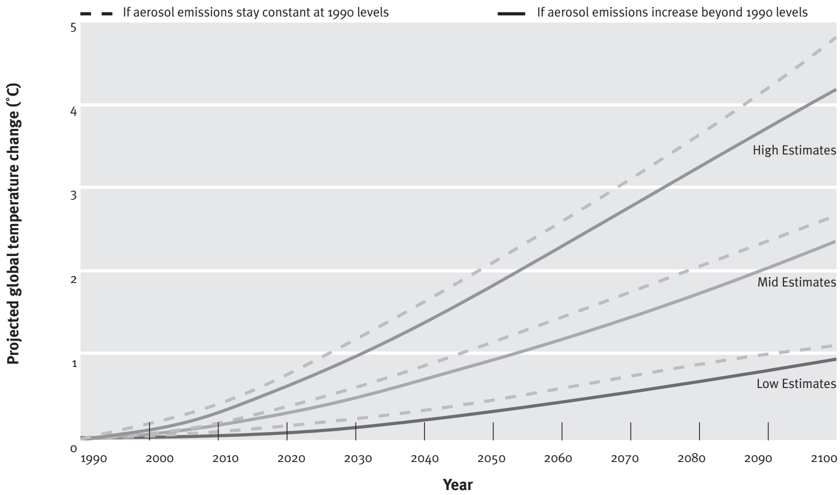
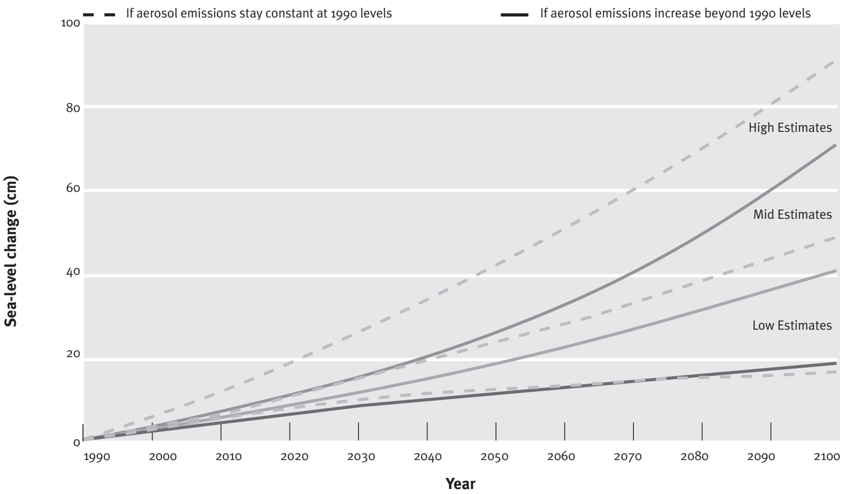



**Figure 5.13**

**IPCC projections of possible increases in sea level**




*Source: Houghton et al. (1996).*

Different greenhouse gases vary in their ability to trap heat. The Global Warming Potential (GWP) index depicts these differences using carbon dioxide as a benchmark for comparison (see Table 5.3). Factors which affect the GWP of a gas include its chemical make-up and the length of time it can remain intact in the atmosphere. Although carbon dioxide is the most notorious of the greenhouse gases it is actually very weak in comparison to the others.

In fact, most halocarbons are many times more potent greenhouse gases than carbon dioxide. CFCs, for instance, which are better known as ozone-depleters, have several thousand times the warming power of carbon dioxide. This is known as the 'direct global warming effect'. Indirectly, however, by destroying large amounts of ozone, which is also a greenhouse gas, the CFCs actually cancel out their own direct effect. Consequently, the warming effect of the CFCs is close to zero, and they may, in fact, have a slight cooling effect. Other halocarbons, such as hydrofluorocarbons (HFCs) and the perfluorocarbons (PFCs)—perfluoromethane and perfluoroethane—which do not 'eat' ozone, retain their very high GWP (see Table 5.3). Methyl bromide ($CH_3Br$) is similar to CFCs. It is a powerful ozone-depleting substance, but does not act as a greenhouse gas and therefore has a GWP of zero.

Gram for gram, the most potent greenhouse gas of all is not a halocarbon, even though it does contain a halogen, in this case, fluoride. It is sulphur hexafluoride ($SF_6$) with a GWP nearly 35,000 times greater than carbon dioxide.

However, the GWP alone is not the full picture. Greenhouse gases also vary in their abundance. After water vapour, carbon dioxide is by far the most abundant of the greenhouse gases and therefore has the greatest total impact on atmospheric temperatures. It is, therefore, is said to have a high warming 'commitment', despite its relatively low warming potential. The global warming commitment of a gas is simply its GWP multiplied by its abundance.

At present the global warming commitment of the super-heater, $SF_6$, accounts for about 1 percent of the total commitment arising from human-induced greenhouse gases. However, the $SF_6$ contribution is climbing, at 9 percent a year, with some users coming from an unexpected quarter—environmental agencies. A number of environmental monitoring programmes in North America and Europe have used the chemical as a marker, adding it to other pollution emissions in order to track their movements (Pearce, 1996b). Emissions of $SF_6$ in New Zealand are not monitored at present, but work is underway to monitor consumption.

**Table 5.3**

**The Global Warming Potential (GWP) of selected greenhouse gases, relative to Carbon Dioxide ($CO_2$) ( ±35%).**

| Species | Chemical Formula | Lifetime (years) | Global Warming Potential (GWP) | | |
|---|---|---|---|---|---|
| | | | 20 years | 100 years | 500 years |
| *Carbon dioxide* | $CO_2$ | *variable* | *1* | *1* | *1* |
| *Methane** | $CH_4$ | *12±3*** | *56* | *21* | *6.5* |
| *Nitrous oxide* | $N_2O$ | *120* | *280* | *310* | *170* |
| *CFC-11* | $CFCl_3$ | *50±5* | *5,000* | *4,000* | *1,400* |
| *CFC-12* | $CF_2Cl_2$ | *102* | *7,900* | *8,500* | *4,200* |
| *CFC-113* | $C_2F_3Cl_3$ | *85* | *5,000* | *5,000* | *2,300* |
| *Halon-1301* | $CF_3Br$ | *65* | *6,200* | *5,600* | *2,200* |
| *HCFC-22* | $CF_2HCl$ | *13.3* | *4,300* | *1,700* | *520* |
| *HCFC-141b* | $C_2FH_3Cl_2$ | *9.4* | *1,800* | *630* | *200* |
| *Carbon tetrachloride* | CCl4 | *42* | *2,000* | *1,400* | *500* |
| *Methyl chloroform* | $CH_3CCl_3$ | *5.4±0.6* | *360* | *110* | *35* |
| *HFC-23* | $CHF_3$ | *264* | *9,100* | *11,700* | *9,800* |
| *HFC-134a* | $CH_2FCF_3$ | *14.6* | *3,400* | *1,300* | *420* |
| *HFC-152a* | $C_2H4F_2$ | *1.5* | *460* | *140* | *42* |
| *Perfluoromethane* | $CF_4$ | *50,000* | *4,400* | *6,500* | *10,000* |
| *Perfluoroethane* | $C_2F_6$ | *10,000* | *6,200* | *9,200* | *14,000* |
| *Sulphur hexafluoride* | $SF_6$ | *3,200* | *16,300* | *23,900* | *34,900* |

* *The methane GWP includes indirect effects of tropospheric ozone production and stratospheric water vapour production, as in IPCC (1994).*

** *The GWP figure does not include 'indirect effects'.*

*Source: IPCC (1996)*

**Table 5.4**

**New Zealand emissions of key greenhouse gases in 1994[1].**

| Sources and sinks of greenhouse gases | Gas emissions and removals in thousands of tonnes (Gigagrams) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | $NO_x$ | CO | HFCs | PFCs | NMVOCs | $SF_6$ | $SO_2$ |
| ***Fuel use (e.g. oil, coal, gas)[2]*** | *24,657* | *30.677* | *2.637* | *124.12* | *700.92* | | | *148.1* | | *NE* |
| *Emissions from fuel burning* | *23,975* | *7.876* | *2.637* | *124.12* | *700.92* | | | *148.1* | | *NE* |
| *Energy production industries[3]* | *5,457* | *0.091* | *0.854* | *18.83* | *1.91* | | | *0.5* | | *NE* |
| *Heavy industry[4]* | *5,247* | *0.459* | *0.769* | *15.85* | *33.00* | | | *1.8* | | *NE* |
| *Transport* | *10,263* | *7.175* | *0.425* | *84.21* | *663.15* | | | *141.3* | | *NE* |
| *Small fuel users[5]* | *2,912* | *0.143* | *0.564* | *5.15* | *2.77* | | | *4.4* | | *NE* |
| *Other fuel use* | *96* | *0.002* | *0.016* | *0.33* | *0.09* | | | *0.1* | | *NE* |
| *Fugitive emissions[6]* | *681.92* | *22.807* | | | | | | | | |
| ***Non-fuel emissions from industry** (including solvent and other product use)[7, 8]* | *2,671* | *0.12* | | *1.61* | *0.60* | *0.06* | *0.03* | *152.97* | *0.18* | *30.92* |
| ***Agriculture[9]*** | | *1,436.189* | *16.145* | *0.167* | *4.127* | | | | | |
| *Livestock eructation* | | *1,418.791* | | | | | | | | |
| *Livestock defecation* | | *17.201* | | | | | | | | |
| *Farmed soils* | | | *16.14* | | | | | | | |
| *Paddock burn-offs* | | *0.197* | *0.005* | *0.167* | *4.127* | | | | | |
| ***Land use change and forestry[10]*** | *-13,796* | | *4.73* | *0.03* | *1.06* | *41.40* | | | | |
| *Exotic forest growth* | *-15,165* | | | | | | | | | |
| *Native forest and scrub clearance* | *1,369* | | *4.73* | *0.03* | *1.06* | *41.40* | | | | |
| ***Waste[11]*** | | | *415.8* | *0.6* | | | | | | |
| *Solid waste disposal on land* | | | *119.8* | | | | | | | |
| *Primary product processing waste* | | | *296.0* | *0.6* | | | | | | |
| ***Total (Gross) Emissions*** | *27,328* | *1,887.516* | *19.412* | *126.957* | *747.047* | *0.06* | *0.03* | *152.97* | *0.18* | *30.92* |
| *Less carbon absorption* | *-13,796* | | | | | | | | | |
| ***Total (Net) Emissions*** | *13,532* | *1,887.516* | *19.412* | *126.957* | *747.047* | *0.06* | *0.03* | *152.97* | *0.18* | *30.92* |
| *International Bunkers[12]* | *2,793* | *0.280* | *0.06* | *34.27* | *6.24* | | | | | |

*NE = not estimated*

1 *Emission estimates are incomplete or missing for some sectors (e.g. firewood, waste treatment, and incineration) and some gases (e.g. $SO_2$ from fuel combustion).*

2 *Fuels include oil, coal, gas, and industrial wood waste (but not firewood).*

3 *Emissions from fuel used while producing other forms of energy, such as electricity, refined oil products (e.g. diesel and petrol), synthetic petrol, and gas.*

4 *Emissions from fuel used in methanol production, forestry processing, and cement production.*

5 *Emissions from small fuel users such as homes, offices, factories, farms, schools, hospitals, and other institutions that use boilers, furnaces, incinerators etc.*

6 *Fugitive emissions are those resulting from gas pipeline leakage, coal mining, and other losses occurring during fuel extraction, transport and storage.*

7 *Non-fuel emissions from industry are given off when raw materials are heated or chemically changed to produce new materials or chemicals. The greatest source of $CO_2$ is steel production. Another major source is the heating of limestone to produce lime and cement. The industries that produce the greatest variety of emissions are aluminium, and iron and steel production, all of which emit $CO_2$, $CH_4$, $NO_x$, CO, and NMVOCs. Aluminium smelting also generates PFCs.*

8 *The end-use of chemical products, such as HFCs, often leads to their escape into the atmosphere. The 61 tonnes of HFCs imported for use as a refrigerator coolant eventually enters the atmosphere. However, the 120 tonnes imported for use as a catalyst regenerator at the Marsden Point oil refinery is broken down in the process.*

9 *The amount of $CO_2$ emitted from ploughed and eroding soil is unknown, as is the amount absorbed through soils and scrub.*

10 *More exotic trees are planted each year than are harvested. The resulting net absorption of $CO_2$ is shown as a negative emission. It is not known how much $CO_2$ is absorbed by native forests and by scrub regenerating on abandoned farmland.*

11 *Emissions from waste treatment plant incinerators are not known. Emissions from wastes generated by processors (e.g. meatworks, dairy factories, wool scours and tanneries) are probably overestimated for $CH_4$ and underestimated for $N_2O$.*

12 *International bunkers are fuels used in international air and sea transport. They are generally excluded from national emission inventories.*

### *Carbon dioxide*

For the past few million years, carbon dioxide levels in the atmosphere have been relatively stable at about 280 ppm. This means that human beings and most of the other species existing today have never experienced $CO_2$ levels above 300 ppm—until this century. In the past 100 years, the concentrations have increased by about 25 percent, from 280 to over 350 ppm and are still rising. The present rate of increase is between 0.4 percent per year, with the Northern Hemisphere leading the Southern Hemisphere by about 3 ppm (Houghton *et al.*, 1994). This reflects a lag effect in which the Northern Hemisphere concentrations are running one to two years ahead of the Southern Hemisphere, with bigger seasonal variations.

In New Zealand the main sources of carbon dioxide are motor vehicles, electricity generation, and the petrochemical, steel, and dairy industries (see Tables 5.4 and 5.5). Our gross carbon dioxide emissions per person are currently about 7,500 kg (reducing to approximately 2,000 kg of net emissions). This compares to gross global emissions of 5,000 kg per person and an OECD emission rate of 11,000 kg per person (see Table 5.1).

In the 24 years that the Baring Head record has been kept, the concentration of carbon dioxide in the Southern Hemisphere has increased by nearly 10 percent (see Figure 5.14). The rate of increase was about 1.2 ppm per year in the 1970s, and 1.6 ppm per year in the 1980s. Carbon dioxide growth rates slowed during the early nineties, but have now started to rise again. Such short-term fluctuations in carbon dioxide growth have been observed before.

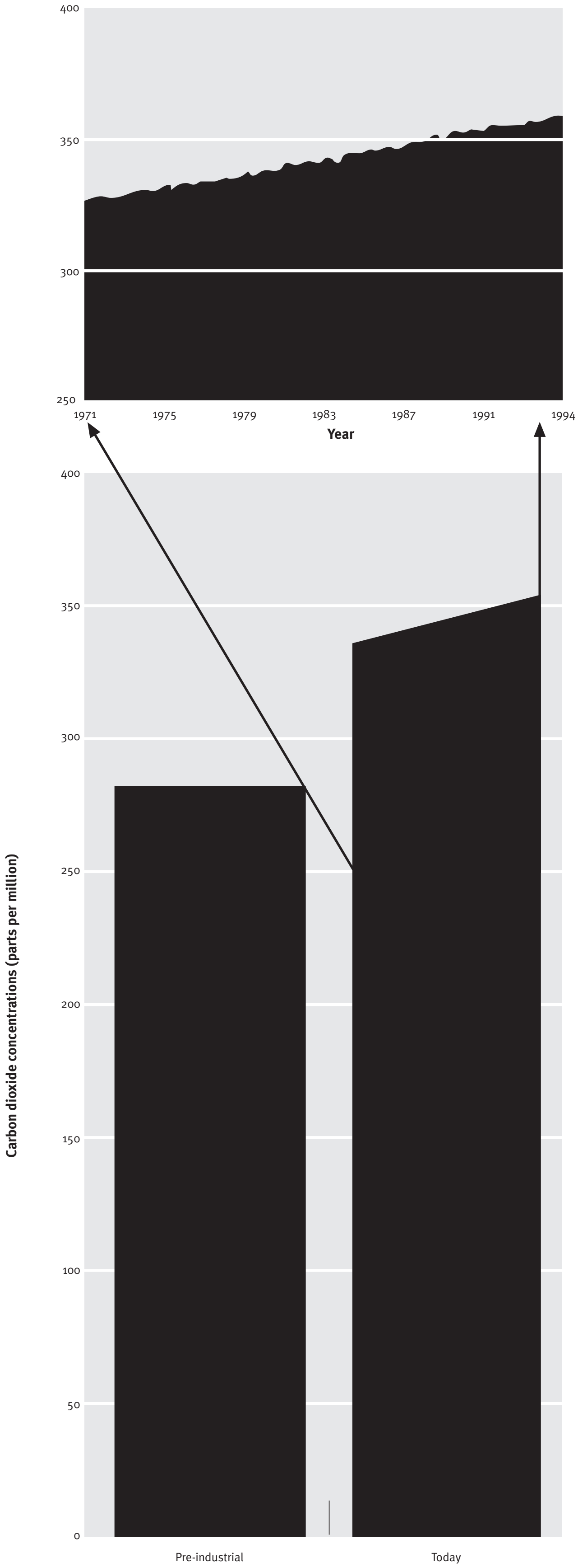
**Table 5.5**
**The main sources of human-induced carbon dioxide emissions in New Zealand.**

| Emitter | Carbon Dioxide kilotonnes (kt) | Data Year |
|---|---|---|
| *Transport* | *10,983* | *1995* |
| *Electricity generation* | *3,263* | *1995* |
| *Synthetic petrol* | *666* | *1995* |
| *Chemical methanol* | *1,249* | |
| *Steel Importing* | *1,668* | *1995* |
| *Dairy Industry* | *1,060* | *1991* |
| *Cement Industry* | *981* | *1995* |
| *Oil Refining* | *955* | *1995* |
| *Forest Industry* | *940* | *1992* |
| *Aluminium production* | *532* | *1995* |
| *Meat Industry* | *413* | *1992* |
| *Ammonia/urea production* | *157* | *1995* |
| *Total* | *11,939* | |

* *Gross carbon dioxide emissions 1995: 27,368 kilotonnes (kt)*

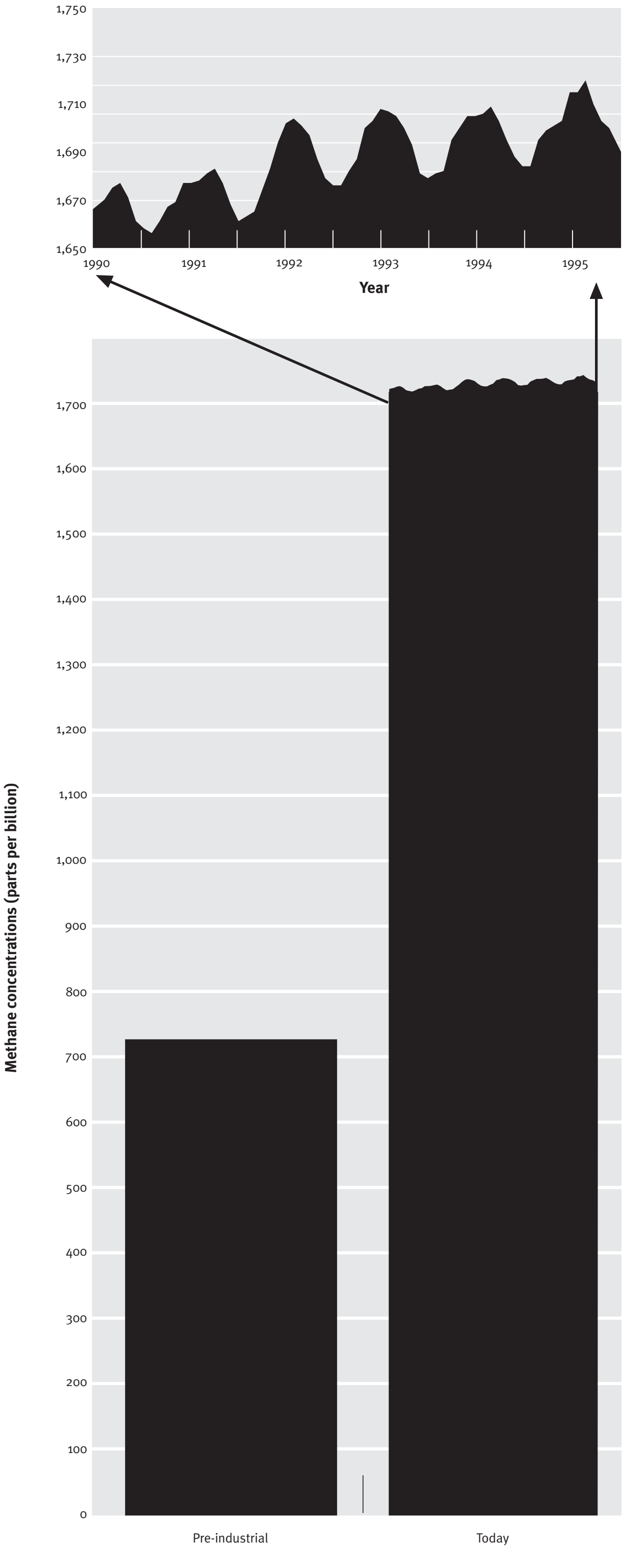
*Source: Ministry of Commerce*

**Figure 5.14**
**Carbon Dioxide concentrations over the Southern Hemisphere, 1971-94.**




*Source: Houghton (1995): NIWA unpublished data*

**Figure 5.15**
**Methane concentrations over New Zealand, 1989-94.**




*Sources: Lowe et al. (1994); NIWA, unpublished data*

### *Methane*

Global methane ($CH_4$) concentrations have always fluctuated on a scale of about 1,000 years. As noted earlier, however, before about A.D. 1600 the concentrations had not exceeded 800 ppb for over 100,000 years (and probably much longer). Since then, mainly as a consequence of increasing global agriculture and industry, atmospheric methane levels have more than doubled to over 1,700 ppb.

In New Zealand, the methane emissions from sheep and cattle (and also deer and goats) exceed all other sources (see Table 5.4). The methane produced in the stomachs of ruminants (and in the paddy-fields of large rice-producing countries) is the by-product of anaerobic (non-oxygen using) bacteria breaking down organic material. Primary production processing waste (e.g. dairy factories and meatworks) and rotting waste at landfills are New Zealand's next largest sources.

The global rate of increase in atmospheric methane was about 0.8 percent per year in the 1980s. In the early nineties the rate slowed considerably, then picked up from 1993 (Houghton *et al.*, 1994). Methane concentrations have been measured in southerly, clean air, conditions at Baring Head since 1989 (see Figure 5.15). The monitoring shows unexpectedly high variability in spring. This is probably caused when the seasonal burning of tropical forests emits large amounts of methane which are carried south by air currents.

New Zealand's large number of ruminant animals makes our methane emission rate per capita about ten times higher than the global average (see Table 5.1). In the early 1990s, methane emissions from New Zealand livestock declined sharply leading to predictions of a 10 percent reduction by the year 2000 (Ministry for the Environment, 1994). However, the increase in cattle numbers, particularly dairy cows, in the mid-1990s has partially reversed this trend so that the overall methane reduction between 1990 and 1995 was 3.5 percent.

***Nitrous oxide***

Nitrous oxide ($N_2O$) is another important long-lived greenhouse gas. The annual global increase is 0.2 percent to 0.3 percent. Atmospheric concentrations are believed to have increased by about 15 percent since the pre-industrial era. The nature of human-related sources (land-use change, fossil fuel combustion, biomass burning, nylon manufacture) remains very uncertain, but the emission rates generally track those of carbon dioxide, suggesting some common factor (Houghton *et al.*, 1992; Battle *et al.*, 1996).

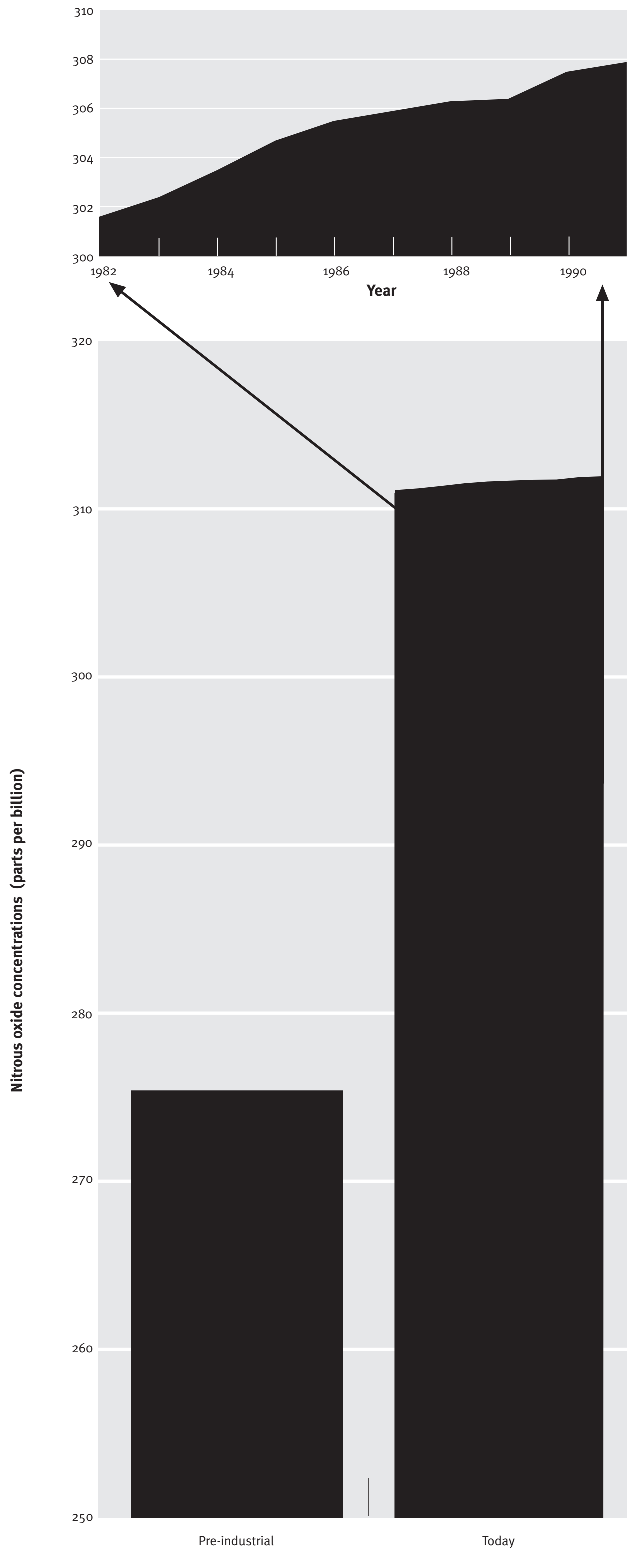
In New Zealand most of the nitrous oxide is thought to come from the soil. The rate of emission is determined by rainfall, temperature, soil texture, drainage, and farming practice. The Cape Grim record, which is representative of a large part of the Southern Hemisphere, shows that nitrous oxide concentrations have been increasing through the 1980s, though not at a constant rate. (See Figure 5.16)

***Halocarbons***

Many of the most potent greenhouse gases are halocarbons (see Table 5.3). **Perfluorocarbons** (PFCs) are molecules containing only fluorine and carbon. They are not ozone depleting, despite their molecular structure. However, they are extremely potent greenhouse gases. Using a 100 year time horizon, their Global Warming Potential (GWP) ranges from 6,500 for perfluoromethane to 9,200 for perfluoroethane. Ten tonnes of emitted PFC can have the same long-term greenhouse warming effect as 92,000 tonnes of carbon dioxide.

Current emissions of PFCs are small, both globally and domestically, so the present global warming commitment of these gases is much less than that of carbon dioxide and methane (see Table 5.3). However, if emissions were to increase, their contribution to future climate change would become more important (UNEP/World Meteorological Organisation, 1994). The main source of PFCs in New Zealand is the aluminium smelter at Tiwai Point, near Bluff. Since 1994, there has been a significant decrease in smelting emissions, although some of this decrease has been offset by a small increase in PFCs imported for industrial purposes in 1995. The uses for

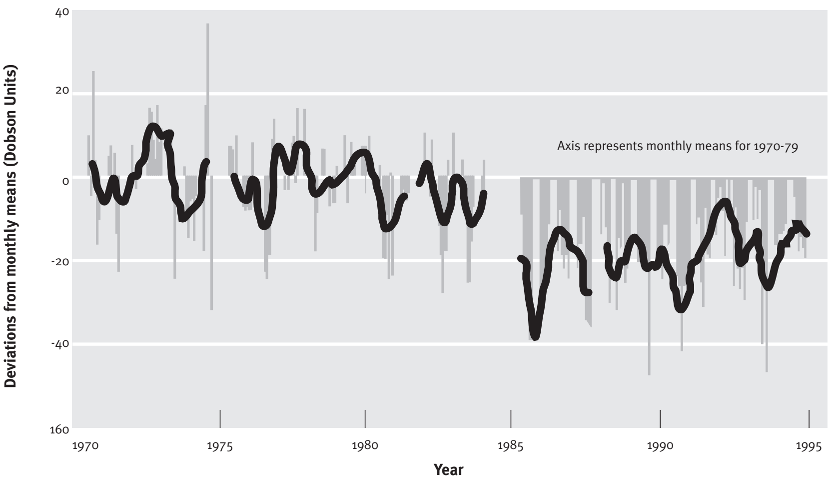
**Figure 5.16**
**Nitrous oxide concentrations over Tasmania, 1982-91.**




*Sources: Lowe et al. (1994); NIWA, unpublished data* industrial purposes is expected to increase slightly over the rest of the decade. The total amount emitted from both sources was estimated to be 0.089 Gg (89 tonnes) in 1990 (New Zealand Aluminium Smelters Ltd, 1993) and 0.029 Gg (30 tonnes) in 1995, a decrease of 67 percent.

Emissions of **hydrofluorocarbons** (HFCs) in New Zealand are thought to be small compared to carbon dioxide, although there are no precise data. They are, however, potentially important because of their increasing use and their high GWP/long atmospheric life. Approximately 120 tonnes of HFC-152a are imported into New Zealand every year. Most is used at New Zealand's only oil refinery at Marsden Point. Less than 20 kg of HFC-134a were imported in 1990—enough for research purposes only. In 1993 about 7.5 tonnes of HCF-134a were imported. However, in 1994 and 1995 the amounts imported rose sharply to 63 tonnes and 141.5 tonnes respectively as refrigerator manufacturers, seeking ozone-friendly alternatives to CFCs, switched to HFCs (Ministry for the Environment, 1994). Imports are expected to rise for some years to come as the use of CFCs and HCFCs decline.

**Figure 5.17**
**Deviations in monthly mean ozone, Invercargill/Lauder, 1970-94.**




*Sources: Nichol and Coulmann (1990); NIWA, unpublished data*

## THE STATE OF THE ATMOSPHERE

Two trends are undisputed among atmospheric scientists: ozone levels have declined and greenhouse gas levels have increased. In both cases, the trends have been marked departures from the natural state of the atmosphere that has prevailed for hundreds of thousands, and probably millions, of years. Where uncertainty and speculation are more prevalent is in predicting the impacts of these changes.

A general consensus exists that solar radiation in temperate zones has intensified as the ozone layer has thinned, and that global temperatures have increased as greenhouse gases have accumulated.

The magnitude of these effects and their significance for humans and the environment is still uncertain. If there are effects, however, they will increasingly manifest themselves in sunburn-related problems in plants, animals and humans, and in climate changes that will alter growing seasons, snowlines, sea levels, rainfall patterns and species distributions.

### The state of the ozone layer

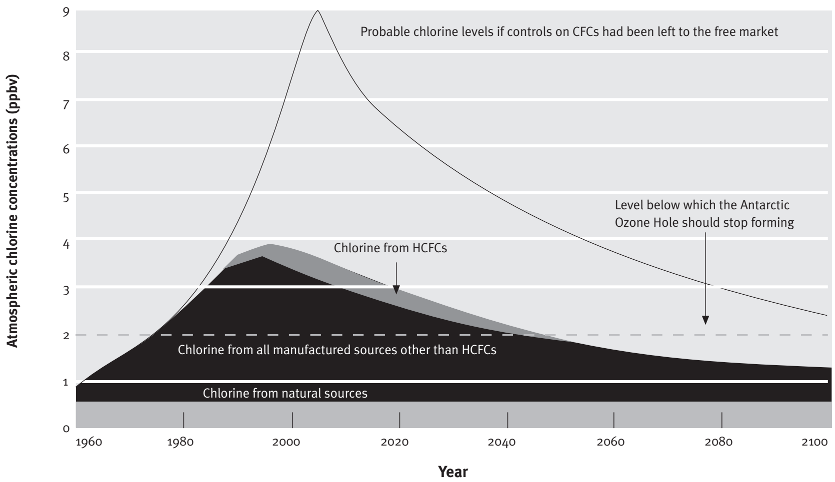
It is now well established that, in the past two decades, the ozone layer has been significantly depleted (World Meteorological Organisation, 1995). Ground-based measurements show an overall drop of about 5 percent through the 1980s, very similar to that observed from space by an orbiting satellite instrument, the Total Ozone Mapping Spectrometer (TOMS) (Reinsel *et al.*, 1994). In mid-latitudes, an annually averaged decrease in total ozone of 4 to 5 percent per decade has taken place since 1979 (UK Stratospheric Ozone Review Group, 1996). A drop of 10 percent in total ozone concentrations increases UV-B radiation on the Earth's surface by some 20 percent (World Meteorological Organisation, 1995).

New Zealand's ozone monitoring shows a decline in ozone concentrations during the 1980s, with a more abrupt decline from the mid-1980s (see Figure 5.17). In only two of the 120 months between 1985 and 1995 did average ozone levels exceed the average 1970s level. In Figure 5.17, the seasonal fluctuations have been removed to show a natural phenomenon known as the global Quasi-Biennial Oscillation (QBO), which is a natural two-yearly fluctuation in the amount of ozone caused by the global circulation pattern.

The good news for the ozone layer is that world governments and the chemicals industry have acted just in the nick of time to stave off a much larger catastrophe (Prather *et al.*, 1996; Andersen and Miller, 1996). Provided countries strictly comply with the provisions of the Montreal Protocol, the international agreement to phase out the use of ozone-depleting substances, ozone depletion is expected to peak between 1997 and 1999 (Montzka *et al.*, 1996; Prather *et al.*, 1996; Kerr, 1996a; Pearce, 1996a; World Meteorological Organisation, 1995). Within that period chlorine concentrations will top out at around 4 ppb (see Figure 5.18).

The bad news is that it will be some time before the damage is undone, because CFCs have such a long lifetime. By the year 2050 chlorine concentrations could be down to about 2 ppb, about half their present level and the ozone layer will have largely recovered. But even with the Montreal Protocol's constraints on the use of ozone-depleting substances, it will be another century before the amount of chlorine in the atmosphere returns to anywhere near its natural level.

**Figure 5.18**
**Atmospheric chlorine levels with and without the Montreal Protocol and its 1992 amendments.**




*Adapted from: United Kingdom Stratospheric Ozone Review Group (1993); Prather et al. (1996).*

### The Antarctic ozone hole

When the first alarm bells were sounded about ozone depletion in the early 1970s, no-one predicted that CFCs would actually tear a hole in Earth's 'bullet-proof vest'. When the Antarctic ozone 'hole' was finally announced in 1985, it came as a surprise (Farman *et al.*, 1985; Gribbin, 1988). But evidence of the hole's development had been accumulating for some time. Data gathered at the British Antarctic Survey station in Halley Bay showed that total ozone had been declining each spring (September–October) since the observations began in 1957.

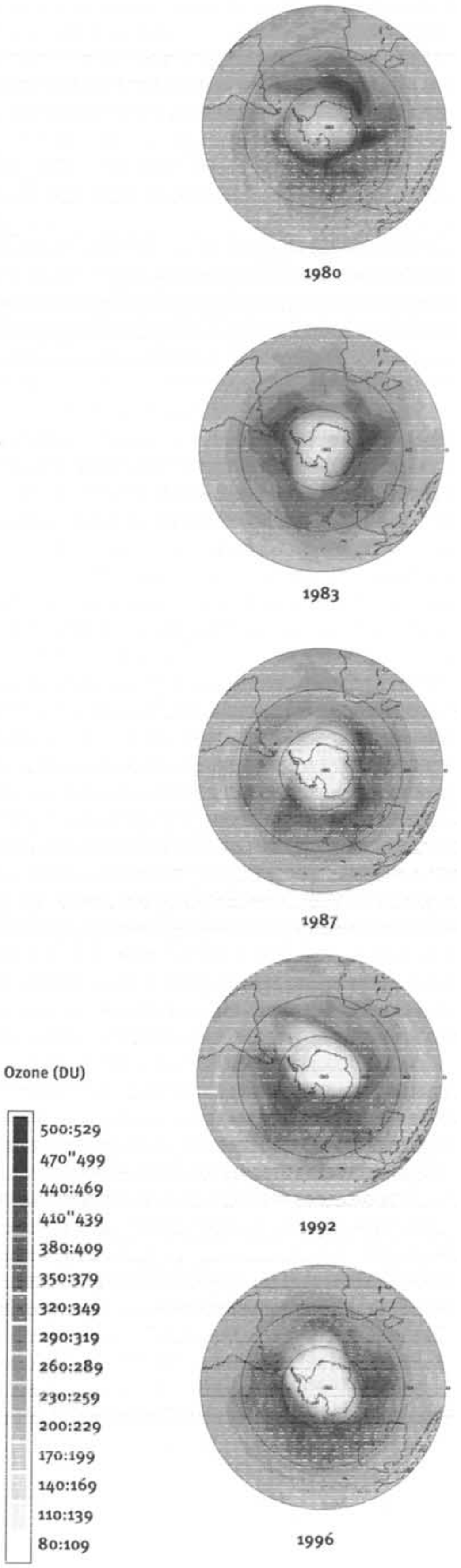
These early observations were made with a ground-based spectrophotometer. With the advent of satellite-based TOMS measurements in 1979 it became possible to cover a much wider area. The satellite data confirmed the ground-based results and showed that the springtime ozone depletion covers most of the Antarctic continent (Newman *et al.*, 1991).

At first, however, the congruence between ground and satellite data was not noticed. The scientists operating the TOMS equipment had dismissed the low Antarctic ozone readings as errors because they were so far below ozone readings from other parts of the world (Gribbin, 1988).

Compared to declines of 1–2 percent elsewhere in the world, the springtime ozone over a large area of Antarctica was dropping by 10–20 percent (see Figure 5.20). The decline accelerated around 1980 and by 1983 ozone levels in some parts of the Antarctic were falling from their normal springtime low of 300 Dobson Units (DU) to levels of 225 DU and lower. Below 225 DU, the thinning ozone layer became known as the 'ozone hole'. At sea level, this would represent a thinning of the layer from 3 millimetres to just over 2 mm. The hole continued to widen and deepen through the 1980s, with ozone levels in some parts declining to less than 150 DU.

Using data from 1979 to 1990, the best computer models successfully predicted the global ozone characteristics for 1991, including a small central area where total ozone fell to less than half its normal level (i.e. less than 150 DU). The models allowed for seasonal effects, the global circulation effect known as the global Quasi-Biennial Oscillation (QBO), and the solar cycle. However, the record low global ozone levels of 1992 and 1993 were 1–2 percent lower than predicted (Gleason *et al.*, 1993; Herman and Larko, 1994).

**Figure 5.19**
**The Antarctic Ozone Hole 1980-1996.**




In 1993, the ozone hole extended over almost 24 million km$^2$ (an area larger than North America). At its October peak, in the atmospheric zone between 14 and 19 km, ozone levels fell to just 1 percent of their usual level (World Meteorological Organisation, 1995). The most likely explanation for this abrupt drop was the eruption of Mount Pinatubo in June 1991, although the mechanism by which ozone might be affected by the volcanic eruption is still being debated by atmospheric chemists and climate modellers. In 1994, things got back to where they had been with ozone levels recovering as the volcanic particles in the stratosphere declined (World Meteorological Organisation, 1995). Despite the return to recent ozone levels, 1994 still produced a sharp reminder of the critical state of the ozone hole: Wednesday 28 September made the record books as the day with the lowest ozone value ever recorded over Antarctica: 88 DU.

Although the 1995 ozone hole did not quite match previous ones in extent or ozone loss, it did set a different record: it lasted longer than any other. The 1995 hole covered an area greater than 15 million km$^2$ for a total of 71 days compared with the previous high of 63 days in 1993 (GECR, 1995).

The latest hole, which formed in September and October of 1996, covered more than 22 million km$^2$. The ozone between altitudes 16 and 22 km was completely annihilated. The area with ozone depletion greater than 50 percent had grown from the small hole of 1991 to an area covering almost two thirds of the Antarctic (World Meteorological Organisation, 1996a, 1996b).

The ozone 'hole' forms over Antarctica and nowhere else because of the peculiar combination of extremely low temperatures (below -80°C) and strong air currents which circle Antarctica during the winter (the Antarctic Vortex). Of these, temperature is the more important (Gribbin, 1993). The Vortex effectively seals off Antarctica from other global air currents, trapping ozone and halogens above the continent.

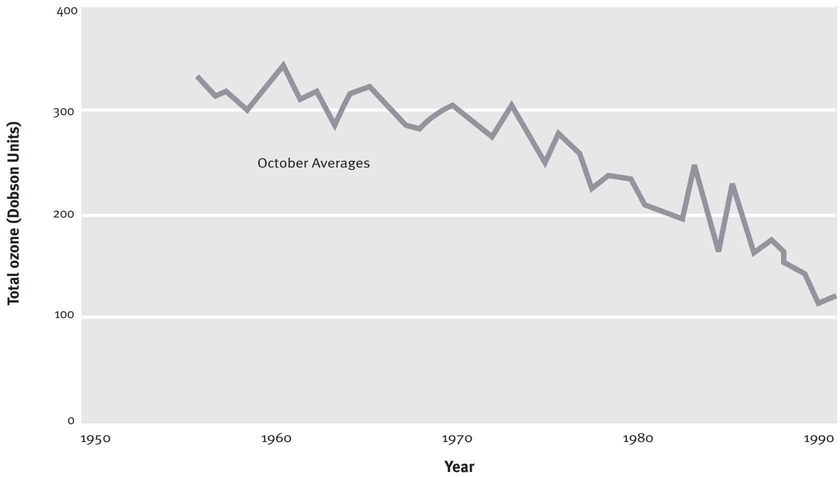
Meanwhile the intense cold produces ice particles in the polar stratospheric clouds. Chlorinated chemicals settle on these particles and react chemically with each other. These reactions turn the chlorine part of the CFC molecules into unstable compounds which begin attacking ozone when they are activated by the returning spring sunlight (see Box 5.4).

After the Antarctic Ozone Hole was discovered, some scientists took the view that it might be a natural event caused by volcanic chlorine emissions from Mount Erebus rather than manufactured chlorinated chemicals. Eventually, however, Mount Erebus was exonerated (Zredna-Gostynska *et al.*, 1993). Most of the chlorine Mount Erebus throws up takes the form of hydrogen chloride (HCl), which (like other chlorine from natural sources) readily dissolves in the water vapour of the lower atmosphere well before it can reach the stratosphere.

For Mount Erebus to affect the ozone layer, the volcano would have to inject a large proportion of its hydrogen chloride directly into the stratosphere, above a height of about 10 km. Mount Erebus has been active since it was first observed by James Ross in 1840, but appears never to have erupted with the force necessary to send chlorine directly into the stratosphere. The mountain itself is almost 4,000 m high (3,794 m), but the volcanic plume seldom rises above 5,000 m. The amount of gas Mount Erebus emits also bears no relation to the size of the ozone hole. In the summer of 1983, chlorine emissions from Mount Erebus were about 170 tonnes a day. In the following seven summers, when ozone depletion was even more severe, the chlorine emissions ranged from one-tenth to one-quarter of the 1983 figure (Zreda-Gostynska *et al.*, 1993).

Another popular misconception is that New Zealand is directly affected by the Antarctic Ozone Hole. At no time since its discovery has the Antarctic Ozone Hole itself ever extended as far north as New Zealand. In springtime, when the ozone hole covers the Antarctic, New Zealand usually lies under an area rich with ozone (see Figure 5.19). However, for about a day in September 1993, an unusual distortion in the polar vortex pushed an area of low ozone over southern New Zealand. This resulted in ozone values of 270 Dobson Units (DU) compared with the month's long-term average of about 380 DU.

**Figure 5.20**
**Average October total ozone, Halley Bay, Antartica, 1957-94.**




*Source: WMO (1995).*

Until then the record September low had been 300 DU.

The Antarctic Ozone Hole is expected to begin getting smaller sometime around 2010 and should cease to form by 2050 if current controls on ozone-depleting substances are maintained indefinitely. The period of most intense ultraviolet-B radiation is likely to be over the next dozen years or so.

### The state of solar ultraviolet radiation

Ozone depletion has led to a significant increase in ultraviolet radiation in New Zealand since the 1970s. Between the mid 1970s and the 1990s, ozone declined by approximately 5–7 percent. Over the same period, it is estimated that skin-damaging (UV-B) solar radiation probably increased by about 6–9 percent (McKenzie, 1996). Ultraviolet radiation has been implicated in the development of malignant melanoma, as well as sunburn, skin ageing, and cataract formation, and several studies are underway to gather hard evidence of the links between ultraviolet radiation in New Zealand and its relationship to skin disorders.

Zheng and Basher (1993) analysed data taken from a Robertson-Berger (R-B) meter at Invercargill from 1981 to 1990. They concluded that in clear sky conditions there is a significant trend to higher UV-B and that this corresponds with the downward trend in ozone. They estimated that UV-B radiation had increased during that decade by about 6 percent in

clear-sky summertime at Invercargill.
The increase was particularly steep between 1982 and 1985.

Since 1990, NIWA scientists have been monitoring spectrally-resolved ultraviolet radiation with narrow band spectroradiometers at the Lauder atmospheric research facility in central Otago. Although these instruments cannot log data continuously, they are much more accurate than R-B meters. Spectrally-resolved measurements clearly show that, when ozone levels go down, ultraviolet radiation levels go up. In New Zealand, however, this trend has not shown up with the spectroradiometer monitoring because the ozone levels have been relatively stable since the instruments were introduced (McKenzie, 1996).

To date the most conclusive evidence that ozone depletion would logically result in more harmful ultraviolet radiation reaching the Earth's surface has come from data collected by the satellite-borne Total Ozone Mapping Spectrometer (TOMS). Recent analysis of the TOMS data shows that ultraviolet radiation capable of damaging DNA must have been increasing at a rate of about 8 percent per decade in the spring, early summer, and autumn around latitude 40°, a zone which includes the lower North Island of New Zealand. Further south, the low temperatures that foster ozone loss appear to have boosted the increase in solar radiation to 10 percent to 12 percent per decade. Only the tropics and subtropics have been spared any ultraviolet increases (Kerr, 1995c).

White *et al.* (1992) measured ultraviolet radiation at Auckland, Wellington, and Christchurch. Although their relatively short data series prevented them from making statements about trends, they determined the actual levels of erythemal (sunburn) and carcinogenic (melanoma) ultraviolet radiation for the three sites, including its variation with latitude, season, and cloud cover.

Latitudinal differences in ultraviolet have been measured by cross-calibrated sensors in the north and south of New Zealand. These measurements show that averaged over a year, the north receives 25 percent more ultraviolet than the south. The north of the country receives approximately 10 percent more ultraviolet than the south in summer, and twice the amount in winter. The dominant factor in the amount of ultraviolet reaching New Zealand is the overhead position of the Sun, which causes large seasonal variations, especially in the south. At both sites, clouds reduced the amount of ultraviolet received by 25–30 percent compared with clear sky conditions. Seasonal changes in ozone also cause significant changes in ultraviolet, and day-to-day variations cause ultraviolet fluctuations of up to 10 percent (McKenzie *et al.*, 1996).

Although ozone levels over New Zealand have been fairly stable since the early 1990s, further depletion can be expected as the ozone-depleting substances released over the past 50 years continue to float into the stratosphere. As a result, levels of UV-B radiation are not likely to decline until well into next century when the ozone layer starts to recover (see Figure 5.18).

Seckmeyer and McKenzie (1992) made the particularly interesting comparison between New Zealand (Lauder in central Otago) and a site of comparable latitude in Germany. They showed that in the New Zealand summer of 1990–1991 the amount of ultraviolet radiation harmful to plants and animals was 30 to 60 percent more than the amount occurring in summer in northern Germany. Two further surveys have confirmed that result (McKenzie *et al.*, 1993; Seckmeyer *et al.*, 1995). The large difference has been attributed mainly to the lower amounts of stratospheric ozone above New Zealand, as well as to the greater amount of tropospheric ozone (caused by pollution and aerosols) over northern Europe.

**Box 5.6**

### *The potential impacts of excessive ultraviolet-b (UV-B) radiation*

Ultraviolet-B (UV-B) radiation can damage property, causing paint to fade, window glazing to yellow, and car roofs to become chalky. At high levels it can also damage many of the plastics used in the building industry and elsewhere. Costly though this sort of damage is, most of the concern about ozone depletion has centred on the potential impacts on health and the environment (UNEP, 1994). UV-B radiation has increased measurably in temperate latitudes as a result of ozone depletion (Kerr and McElroy, 1993; Appenzeller, 1993b; Kerr, 1995c; Madronich *et al*., 1995; Slaper *et al*., 1996). In New Zealand, the increase of about 6–9 percent since the 1970s is compounded by the fact that our summer coincides with the period of lowest ozone and with the phase of the Earth's orbit which takes us slightly closer to the Sun (McKenzie, 1996). As a result, peak summertime levels of sunburning radiation are 40 percent more intense here than at comparable northern latitudes. Because the majority of people living in New Zealand are fair-skinned, and the majority of our farm animals spend the entire year outdoors, the potential health risks from UV-B are higher here than in many other countries.

UV-B rays are known to damage the proteins that make up living tissue (such as skin or plant tissue). They can also cause mutations in the underlying genes that manufacture these proteins. Such damage can cause the exposed tissue to die (e.g. the peeling skin which follows sunburn), or form scar tissue (e.g. cataracts and the yellow lumps on the eyeball known as pterigia), or grow aberrantly (e.g. skin cancers). Excessive exposure to UV-B can also suppress the efficiency of the body's immune system, reducing resistance to disease, such as cancers, and latent viral infections (e.g. *Herpes simplex* and *H. zoster*). Three forms of skin cancer are associated with UV-B damage: the non-melanocytic skin cancers (which include both squamous and basal cell carcinomas) and melanoma. Non-melanocytic skin cancer does not spread and usually responds to treatment. Melanoma, however, (the type most people refer to as 'skin cancer' or simply 'melanoma') can spread and cause death if not treated. Early detection of melanoma results in successful treatment in 95–100 percent of cases, but a delay of 5 years in detection can lower the chance of survival to 20 percent.

Over the past few decades, skin cancer has become a serious problem. The number of melanoma cases in virtually all fair-skinned Caucasian populations around the world has risen over the past 40 years. Incidence rates of melanoma in New Zealand's non-Maori population have continuously been among the highest registered worldwide, and are only exceeded by rates in some Australian States, and among white Hawaiian men. New Zealand men and women have the highest melanoma death rates in the world (Bulliard and Cox, 1996). The main cause of rising skin cancer rates in New Zealand, Australia, and North America appears to be human behaviour, that is the fad for fair-skinned people to tan their skins by 'sunbathing'. About 9 out of 10 melanomas occurring among populations of European descent in Australia and New Zealand are attributable to sun exposure. Potentially, this makes melanoma one of the most preventable cancers (Bulliard and Cox, 1996). Worldwide, around 10,000 people die from melanoma each year. Roughly 2 percent of these are New Zealanders—180 in 1991, rising to about 260 today, and projected to reach around 380 by 2005 (Cox, 1995; Ansley, 1996). During the 1980s, the number of recorded new melanoma cases increased by about 2.5 percent per year and had reached 1,000 by 1991 (Public Health Commission, 1994). The rate appeared to have levelled off from the late 1980s (Bulliard and Cox, 1996) but the latest figures indicate that this was probably because of under-reporting. Melanoma reporting became compulsory for medical practitioners from 1 July 1994 under the Cancer Registry Act 1993. In the first full year of compulsory reporting (1 July 1994 – 30 June 1995) the New Zealand Health Information Service's provisional figure for the number of melanoma cases was 1,618. The provisional figure for the 1993 calendar year (January–December) was 1,037.

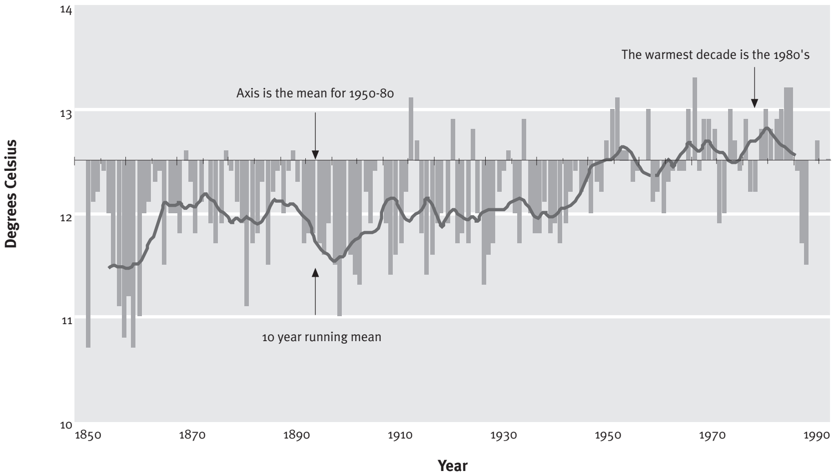
Although ozone depletion increases the biologically harmful solar ultraviolet radiation reaching the surface of the Earth, the actual contribution of ozone depletion to the skin cancer trend is not known. Estimated increases in skin cancer rates due to ozone depletion generally refer to non-melanocytic skin cancer. This is because melanoma risk is related to intermittent ultraviolet exposure whereas squamous cell carcinoma, and to a lesser extent basal cell carcinoma, are associated with chronic, and thus cumulative, ultraviolet exposure. Any direct links between ozone depletion, increased ultraviolet radiation, and rising rates of skin cancer are also blurred by the time lag between skin damage and the onset of cancer. However, researchers have estimated that under a 'no restrictions' scenario, unlimited production of ozone-depleting substances would have led to a quadrupling of skin cancer incidence by the year 2100—assuming no change in human behaviour to limit exposure to the sun (Slaper *et al*., 1996). Limited restrictions under the original Montreal Protocol would have seen a doubling of the incidence by the same date. However, a scenario based on the much tighter 1992 Copenhagen Amendments to the Montreal Protocol, shows a peak increase in the incidence of skin cancer of only 10 percent occurring 60 years later (see Figure 5.18).

UV-B related cancers are not confined to humans. Where pigs and goats, cattle and horses have inadequate access to shade they also fall victim to skin and eye cancers, and their exposure is less subject to seasonal fashions. It is not known whether their melanoma rates have increased in recent years. Plants are also affected by excessive UV-B light, and, because they rely on direct sunlight for energy, many species have developed protective mechanisms against high levels of UV-B. Despite this, experiments have shown that cotton, peas, beans, melons, and cabbage grow more slowly under intense UV-B, and pollen fails to germinate in some plants. Plant hormones and chlorophyll, the chemical mainly responsible for photosynthesis, can also be damaged. New Zealand scientists are currently studying ways of making crop plants more ultraviolet-resistant through selective breeding programmes and gene modification (Markham and Ryan, 1996).

Aquatic ecosystems are also vulnerable. UV-B can penetrate clear water to a depth of many metres, posing a threat to single-celled algae which are known from laboratory studies to be sensitive to UV-B. These organisms are at the very base of the aquatic food chain, and are also major consumers of carbon dioxide and emitters of anti-greenhouse sulphate aerosols. A serious reduction in algal biomass could therefore reduce fish populations and enhance the build-up of greenhouse gases in the atmosphere.

A study of Antarctic algae which were shielded from UV-B radiation by ice found no change in species composition over two decades of ozone depletion (McMinn *et al.*, 1996). However, a survey of algal blooms in open water found that biomass (total weight) fell by 6–10 percent in the waters where UV-B was most intense, beneath the springtime 'ozone hole' (Smith *et al.*, 1992). This represents about 7 million tonnes of lost photosynthesis per year, or a 2 percent depletion of the Southern Ocean's phytoplankton. The researchers noted that this reduction, though significant, was small compared to the seasonal advance and retreat of the ice pack which causes biomass reductions as high as 50 percent.

**Figure 5.21**
**New Zealand temperatures, 1853-1996.**




*Source: NIWA, unpublished data*

### The state of the climate

Over the years, instruments not very different from those being used today have measured the major climate variables of pressure, temperature, rainfall, and wind. Measurements at many New Zealand sites go back to the 1860s. Together, those indicators of the climate and its rate of change, give a guide to the state of our present atmospheric environment, and signal some trends.

### Temperature

Temperature is one of the most useful climate indicators available. Although it is difficult to identify rapid global temperature changes for the Earth in prehistoric times, global temperatures can be deduced for most of the planet's history. Good instrumental measurements have been taken from an increasing number of regions since the mid-nineteenth century.

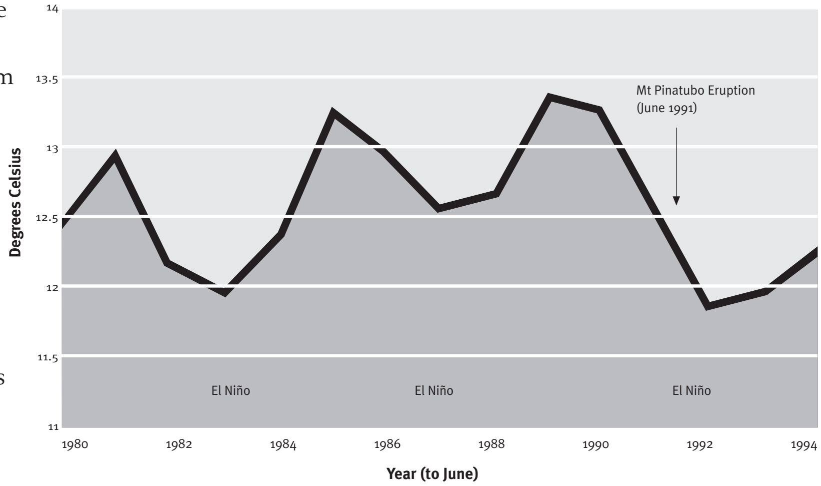
Climatologists attempt to track climate change by using global average temperature as an indicator. Despite the difficulties in establishing a true average for the whole globe through all seasons, the efforts are sufficiently accurate to show global temperature trends. Enormous amounts of meteorological data have been collected and archived over the past century. These high-quality records are described in the IPCC Report (Houghton *et al.*, 1992).

The climate monitoring records begin about 1860, and show a general temperature increase through to about 1940, little change to 1970, then an increase through to the 1990s. Globally, the four warmest years from the whole period are all in the 1990s: 1995 was the Earth's warmest year, while 1990, 1991, and 1994 were the second, third, and fourth warmest in that order. The 1995 global average surface temperature was 0.40°C above the 1961–1990 baseline, just eclipsing the previous record of 0.36°C of 1990. The 1991–95 period also tied for the warmest ever half-decade, despite the effects of Mount Pinatubo which erupted in the Philippines in June 1991 and cooled global temperatures in 1992 and 1993.

The New Zealand land surface temperature record has been constructed from data collected at 22 reference climatological stations (Salinger *et al.*, 1992a). Although each data series represents a single site, it is possible to derive from them a single figure representative of an annual temperature for the whole of New Zealand (see Figure 5.22). The pattern of temperature change in New Zealand has been similar to the global pattern over the past 130 years, but recent evidence suggests that New Zealand's temperature is increasing at a rate higher than the global average. Global average surface temperatures for the land and sea have increased by 0.45°C over the past 100 years, but New Zealand's temperature since 1900 has risen by 0.7°C (Salinger, 1995).

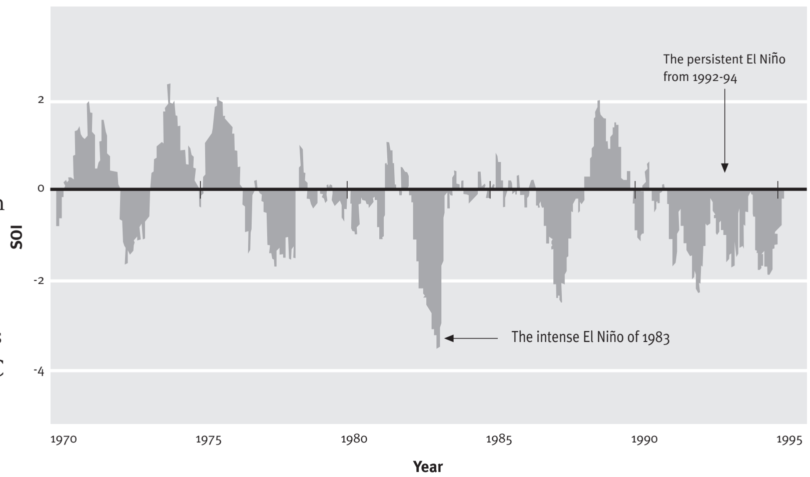
The warmest decade in New Zealand was the 1980s, and just as 1995 was the Earth's warmest year on record, it was also New Zealand's warmest year since 1990. Global temperatures have remained high in the 1990s, but recurring El Niño episodes since 1990 have had a cooling effect on New Zealand's climate. New Zealand's very much cooler year of 1992 was directly attributable to the combination of Mount Pinatubo's eruption and the persistent El Niño event. The national average temperature began increasing again from 1992 as the cooling effect of Mount Pinatubo faded away (see Figure 5.22).

**Figure 5.22**
**New Zealand average temperatures 1980-94.**




*Source: NIWA, unpublished data*

**Figure 5.23**
**The Southern Oscillation Index (SOI), 1970-95.**




*Source: NIWA, unpublished data*

**Rainfall**

Short-term fluctuations in local or regional rainfall from year to year, or decade to decade, reflect airflow changes and their interaction with the mountains, as well as changes in airflow induced by El Niño/La Niña events. Salinger *et al.* (1992) conclude that in the last decade, most North Island sites were drier than normal by up to 20 percent. Most western South Island stations recorded wetter than normal conditions in the 1980s, although there were some exceptions, such as Blenheim, Lincoln, and Dunedin, which were all drier than normal. These trends were caused by an unusually high number of El Niño episodes in that period (see Figures 5.23 and 5.24).

**Box 5.7**

***The potential impacts of global warming and climate change***

Nobody knows for sure what the effects of climate warming will be in any particular region, but there is broad agreement on the general changes that might occur (Tegart *et al.*, 1990; Tegart and Sheldon, 1993; Watson *et al.*, 1996). Models predict that the world's desert regions will become more arid, a third to a half of the mountain glaciers will melt, snowlines will rise by 150–550 metres, sea levels will rise by 20–80 centimetres, and the distributions of tropical and sub-tropical organisms will spread north and south by 150–550 kilometres (Watson *et al.*, 1996). The rising sea may inundate low-lying coastal areas, including a number of Pacific Islands. It may also erode coastlines and beaches and make groundwater supplies salty. Rainfall patterns will change, in some cases bringing more extreme conditions of flood or drought. One recent study found that, although the slight global warming of the past century has not changed the overall amount of rainfall, there has been an increase in rainfall variability with more extremes (Tsonis, 1996). Tropical cyclones may extend their range north and south. River and groundwater flows may change, reducing water supplies in some areas and increasing floods in others.

Natural ecosystems, and wild species of plants and animals, will undergo changes in their distributions and ranges. Warm-adapted species will increase and cold-adapted species will decline. Some alpine, sub-polar and cool temperate species may become extinct. Warmer seas will also favour algal growth, including increased blooms of toxic plankton. The abundance and distribution of some fish, marine mammal and seabird species may decline, though global marine fisheries production is expected to remain the same. Temperate forests may experience climatic stress in some areas, and although changed climatic conditions may favour the expansion of tropical forests, this is unlikely to offset the decline caused by human activities (Watson *et al.*, 1996).

Agricultural production in temperate regions will increase because of significantly longer growing seasons and fewer frosts, but will also be subject to greater weed and pest invasions from warmer regions. In the tropics, agricultural production will decline, causing increased risk of hunger and famine in areas of high population and low income.

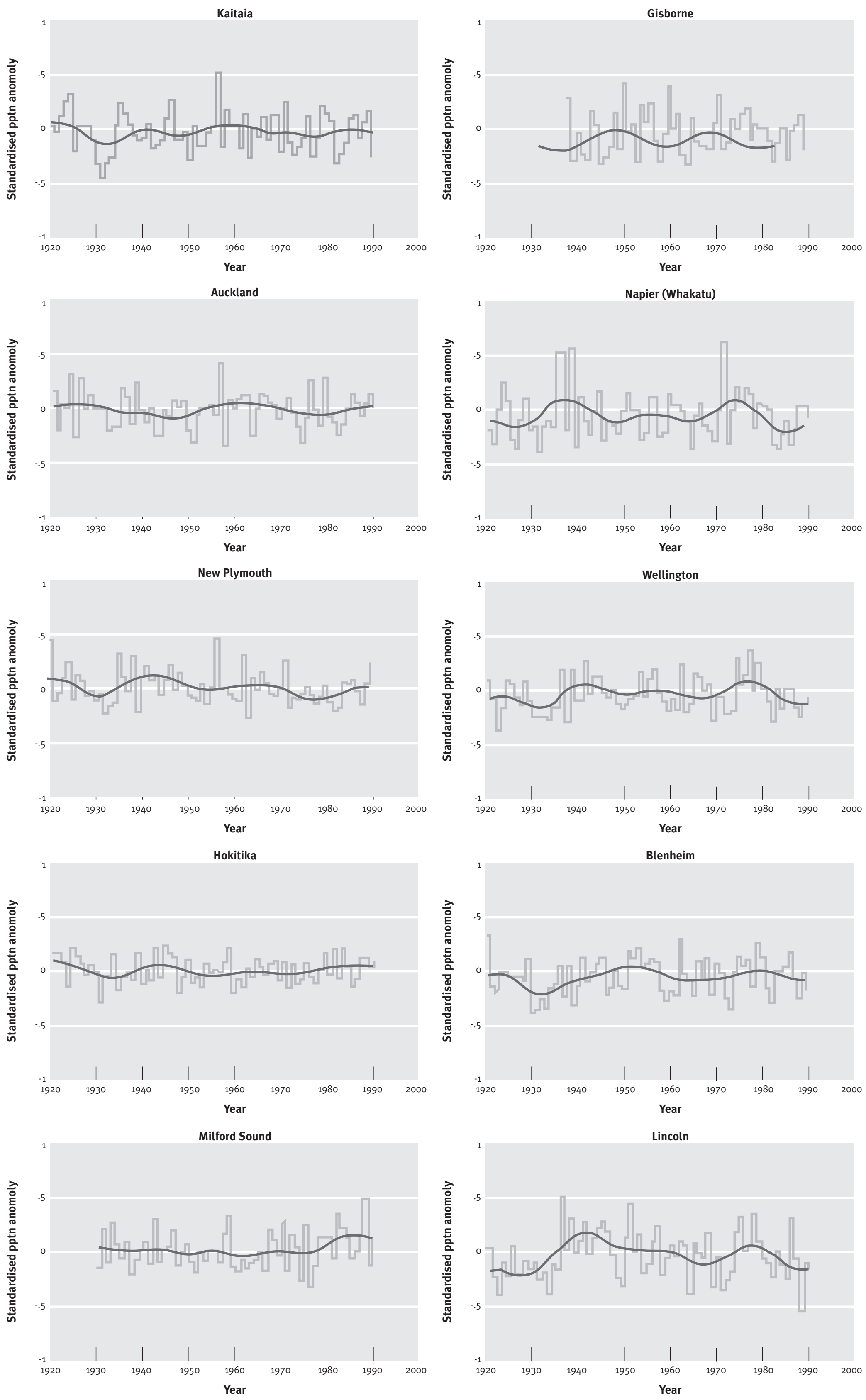
Other health impacts are expected to be wide-ranging and mostly adverse (Watson *et al.*, 1996; WHO, 1996). While cold-related deaths in temperate cities will decrease, heat wave deaths in warmer urban areas will increase, especially for the elderly and the poorly-housed. More significantly, infectious tropical and sub-tropical diseases, especially mosquito-borne pathogens (e.g. malaria, filariasis, dengue and yellow fever), will become more widespread (Stone, 1995; Weinstein, 1996). The proportion of the world's population at risk from them may expand from 45 percent to 60 percent. Rats and insect pests will also expand their ranges (Watson *et al.*, 1996; Saul, 1996). Temperate countries will become more vulnerable to a wider range of pests, weeds and diseases.

The impacts on New Zealand are uncertain, but two scenarios are commonly suggested (Royal Society, 1988, 1990 and 1992; Ministry for the Environment, 1990; Wratt *et al.*, 1991). The most likely scenario is based on New Zealand's previous period of maximum warmth 8–10,000 years ago and assumes a 1.5°C increase in temperature by 2050. The frost-free season would be some 40 days longer, the snowline would be 100–300 metres higher and the sea would be 20–40 cm higher. Westerly winds would decline by 10 percent, bringing fewer rainy days to western regions. However, rain would be heavier than at present so that the west and north would be about 10–15 percent wetter and the east and south would be 5–10 percent drier (Salinger and Hicks, 1990).

Westerlies would also decline in the second scenario, which assumes a temperature increase of 3°C. This would be accompanied by more frequent rain in the north associated with moist northerlies from the cyclone belt, and less rain in the south, particularly in Southland and Otago. The frost-free season would be at least 60 days longer than at present, the snowline 300–400 metres higher and the sea level about 30–60 cm above present levels (Salinger and Hicks, 1990). Under both scenarios, rainfall extremes are expected to be more frequent and widespread, causing flooding and erosion (Campbell and Ericksen, 1990; Griffiths, 1990). Droughts would increase in the east, with

**Figure 5.24**

**Variations in average yearly rainfall, 1920-90 (expressed in percentage terms, with -0.2 corresponding to 20% less rainfall, and 0.5 corresponding to 50% more rainfall).**




*Source: Salinger et al. (1992b)*

a 40 percent reduction in surface water in parts of Otago, Canterbury and Hawke's Bay. Sea level rise and increased rainfall would cause drainage problems in low-lying areas. Stormwater and sewerage systems could become overloaded more frequently, spilling contaminated water into surface waters. Smaller South Pacific nations may be more vulnerable to many health effects of climate change, including the direct effects of sea level rise and storms (Woodward, 1995).

Many of the most important medical conditions in New Zealand vary geographically and may be climate sensitive. Examples include asthma, heart disease, cot death, melanoma, and communicable diseases such as Hepatitis B. Little is known about how long the frequency and severity of these conditions may change under global warming. (There may be gains as well as losses.) There is potential for introduced disease, particularly arboviruses that cause Ross River fever and dengue, to be introduced and become established. Indirect health effects resulting from changes in food production, migration, and the extension of infectious diseases from tropical zones may also be important (Woodward, 1995). Researchers at the Wellington School of Medicine already say there is evidence that outbreaks of dengue fever (a viral disease spread by mosquitoes) in the South Pacific are closely linked to El Niño events (Hales, *et al*., 1996).

It is generally assumed that New Zealand's pastoral agriculture would be able to adapt to the new conditions, but crops, horticulture and viticulture may undergo some disruption if moisture levels and other micro-climatic conditions change significantly, and if invasive sub-tropical pests and weeds (such as the grass, paspalum) spread here. A complicating factor is the role of the El Niño–Southern Oscillation climate pattern and whether this is likely to aggravate the impacts of climate change (see Box 5.3).

A project called CLIMPACTS is making integrated assessments of the climatic effects on New Zealand agriculture, horticulture, grasslands, and soil nationally and regionally as well as at specific sites. CLIMPACTS is a collaborative programme involving two universities and five Crown Research Institutes (CRIs). It will increase the knowledge of the environmental effects of climate variability and change in New Zealand by pooling information and data from various sector-oriented science programmes into a mathematical model. This will be used as a basis for improved decision making in New Zealand (Royal Society of New Zealand, 1996).

## SOCIETY'S RESPONSES TO ATMOSPHERIC CHANGE

### Responses to ozone layer depletion

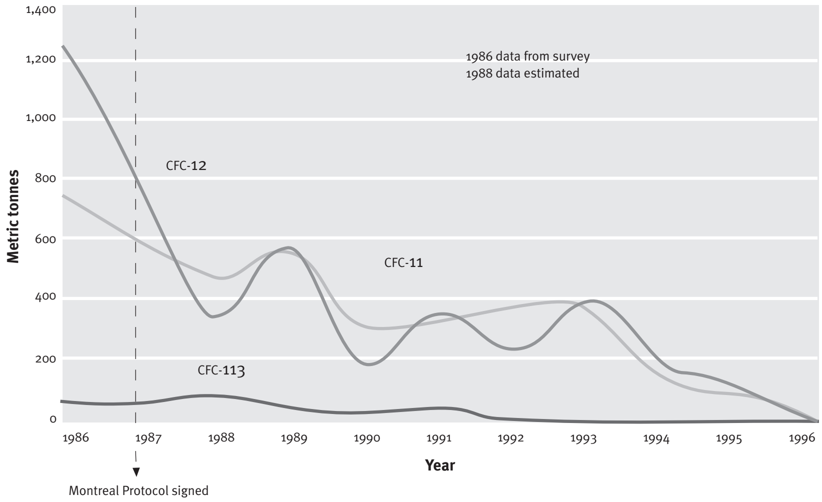
The concern about the destruction of the ozone layer by chlorofluorocarbons (CFCs) led to the signing of the Vienna Convention for the Protection of the Ozone Layer in 1985 (see Box 5.8). This was an international agreement by nations to take some action to stop atmospheric ozone depletion, but the nature of the action was not spelled out. The Vienna Convention was given teeth with the signing of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987. The Protocol set timetables for the phase-out of specific chemicals. As increasing numbers of synthetic chemicals have been implicated in ozone depletion, and as the science of the destruction process has become better understood, the Protocol has been amended twice (London in 1990, and Copenhagen in 1992), and adjusted once (Vienna in 1995). These amendments and adjustments have added new chemicals to the list and tightened the phase-out timetables (see Boxes 5.8 and 5.9). (Amendments to the Protocol must be ratified by governments to take effect; adjustments do not require ratification.)

A ban on the production of various CFCs and halons began in January 1996, as required by the Montreal Protocol, and the consumption of CFCs and halons is now dropping globally. There are indications that the ozone-destroying potential of atmospheric chlorine and bromine peaked in the troposphere in 1994.

Provided countries abide by the provisions of the Montreal Protocol, the chlorine/bromine destruction potential should peak in the stratosphere between 1997 and 1999. The ozone layer would then begin to heal slowly, reaching pre-ozone-hole levels by about the year 2050 (Hofmann, 1996) (see Figure 5.18).

Because New Zealand does not manufacture CFCs and halons, assessment of local use is based on import data. Figure 5.25 shows the amount of three ozone-depleting substances imported into New Zealand from 1986 to 1996, the phase-out completion year. The international phase-out timetables for ozone-depleting substances, and the staggered deadlines applying to New Zealand industries which use them, are shown in Box 5.9.

**Figure 5.25**
**New Zealand imports of three continuously used ozone-depleting substances, 1986-96.**




*Source: Ministry for the Environment, unpublished data*

Parties to the Montreal Protocol must also monitor the manufacture or the importation of other ozone-depleting substances. These include hydrobromofluorocarbons (HBFCs), hydrochlorofluorocarbons (HCFCs), carbon tetrachloride, methyl bromide, and methyl chloroform (see Box 5.9). In addition, the non-ozone-depleting greenhouse gases, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), are monitored by the Ministry for the Environment.

Imports of HBFCs were banned in advance of the Montreal Protocol's requirements from 1 July 1992. Imports of hydrochlorofluorocarbons (HCFCs) were frozen at 75 percent of the permitted 1989 'base year' figure from 1 January 1996. (New Zealand capped its HCFC imports 25 percent lower than allowed under the Copenhagen Amendments to the Protocol because only about half the permitted amount was imported in 1994.) Government policy is that HCFCs must be phased out by 2015, 15 years ahead of the Montreal Protocol requirement.

**Box 5.8**

***The Vienna Convention and the Montreal Protocol***

The controversial theory put forward by Molina and Rowland (1974) that chlorofluorocarbons could be destroying the ozone layer was debated by scientists and challenged by industry. Nevertheless, it captured the public imagination, and for the next three years pressure built up in the United States and other countries for controls to be placed on the use of CFCs. During 1975 and 1976, the United Nations Environment Programme (UNEP) organised several conferences to discuss threats to the ozone layer. In May 1977 the United States announced that it would phase out the use of CFCs in aerosol spray cans. CFC consumption fell temporarily in the early 1980s, but lingering scientific uncertainty about the impact of CFCs on the ozone layer caused some people to cast doubt on the need to reduce their use. Consumption began rising again with other uses making up for the cuts produced by the aerosol bans.

Firmer evidence of CFCs' impact on ozone came from laboratory studies and computer models in 1980. It suggested that CFCs could pose a serious threat to human health and the well-being of the planet. The threat was answered in 1985 when concerned nations met to sign the Vienna Convention for the Protection of the Ozone Layer. The Vienna Convention simply obliged signatory nations to take "appropriate measures to protect human health and the environment against adverse effects resulting, or likely to result from human activities which modify, or are likely to modify the ozone layer." The measures, however, were not specified. CFCs were only mentioned towards the end of the annex to the treaty, where it was suggested that the chemicals should be monitored.

The first evidence that urgent action was required came in mid-1985 when Dr Joe Farman and colleagues from the British Antarctic Survey published a paper showing that there appeared to be a massive loss of ozone in the spring at the Halley Bay station (Farman *et al.*, 1985). They had discovered what is now known as the Antarctic Ozone Hole (see Figures 5.15 and 5.16). On 16 September 1987, the Montreal Protocol was signed into being by representatives of 21 nations. The Protocol actually came into force on 1 January 1989, by which time 29 countries and the EEC had ratified it. It set the minimum requirement of freezing the consumption of five CFCs (CFCs 11, 12, 113, 114, and 115) at 1986 levels by 1 July 1989, with a similar freeze on the consumption of three halons (Halons 1211, 1301, and 2402) to be achieved by 1 February 1992.

Since the Montreal Protocol came into force, the phase-out schedules have been tightened three times, first by the London Amendments in 1990, then by the Copenhagen Amendments in 1992, and most recently, by the Vienna Adjustments in 1995. The London Amendments added methyl chloroform, carbon tetrachloride, and ten other CFCs to the list of ozone-depleting substances. The Copenhagen Amendments added HCFCs, HBFCs, and methyl bromide to the list of chemicals in the phase-out schedules. They also required Protocol Parties to completely phase out their consumption of ozone-depleting substances (except HCFCs and methyl bromide) by 1 January 1996. The Vienna Adjustments added a phase-out schedule for methyl bromide and brought forward the phase-out schedule for HCFCs.

**Box 5.9**

### *Phase-out timetables for ozone-depleting substances*

As a Party to the Montreal Protocol on Substances which Deplete the Ozone Layer, New Zealand has agreed to phase out all ozone-depleting substances no later than prescribed by the Protocol's timetables. Not all substances have to be phased out at the same rate, or have the same deadline, although all known ozone-depleting substances except HCFCs and methyl bromide, became prohibited imports from 1 January 1996. The phase-out schedules for New Zealand users are contained in the Ozone Layer Protection Act 1990. As no ozone-depleting substances are manufactured in New Zealand, the phase-out schedules relate to imports.

### *New Zealand phase-out schedules for imports of ozone-depleting substances*

**Halons:** Imports banned from 3 October 1990.

**HBFCs:** Imports banned from 1 July 1992.

**CFCs:** (CFC phase-out schedules differ for each industry. CFC use in spray cans was banned in 1990, except for those required for medical purposes.)

*National Overall Target:*
75% phase-out by 1 January 1994.
100% phase-out by 1 January 1996.

*Refrigeration and Air conditioning Industry:*
55% phase-out by 1 July 1992.
70% phase-out by 1 January 1994.
90% phase-out by 1 January 1995.
100% phase-out by 1 January 1996.

*Plastic Foam Making Industry:*
55% phase-out by l July 1992.
100% phase-out by 1 January 1996.

*General Solvent Use:*
50% phase-out by 1 July 1993.
60% phase-out by 1 January 1994.
90% phase-out by 1 January 1995.
100% phase-out by 1 January 1996.

*Dry Cleaning:*
20% phase-out by 1 July 1990.
100% phase-out by 1 January 1996.

**Methyl chloroform:**
10% phase-out by 1 July 1993.
50% phase-out by 1 January 1994.
100% phase-out by 1 January 1996.

**Carbon tetrachloride:**
85% phase-out by 1 January 1994.
100% phase-out by 1 January 1996.

**Methyl bromide:** The Montreal Protocol requires that methyl bromide production and consumption be frozen at 1991 levels from 1 January 1995 and phased out in four steps by 2010. (Quarantine and pre-shipment (QPS) fumigation uses are exempt.) Consideration is also being given to a 'critical agricultural uses' exemption after 2010. This term was not defined at the Parties' conference in Vienna in 1995.
A timetable for phasing out methyl bromide use in New Zealand is still under consideration.

**HCFCs:** Protocol requirement: freeze at 1989 'Base Year' figure from 1 January 1996.
100% phase-out by 1 January 2030.
New Zealand has agreed to a phase-out schedule faster than required for HCFCs under the Montreal Protocol. This caps consumption at 75% of the base year figure, and completely phases out consumption by 2015. (HCFC use in spray cans was banned in 1990, except those required for medical purposes.)

**Responses to the threat of climate change**

Unlike ozone depletion, which can only be dealt with by reducing emissions of the main pollutants, the threat of climate change can be dealt with in two ways: reducing emissions, or increasing the amount of carbon dioxide that is absorbed from the atmosphere.

Emissions can be reduced by either cutting back the activities that give rise to them (e.g. transport, industrial processes, agriculture), or developing new ways of doing things so that fewer emissions are produced (e.g. by using non-carbon energy sources, or more fuel-efficient technology).

Carbon absorption can be increased by boosting the amount of photosynthesis on Earth. Plants, algae and cyanobacteria absorb carbon dioxide whenever they trap the sun's energy through photosynthesis. The carbon is stored in their tissues and is only released back into the atmosphere when the organisms are oxidised—that is, when they are consumed by bacteria or fungi (i.e. decomposition), or animals (i.e. digestion), or fire (i.e. combustion). When trees are harvested for timber, some of the carbon remains in storage, as planks and other wood products, but the rest is released back into the atmosphere through these oxidative processes.

A mature forest is a carbon 'reservoir'. The trees have stopped growing and have locked up all the carbon they can. As a result, the amount of carbon dioxide absorbed by a mature forest is roughly equal to the amount lost through the natural oxidation of dead trees, fallen branches and leaves, and ingested wood and foliage. In contrast, an immature forest absorbs much more carbon than it releases because it is still growing. Young forests are therefore carbon 'sinks' that actively remove carbon dioxide from the atmosphere.

Globally, carbon reservoirs and sinks are declining through deforestation, but, in New Zealand, that trend has reversed. Most of our indigenous forests are mature carbon reservoirs that are legally protected from deforestation while many commercial exotic forests are young and fast-growing carbon sinks. This has led New Zealand to take a somewhat different approach from other countries in trying to meet its international obligations on greenhouse gas emissions.

The international movement to reduce the risk of climate change began in the early 1980s when the United Nations first recognised the increasing scientific concern about rising greenhouse gas emissions. In 1988 the UN General Assembly resolved to protect the global climate for present and future generations. As part of the response, the UN established the Intergovernmental Panel on Climate Change (IPCC) to provide the best possible scientific information and advice (see Box 5.5). That same year, New Zealand's Climate Change Programme was established, calling on all sectors of society to voluntarily make every effort to prevent detrimental effects on the world's climate.

Meanwhile, officials from UN member countries formed the Intergovernmental Negotiating Committee (INC) and began negotiating to get wide acceptance for a treaty that would commit each country to take steps to reduce the risk of climate change. In June 1992, at the United Nations Conference on the Environment and Development (UNCED or the 'Earth Summit') held in Rio de Janeiro, more than 150 nations signed the Framework Convention on Climate Change (FCCC) (see Box 5.10).

**Box 5.10**

### *The UN Framework Convention on Climate Change (FCCC)*

The United Nations Framework Convention on Climate Change ( FCCC) is the international agreement negotiated under United Nations auspices to address concerns about climate change. It came into force on 21 March 1994. Its objective is:

> ... stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

Among other things, the FCCC requires a commitment from developed countries to limit carbon dioxide and other human-induced greenhouse gas emissions not controlled by the Montreal Protocol, and to protect and enhance greenhouse gas sinks and reservoirs. Although the FCCC contains no legally binding targets or timetables, the general interpretation is that developed countries are committed under the convention to reducing their emissions to 1990 levels by the year 2000.

In April, 1995, at the first Conference of the Parties to the Convention, it was decided that existing commitments in the FCCC were inadequate to achieve the objective of avoiding dangerous human-induced interference with the climate system. The Parties established the Berlin Mandate process to negotiate strengthened commitments for developed countries, and to advance the existing commitments of developing countries, for the period beyond 2000. These negotiations are still in progress and are set to conclude in December 1997.

In July 1994, four months after the FCCC came into force, the New Zealand Government announced a set of measures to reduce carbon dioxide emissions. Like other developed countries (i.e. those in the OECD), New Zealand set itself the target of reducing emissions to 1990 levels by the year 2000 and maintaining them at that level from then on (Ministry for the Environment, 1994). However, while the other countries chose to reduce and stabilise their 'gross' emissions, New Zealand opted to reduce its 'net' emissions.

The difference is significant. 'Gross' emissions are the total amount of carbon dioxide that is released into the atmosphere from fossil fuel use and lime-burning industries such as cement manufacture. However, this does not include the extra carbon added by deforestation or the amount removed by forest growth. 'Net' emissions do take forest changes into account. As a result, 'net' emissions will be greater than 'gross' emissions wherever forest losses from harvesting, fires, pest damage and land clearance exceed a country's new forest growth. Conversely, 'net' emissions that will be lower than 'gross' emissions in countries whose forest growth exceeds deforestation. New Zealand's 'net' emissions are much lower than its 'gross' emissions so the 'net' target was adopted because it seemed much more achievable and less economically disruptive than a 'gross' target.

The spread of young commercial forests in New Zealand has been facilitated by a tax regime that allows businesses to deduct virtually all the costs of establishing and maintaining a forest in the year the expenditure is incurred. Of course, tax eventually has to be paid on the sale of the harvested trees but that is 25–35 years after planting. However, forest sinks cannot expand indefinitely, and ultimately emissions will have to be reduced to meet our international obligations. Recent assessments of forest plantings have reinforced this fact. In 1994, when new forest plantings reached a record high of 98,000 hectares, it seemed that they would continue at a rate of 100,000 hectares per year for the rest of the decade. But since then they have declined. New estimates by the Forest Research Institute now predict a planting rate of around 72,000 hectares per year until the year 2000, falling to 57,000 hectares per year for the next decade (Glass, 1996).

Of course, New Zealand's climate change policy recognised that forest growth alone would not offset all emissions and that something would also have to be done about gross emissions. Although it did not aim to reduce gross emissions, the policy did aim to slow down their growth by at least 20 percent. The key measures designed to achieve this were: energy sector reforms; an energy efficiency strategy managed by the Energy Efficiency and Conservation Authority (EECA); further development of renewable energy sources, also managed by EECA; use of the Resource Management Act; and a voluntary agreements scheme with industry. There were parallel policies to encourage increased carbon storage in plantation forests. It was expected that these measures in combination would ensure that New Zealand would achieve its $CO_2$ policy objectives.

Also in the 1994 policy package was the warning that a low-level carbon charge would be introduced in December 1997 if it looked as though net carbon dioxide emissions would not stabilise at 1990 levels by the year 2000, or if the combination of measures for gross emissions did not achieve at least a 20 percent reduction in the growth in annual emissions for the period up to the year 2000. To encourage lower increases in carbon dioxide emissions, the Ministry of Commerce negotiated voluntary agreements with key industries and, by mid-1996, 21 agreements had been made.

To date, the only laws or regulations applying to greenhouse gas emissions are the controls on industrial air pollution imposed by local authorities under the Resource Management Act. Large emitters, such as companies engaged in energy-intensive industries like metal smelting, powdered milk manufacture and paper production, must receive an air discharge consent from their local authority. In one case, the Minister for the Environment decided to 'call in' a consent application for a new power station because it had the potential to increase New Zealand's $CO_2$ emissions by 5 percent (see Box 5.11).

**Box 5.11**

### *The Stratford power station 'call-in'*

In December 1993, the Minister for the Environment used the provisions of the Resource Management Act 1991 to 'call in' an application by the Electricity Corporation of New Zealand (ECNZ) to the Taranaki Regional Council for a consent to build a new gas-fired combined cycle power station at Stratford in Taranaki. The proposed station had the potential to add 5 percent to New Zealand's gross carbon dioxide emissions, and the Minister was concerned at both the domestic and international implications of the project in terms of greenhouse gas emissions and climate change policy.

A Board of Inquiry studied the proposal and recommended to the Minister that the consent be issued with a condition that the consent holder establish a carbon sink of sufficient size to absorb as much carbon as would be released from the plant during the term of the permit. This would have required the planting of about 3,500 hectares of new plantation forest for each year of the station's operation. The Minister granted the consent in March 1995 but made the condition more flexible so that, besides tree planting, $CO_2$ mitigation measures could take the form of reductions in existing power generating emissions or cuts in carbon dioxide emissions in sectors outside electricity generation (i.e. through energy efficiency measures).

The Minister also reduced the mitigation requirement to apply only when emissions from the electricity sector exceeded the level reached just before the plant began operation. This rewarded the station owners for indirectly reducing $CO_2$ emissions by replacing some older, less efficient, stations with the new plant. The proposed station and consent were subsequently sold to a consortium consisting of TransAlta, a Canadian utility, and two New Zealand companies, Mercury and Fletcher Challenge, the latter with extensive energy and forestry interests.

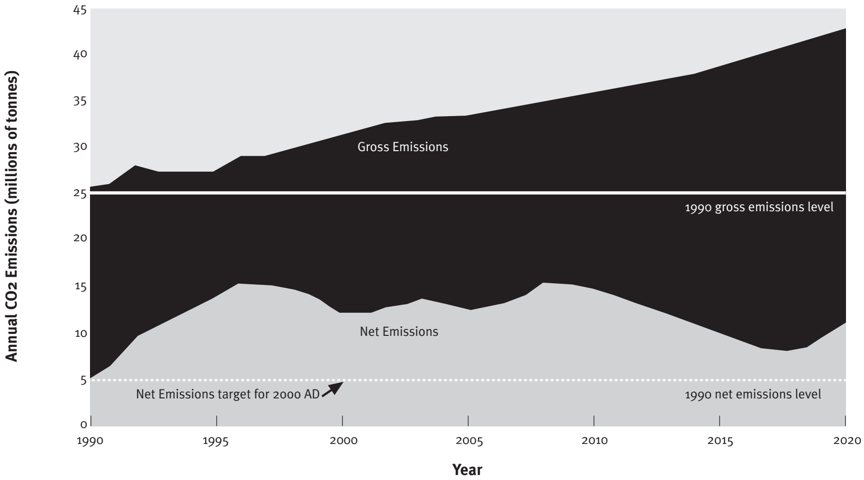
In August 1995, the New Zealand Government followed up its 1994 measures by establishing the Working Group on $CO_2$ Policy. The Working Group was instructed to report back on several issues:

- whether the Resource Management Act is an appropriate mechanism for dealing with global pollutants such as carbon dioxide;
- the effect of strong economic growth on emission levels;
- whether New Zealand should continue to pursue the 'net' approach to carbon dioxide limitation; and,
- whether a carbon tax, or some other economic instrument (such as a tradeable emission permit system), is the best way to achieve the Government's carbon dioxide objectives.

The Minister for the Environment released the Working Group's report for public consultation on 20 June 1996 (Ministry for the Environment, 1996). The report concluded that New Zealand should continue with the 'net' approach in dealing with carbon dioxide. It also advocated the use of an 'economic instrument' to control carbon dioxide emissions, concluding that this approach would be more flexible and less costly than subsidies or regulations. In the four months following the report's release, submissions were invited from the public to assist in the further development of New Zealand's climate change policy (Ministry for the Environment, 1997b).

The need for further policy development is driven by the fact that New Zealand is not on track to achieve its current policy target of reducing 'net' carbon dioxide emissions to the 1990 level by the year 2000 and maintaining them at that level thereafter. In fact, 'net' carbon dioxide emissions in 1995 were nearly three times their 1990 level and are projected, in the absence of further measures, to remain well above the target level for the next three decades (see Figure 5.26).

**Figure 5.26**
**Projected 'gross' and 'net' emissions of carbon dioxide in New Zealand[1,2]**

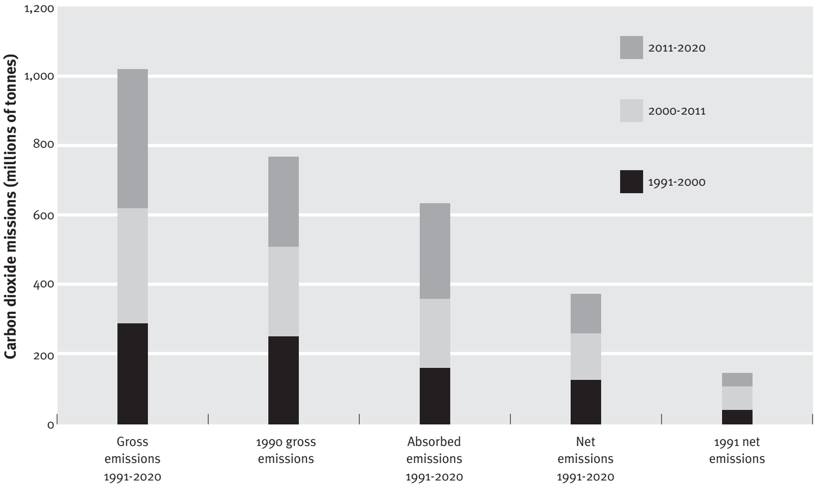



*Source: Ministry for the Environment (1997a)*

1 *These projections cover emissions from energy and industrial sources as well as those from forest harvesting, scrub clearance for new planting, wild fires and prescribed burning. They assume: (1) no additional policy measures; (2) GDP growth of 3 percent per year; and (3) new forest plantings of 70,000 hectares per year up to 2005 AD, falling to 55,000 hectares per year thereafter.*

2 *The 1994 policy target of reducing net emissions to 1990 levels by the year 2000 and maintaining them thereafter is currently being reassessed and different targets may be set for the period for the period beyond 2000.*

**Figure 5.27**
**Cumulative carbon dioxide emissions in New Zealand 1991-2020[1].**




*Source: Ministry for the Environment (1997b)*

[1] *Assumptions are the same as in Figure 5.26. The 1990 cumulative emissions are included here as a benchmark for comparison. They have been calculated by simply multiplying the emissions for that year over the three decades.*

Between 1990 and 1995 our yearly 'gross' carbon dioxide emissions increased by about 7 percent as economic growth increased. At the same time, the amount of carbon absorbed annually by plantation forests fell by 34 percent as more trees than expected were harvested and fewer planted. The increase in 'gross' emissions was in line with the policy (i.e. 20 percent lower than 'business as usual' projections). However, despite the slowed rate of increase, 'gross' emissions are projected to keep rising beyond the year 2000, driven by economic growth, while forest planting rates are expected to decline after that point. As a result, New Zealand's 'net' carbon dioxide emissions in and beyond the year 2000 will remain above the 1990 level even though the total size of the nation's carbon sink will keep expanding.

Under the current policy, New Zealand measures its performance in dealing with carbon dioxide by comparing the 'net' emissions in a given year with those in 1990, the chosen baseline year. However, single year comparisons can obscure the overall trend by omitting the intervening years. An alternative approach is to sum all the emissions over a given time period and compare the cumulative totals. When viewed in this way, the bigger picture can be seen more clearly and the cumulative contribution of forest growth can be better assessed.

Under a continuation of the current policy, for example, our cumulative 'net' emissions in 2020 would be around 375 million tonnes—two and a half times the 1990 level aggregated over the same period (see Figure 5.27). This confirms the trend seen in year-to-year comparisons but also shows that the 'net' emissions would be three times greater were it not for young forests absorbing most of our gross emissions. The cumulative view also shows why the 1990 'net' emission level cannot be met without an actual reduction in gross emissions. On current trends, 'gross' emissions will exceed a billion tonnes by the year 2020, which is 33 percent higher than they would have been if 'gross' emissions had been held at the 1990 level. Had 'gross' emissions been held at the 1990 level, forests would have absorbed 84 percent of them, pushing New Zealand's 'net' emissions below the 1990 level.

**Table 5.6**
**Greenhouse gas emissions inventory 1990–95.**

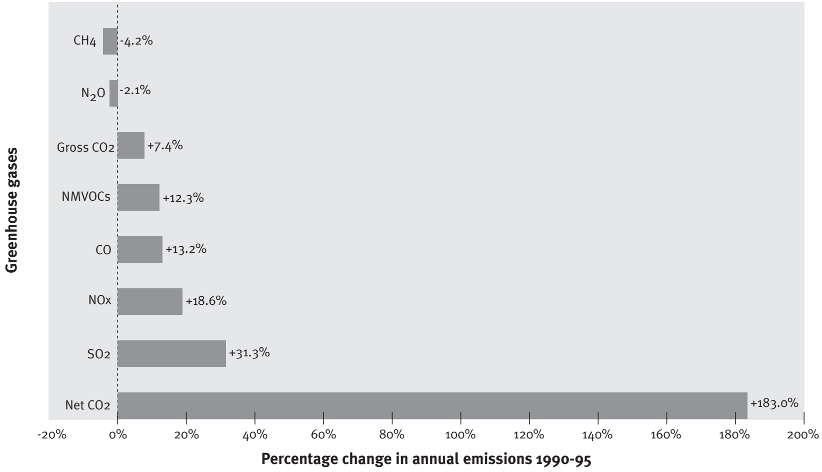
| | Annual emissions (1,000 tonnes) | | | | | |
|---|---|---|---|---|---|---|
| **Greenhouse Gases** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** |
| *$CO_2$ emissions* | 25,476 | 26,007 | 27,954 | 27,276 | 27,326 | 27,368 |
| *$CO_2$ absorption* | -20,569 | -19,630 | -18,173 | -16,136 | -14,708 | -13,490 |
| *Net $CO_2$ emissions* | 4,907 | 6,377 | 9,781 | 11,140 | 12,618 | 13,878 |
| *$CH_4$* | 1,706 | 1,669 | 1,623 | 1,593 | 1,616 | 1,635 |
| *$N_2O$* | 47.5 | 45.8 | 45.9 | 46 | 46.2 | 46.6 |
| *$NO_X$* | 113.4 | 115.8 | 125 | 125.3 | 128.4 | 133.6 |
| *CO* | 703.9 | 702.5 | 716.8 | 737.5 | 768.5 | 797.2 |
| *NMVOCs* | 178.9 | 176.2 | 186.7 | 188.3 | 194.7 | 200.6 |
| *HFCs* | neg | neg | neg | 0.008 | 0.064 | 0.141 |
| *PFCs* | 0.089 | 0.096 | 0.094 | 0.1 | 0.034 | 0.029 |
| *$SF_6$* | 0.023 | 0.021 | 0.007 | 0.023 | 0.184 | 0.183 |
| *$SO_2$* | 16.3 | 17.1 | 18.4 | 21.9 | 21.9 | 20.8 |

*Source: Ministry for the Environment (1997a).*

Carbon dioxide is not the only New Zealand greenhouse gas whose emissions have increased since 1990 (see Table 5.6 and Figures 5.28 and 5.29). This has led some industrial emitters of $CO_2$ to complain that too little attention is being paid to emissions from other sectors, such as transport and agriculture, whose greenhouse gases come from many small, dispersed sources, such as motor vehicles and livestock (Brasell, 1996).

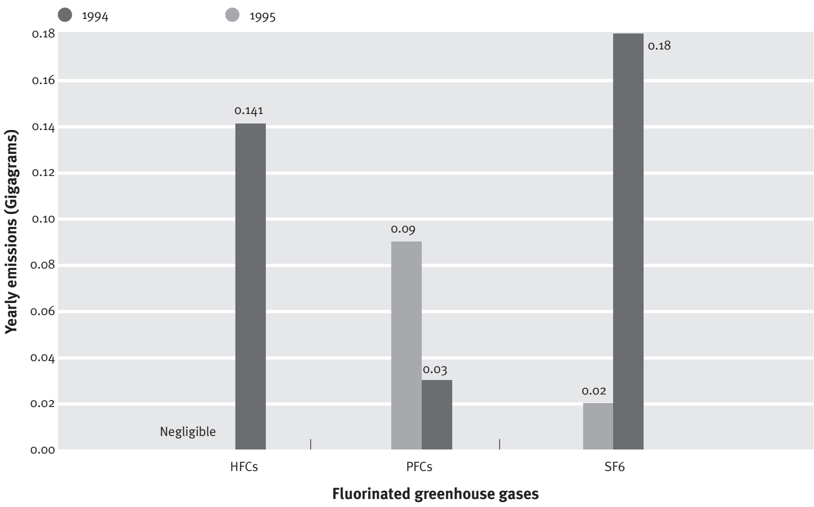
The following greenhouse gases increased between 1990 and 1995: carbon monoxide (CO); other non-methane carbon gases (NMVOCs); sulphur dioxide ($SO_2$); the nitrogen oxides ($NO_X$); hydrofluorocarbons (HFCs); and sulphur hexafluoride ($SF_6$). The last of these, $SF_6$, is the most potent greenhouse gas yet discovered (see Table 5.3) but its seemingly dramatic increase is almost certainly exaggerated. Because actual usage and emission rates of HFCs and $SF_6$ are unknown, estimates are based on the amount imported each year. Imports have risen steeply in recent years, but emissions are unlikely to have risen at the same rate. In fact, they may not have increased at all because the product that $SF_6$ is used in (underground electrical insulation) is believed to have very low emission levels, if any. The Ministry for the Environment is currently funding research on this.

**Figure 5.28**
**Percentage change in annual emissions of carbon, sulphur-based greenhouse gases, 1990-1995**




*Source: Ministry for the Environment (1997)*

**Figure 5.29**
**Changes in annual emissions of fluorine-based greenhouse gases, 1990-1995[1].**




[1] Actual emissions are not monitored and are, instead, estimated from yearly import statistics.

*Source: Ministry for the Environment (1997b)*

Although yearly emissions of most greenhouse gases increased between 1990 and 1995, three showed a decrease—methane ($CH_4$), nitrous oxide ($N_2O$), and perfluorocarbon (PFC) (see Figures 5.28 and 5.29). The declines in methane and nitrous oxide occurred in the early 1990s as a result of falling sheep numbers and increased forest planting in the agricultural sector (see Table 5.6). These emissions have increased slowly since then, but are expected to still remain below 1990 levels in the year 2000 (Ministry for the Environment, 1994).

The declines are significant because, molecule for molecule, methane, nitrous oxide, and perfluorocarbons have much greater potential impacts on the climate than does carbon dioxide (see Table 5.3). Although their declines were still outweighed by the increase in carbon dioxide emissions, they did limit the overall impact of the $CO_2$ increase. In fact, when the total global warming potential (GWP) of all three gases is calculated, it appears that their combined impact increased by just 0.2 percent between 1990 and 1995, and will have risen by 2 percent at the close of the decade. When other greenhouse gases are added in, the net rise in the nation's GWP is only one or two percent greater—assuming that $SF_6$ emissions are well below their import levels. This means that, if carbon dioxide emissions had been a little lower, New Zealand could have finished the decade with a lower GWP than it began with. However, the agricultural and forestry developments that made this possible cannot be expected to repeat themselves in future decades.

New Zealand is not alone in not meeting its carbon dioxide emission targets, though our 'gross' emissions have risen at nearly twice the OECD rate. Between 1990 and 1995, the OECD countries registered an overall increase in yearly $CO_2$ emissions of 4 percent compared to New Zealand's 7 percent rise (Masood, 1996). Over the same period, however, global carbon dioxide emissions from fossil fuels rose by an average of 12 percent, in part because the non-OECD countries that signed the FCCC do not yet have specific targets for reducing or stabilising their emissions. Emissions rose by 8 percent in Latin America, 12.5 percent in Africa, 30 percent in the Asia-Pacific (excluding New Zealand, Australia and Japan) and 35 percent in the Middle East.

Recognising the inadequacy of current commitments, New Zealand, along with other countries, is now involved in a round of international negotiations, known as the Berlin Mandate process, that is expected to develop stronger commitments for the period beyond 2000. The new commitments are also expected to be legally binding, in contrast to the 'aim to' commitments that countries originally made under the FCCC.

With these international negotiations set to run until December 1997, the New Zealand Government deferred a decision on the foreshadowed carbon charge until early 1998. The Minister for the Environment said that, for effective progress at a global scale, there needs to be widespread adoption of measures, and it is far better that New Zealand act in concert with other nations than act unilaterally. For these reasons the Government decided it would be better to wait for the outcome of the international negotiations before making decisions on additional measures.

## CONCLUSION

Earth's atmosphere has changed markedly in 4.6 billion years, but, apart from asteroid and volcano impacts, no changes have been as rapid as the recent growth of greenhouse gases and the depletion of the ozone layer through human activities. In fact, for the past few million years, as humans and most of our fellow species were still evolving, the atmosphere's composition has stayed relatively stable.

During this time, small fluctuations in greenhouse gas concentrations have been associated with significant climatic changes, particularly the recurrent pattern of alternating ice ages and warm interglacials. Now, as greenhouse gases rapidly accumulate in the atmosphere, the current Holocene interglacial may turn out to be warmer than any of the previous ones, with unpredictable impacts on weather, ecosystems and economies.

Conclusive evidence that the human-induced greenhouse gas build-up may change the climate by boosting the natural greenhouse effect (greenhouse forcing) is still being sought. However, the Scientific Working Group of the United Nations Intergovernmental Panel on Climate Change (IPCC) concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate."

New Zealand is as exposed to the impacts of climate change as any other country. Distance from other large land masses may offer protection from short-lived atmospheric contaminants, but long-lived contaminants affect New Zealanders as much as anyone else. In fact, our average annual temperatures have risen more than the global average this century. While some of the potential impacts of climate warming may be positive for New Zealand (e.g. extended growing seasons and new crops), others are likely to be negative.

The projected negative impacts include greater weather variability, more floods and droughts, increased pressures on water supply and disposal systems, increased risk of being invaded by infectious diseases, pests and weeds, and a reduction in alpine and cold-adapted plant and animal species. These impacts may be further compounded by repeated unwelcome visitations of the El

Niño–Southern Oscillation (ENSO) climate pattern which some scientists suspect of being intensified by global warming.

A feature of most climate change scenarios is their tendency to focus only on a fixed point in time (e.g. 2050) as if the impacts will stabilise at that point. However, on current trends, greenhouse gases will continue to accumulate for several centuries, meaning that the scenarios envisaged for 2050 are just the start of what lies ahead. Aware of the potential for climate change to cause severe disruption both locally and globally, New Zealand as a Party to the United Nations Framework Convention on Climate Change (FCCC) undertook to return net carbon dioxide emissions to 1990 levels by 2000 and keep them at that level from then on.

However, with just three years to go, New Zealand's 'net' emissions of carbon dioxide are projected to be well above 1990 levels in the absence of further policy measures. On the other hand, much of the global warming potential of the carbon dioxide increase has been offset by small declines in methane and nitrous oxide emissions. These are already below 1990 levels and are expected to remain below them by the end of the decade. Perfluorocarbon emissions have also declined and are expected to be stable. However, other greenhouse gases have increased. Along with all other developed country parties, New Zealand is now in the process of negotiating new objectives for all greenhouse gases for the period beyond 2000.

New Zealanders have also become more aware of their vulnerability to ozone depletion. Rising skin cancer rates have reinforced this awareness, even though most cases are attributable to sunburning that occured in the decades before ozone depletion. However, the risk is increasing. Solar radiation is now 6–9 percent more intense in New Zealand than it was three decades ago and New Zealand summers coincide with the season of lowest ozone density. While many people now take active measures to avoid sunburn, it will be half a century or more before the ozone layer recovers and the risk of sun damage to people, property and other species declines.

That recovery depends very much on worldwide efforts to limit the use of ozone-depleting substances under the international agreement known as the Montreal Protocol. So far, the Protocol and its amendments have been hailed as successful, though ozone depletion will continue to occur for some decades because of the longevity of the ozone-depleting chemicals and because many of the world's poorer nations have yet to begin limiting their use of these.

New Zealand's phase-out of ozone-depleting substances is meeting the timetable set out in the Montreal Protocol. Imports of most synthetic ozone-depleting substances were stopped on 1 January 1996. However, manufactured products containing chlorofluorocarbons (CFCs) can still be imported, and imports of methyl bromide for quarantine use and fumigation of export products have increased. As a result, methyl bromide now appears to be the major ozone-depleting gas emitted in New Zealand.

The idea that human actions could have measurable impacts on something as vast as the atmosphere was almost unheard of two decades ago, and is still resisted by some today. Given this, the speed of the international response to both ozone depletion and the risk of climate change has been quite remarkable. However, the response has not been uniformly successful. The ozone issue has been relatively easy to deal with because ozone-depleting substances play a relatively small role in the world economy and alternatives have readily been found.

The climate change issue has been harder to deal with because fossil and wood fuels play such a vital role in most of the world's economies, as do rice paddies and ruminant farm animals. New Zealand is therefore not alone in finding it hard to contain the rise of greenhouse gases. Fortunately, we are also not alone in the search for solutions and are participating fully in international efforts to develop an effective response, not only for New Zealand, but for the world.

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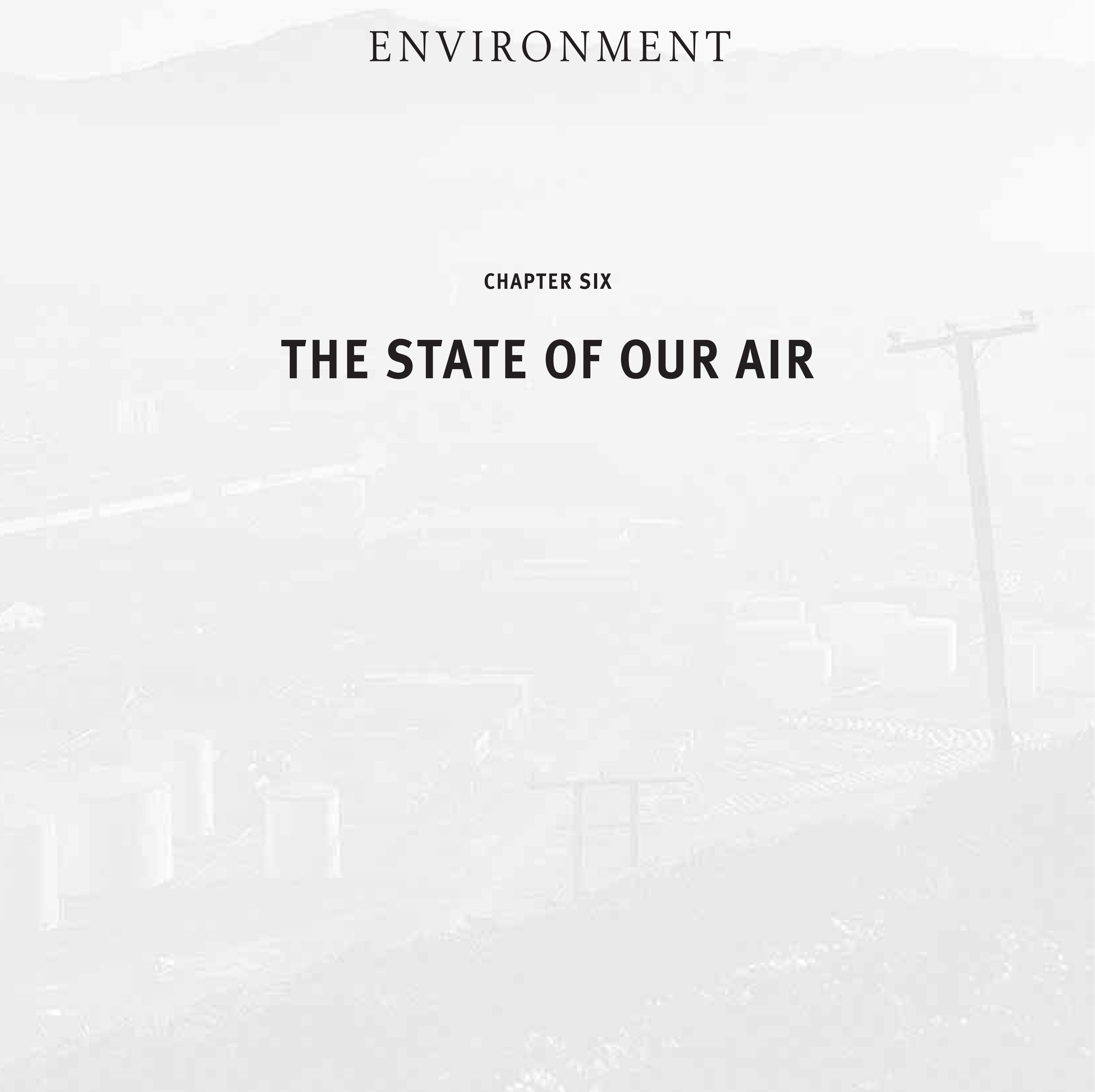
THE STATE OF

# NEW ZEALAND'S ENVIRONMENT



CHAPTER SIX

# THE STATE OF OUR AIR

## CONTENTS

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **μg** | Microgram |
| **Beta** | Beta gauge (an instrument which uses Beta radiation to monitor particulate matter) |
| **BPM** | 'Best practicable means' |
| **CO** | Carbon monoxide |
| **$CO_2$** | Carbon dioxide |
| **Fl** | Fluorine |
| **g** | Gram |
| **GEMS** | Global Environment Monitoring System |
| **$H_2S$** | Hydrogen sulphide |
| **Hi-vol** | High volume |
| **l** | Litre |
| **$m^3$** | Cubic metre |
| **mg** | Milligram |
| **$NH_3$** | Ammonia |
| **NO** | Nitric oxide |
| **$NO_2$** | Nitrogen dioxide |
| **$NO_x$** | Oxides of nitrogen |
| **$O_3$** | Ozone |
| **Pb** | Lead |
| **$PM_{10}$** | Fine particulates (less than 10 microns diameter) |
| **ppb** | Parts per billion |
| **RMA** | Resource Management Act |
| **$SO_2$** | Sulphur dioxide |
| **$SO_x$** | Oxides of sulphur |
| **TEL** | Tetraethyl lead (a lead compound used in petrol as an octane enhancer) |
| **TEOM** | Transverse element oscillating microbalance (an instrument to monitor particulate matter) |
| **TML** | Tetramethyl lead (a lead compound used in petrol as an octane enhancer) |
| **TS** | Total sulphur |
| **TSP** | Total suspended particulates |
| **VOC** | Volatile organic compound |

## KEY POINTS

- *By world standards urban air pollution in New Zealand is comparatively low. This is because of the country's geographical location in the South Pacific Ocean, the constantly-blowing westerly winds, the coastal location of most large cities, and the limited amount of heavy industry.*

- *Air quality monitoring in New Zealand has often been limited, sporadic, and in response to specific perceived problems. As a result, insufficient data makes it difficult to assess many aspects of New Zealand air quality.*

- *Recent monitoring has uncovered air pollution levels in some urban locations that occasionally exceed New Zealand's air quality guidelines. These pollution events occur most often in inner city 'traffic corridors' but can occur over wider 'ambient areas' in winter or during temperature inversions.*

- *Urban air pollution is caused by the cumulative impacts of wintertime open fires and wood burners, motor vehicle emissions and, in some locations, industrial emissions. Household fires are the main contributors to 'ambient' air pollution while motor vehicles are the main contributors to 'traffic corridor' air pollution. Emissions from industry are more easily managed than the diffuse and dispersed emissions from homes and vehicles.*

- *Carbon monoxide (CO) in heavily-used traffic corridors often exceeds the air quality guidelines, particularly when vehicle density is high and wind speed is low or when winter-time fires add to the emissions from vehicles. CO pollution events also occur in some 'ambient' areas where they are caused by wintertime fires. Monitoring has been sporadic and centred mainly on Auckland and Christchurch, but recent results from Gisborne and Whangarei show the problem also occurs in smaller cities.*

- *Lead levels in the air have been dropping since 1986 when the lead content in petrol was reduced. With the banning of leaded petrol in 1996, airborne lead has become a negligible problem, except for people exposed to uncontrolled lead-based paint removal.*

- *The amount of particulate matter (such as dust and smoke and exhaust emissions from diesel vehicles) in the air has decreased in the past decade and is generally low. The exception is in Christchurch where temperature inversion frequently contributes to high wintertime smoke levels caused principally by domestic fuel burning. Particulate levels may be a concern in any town where wood and coal fires burn on calm winter nights.*

- *Sulphur dioxide levels have been dropping over the past 20 years and are generally low when compared with the Ambient Air Quality Guidelines. The most publicised specific source causing concern is the oil refinery at Marsden Point, near Whangarei; but as with particulates, sulphur dioxide from domestic coal fires can be a problem on still winter nights, even in small towns.*

- *Spraydrift from agricultural chemicals, such as 2,4-D butyl ester, is a cause of frequent complaints in some regions.*

- *There is no evidence at present that acid rain, a serious problem in some Northern Hemisphere countries, is a problem in New Zealand. Rainfall chemistry monitoring by the National Institute of Water and Atmosphere Research (NIWA) has now been terminated because of limited resources and other research priorities.*

- *The development of a national set of air quality indicators, coordinated by the Ministry for the Environment, is expected to improve the consistency and coverage of air quality data in the near future.*

## INTRODUCTION

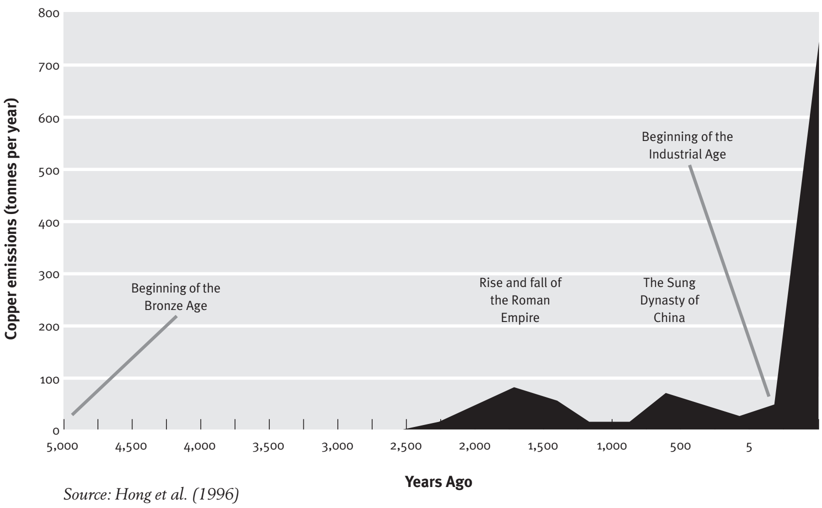
For humans, and other animals, the most important atmospheric gas is oxygen. It makes up less than one-quarter of the air that we breathe (21 percent), but without it we die. It is found in breathable quantities in a layer less than 10 kilometres deep, and is most concentrated at ground level, becoming progressively thinner as altitude increases. Mountain climbers know just how thin it can get. The atmosphere at the summit of Mount Everest, Earth's highest mountain at 8,848 metres (29,022 feet), does not contain enough oxygen to sustain life.

Oxygen, of course, is not all that we breathe. With each lungful of air, we take in many other gases and small particles. The unwelcome gases and particulate matter in the air are generally most concentrated in the towns and cities where cars, factories, and houses constantly burn materials that give off smoke and fumes. Some of these are merely irritating, but others can be harmful to health.

With the exception of some nuisance odours, and agricultural spray drift, New Zealanders' air quality concerns have generally been limited to the few cities where wintertime smoke and fumes cause visible pollution problems. Today, however, awareness is growing that air pollution does not have to be visible to cause problems, and that apparently moderate levels of air pollution can cause serious problems for some people, particularly those with asthma, emphysema, or chest infections.

**Figure 6.1**

**Heavy metal air pollution (copper) from ancient times to today**




*Source: Hong et al. (1996)*

Smoke has shadowed human society since the first fires were lit tens, perhaps hundreds, of thousands of years ago. Evidence of prehistoric air pollution is found on the walls of European caves where small amounts of trace heavy metals escaped from firewood over long periods of time (Nriagu, 1996). Air pollution probably intensified with the development of towns and cities in the Middle East, northern India, and China about 10,000 years ago. The concentrations of people, domestic animals, and cooking fires in small areas would have created an ambient air quality which combined wood smoke with the odours of rotting rubbish, tanning hides, and waste from both humans and animals.

Some time later, metal smelting would have added to the mix—though the early smiths tended to live apart from the main community to protect their magical trade secrets (a tradition which lingers on in Europe's gypsies and tinkers). Metal smelting was probably discovered by accident when implements made of hammered copper, or ores containing copper, lead, and other metals, found their way into high temperature pottery kilns. This happened separately in southern Europe and China about 6,000 years ago. It took several thousand years for smelting to become widespread, and it was not until the era of the Greek and Roman civilisations about 1,700 years ago (500 B.C. to A.D. 300) that large-scale air pollution resulted (Hong *et al.*, 1994, 1996).

The widespread use of lead in ancient Rome probably caused a considerable amount of lead poisoning (Nriagu, 1983). The impact of this on Roman society is a matter of speculation, but its scale is not. The evidence of extensive lead and copper pollution has been faithfully preserved in polar ice caps, bogs and aquatic sediments. Modern studies indicate that for some 800 years, from roughly 500 B.C. to A.D. 300, lead concentrations in the air appear to have been up to four times higher than the natural background level while copper levels were a dramatic 400 times higher.

After the fall of Rome, lead pollution disappeared for some 500 years, causing the air to lighten somewhat during the otherwise unenlightened Dark Ages. Copper levels also declined significantly but rose to another peak some centuries later when China's Sung Dynasty began extensive copper and tin smelting to produce bronze (see Figure 6.1).

It has been estimated that the total amount of copper dust deposited in the Northern Hemisphere during the 800–year flowering of Greco-Roman civilisation was about ten times greater than that deposited within the last 200 years by industrial society (Hong *et al.*, 1996). However, the reverse is the case with lead. In just two centuries, modern society has emitted ten times more lead than the ancient civilisations could deposit in eight centuries (Hong *et al.*, 1994). The main reason is the widespread use of leaded petrol in motor cars for most of this century.

Even an area as pristine, and as far away from the industrial North as Antarctica, has not escaped the global lead pollution of modern times. Recent analyses of Antarctic ice have found that snow deposited in the 1920s contains lead levels five times higher than natural background levels, making it slightly more polluted than the Arctic snow deposited in the time of ancient Rome (Nriagu, 1996). More recent Antarctic snow has even higher levels.

Air pollution in New Zealand began long before our arrival here. Volcanic eruptions have occasionally formed clouds of ash and smoke that proved lethal to plants and animals. Human-induced air pollution probably began with the extensive Maori forest fires which were lit repeatedly over several centuries and are still dimly recalled in the stories of Tamatea (Orbell, 1985). But vast as these smoke clouds would have been, they were episodic, not persistent. Four centuries later, when European farmers arrived to clear more forest and scrub for pasture, large fires again clouded the air and charred the hillsides, but they too were ephemeral.

It was in some of the newly-established colonial towns and cities that air pollution became a more persistent problem. Aside from chimney smoke, the towns also generated other air problems, such as the odours of rotting garbage, factory wastes, horse dung, and human sewage. These problems were probably worst in Christchurch where the swampy terrain and the frequent air inversions contributed to their intensity. Strident protests eventually led the city fathers to install a sewerage system, but, except for some factory emissions, nothing was done about the smoke and most people seemed content to put up with it.

The lack of alternatives to the open fire probably accounted for this general air of acceptance, perhaps aided by memories of far worse conditions in the big cities back home. As early as 1661, for example, before the Industrial Revolution had even begun to gather steam, one writer, John Evelyn, described the city of London as more like:

> *the face of Mount Aetna, the Court of Vulcan ... than an Assembly of Rational Creatures and the Imperial Seat of our incomparable Monarch ... For there is under Heaven such Coughing and Snuffing to be heard, as in London churches and Assemblies of People, where the Barking and the Spitting is uncessant and most importunate ... It is this horrid Smoake which obscures our Churches, and makes our Palaces look old, which fouls our Clothes and corrupts the Waters, so as the very Rain, and refreshing Dews which fall in the several Seasons, precipitate this impure vapour, which, with its black and tenacious quality, spots and contaminates whatever is exposed to it. (Quoted in Ponting, 1991).*

By the time cities were being established in New Zealand, London's infamous smogs were killing people—a situation which continued to worsen until the terrible smog of December 1952 when over 4,000 people died (Ministry of Health, 1954). Compared to this, Christchurch's problems must have seemed mild. Nevertheless, occasional efforts were made to measure the city's air pollution (Gray, 1910). From 1884 to 1888 and again from 1907 to 1909 the dissolved solids in Christchurch's rainwater were measured and were found to be about 50 milligrams per square metre ($mg/m^2$) per day, a level not too much lower than the 70 $mg/m^2$ recorded many years later in the 1970s (Pullen, 1977).

By the 1930s, an organisation called the Christchurch Sunlight League began agitating for cleaner air, a cause taken up in later decades by the Clean Air Society. These Christchurch-centred campaigns eventually led to the establishment of the Clean Air Act 1972, which contained measures for reducing pollution pressures in known trouble spots. That Act has now been superseded by the Resource Management Act 1991 which requires local communities, through their regional councils, to sustain the physical and natural environment, and to monitor it as necessary.

As councils attempt to meet their air management obligations, attention has been drawn to the general lack of information on air quality, outside of a few city centres, and has stimulated a rush of activity to improve the situation. The fruits of this activity will become apparent in the years ahead. In the meantime, using existing information it is still possible to derive a general picture of the state of our air, in the main centres at least, and of the current pressures affecting it.

This chapter reviews what is known of New Zealand's air quality and what has been done to remedy perceived problems. It begins by describing the general characteristics of the air over New Zealand and the pressures which human activity can put on air quality. It then assesses the state of our air, based on existing data, and summarises the responses which the community has made to address air quality problems.

## SOURCES OF AIR QUALITY DATA

There is no doubt that the level of air quality monitoring in New Zealand is low compared to that carried out in other countries (Fisher, 1996). The reasons for this are, perhaps, justifiable in that New Zealand has often been perceived as having few air quality problems, and the population (and thus the tax base) is relatively low.

Although the first published reports relating to air pollution in New Zealand can be traced back to the end of last century, detailed air quality studies did not come until the mid- to late 1950s when they were needed to address specific problems in Christchurch and Auckland.

Christchurch had a problem with wintertime air pollution caused mainly by the smoke and sulphur dioxide from domestic fires and motor vehicles. In Auckland, the main concern was the smelly 'rotten egg' gas, hydrogen sulphide, emitted from the Manukau mudflats, although there were also some problems with a few local industries.

Although the hydrogen sulphide problem in Auckland effectively vaporised with the diversion of industrial liquid wastes to the new Mangere sewage plant in 1961, the sewage plant itself began to cause problems. The plant has been the cause of odour complaints almost from the time it opened, though to a much lesser degree than the original Auckland 'fumes'.

The wintertime problem in Christchurch also lingers on despite the fact that sulphur dioxide levels have dropped markedly over the last three decades with the significant overall reduction in coal and oil consumption, and the controls on the use of high-sulphur coals and the declaration of Clean Air Zones in Christchurch under the Clean Air Act 1972. Smoke levels have gone down as well.

These problems triggered the first air monitoring programmes in both cities. The programmes still operate but in substantially different forms. In both cases measurements were taken frequently for about the first five years. They were continued at a reduced level as the situation became better understood and resources were directed at other air pollution issues, such as carbon monoxide from motor vehicles.

Monitoring activity expanded after the Clean Air Act was passed in 1972. Studies were undertaken in a number of centres around the country, although many of the measurements were at a fairly basic level and were continued for only a few years. More intensive investigations of wintertime pollution were again carried out in Christchurch, while in Auckland the potential for photochemical smog was given a significant amount of attention. Specific programmes were also established around some of the larger industries throughout the country as these came under the control of the Clean Air Act.

By the end of the 1970s, much of the above effort had been scaled down once again, with routine monitoring mainly confined to a few sites in Auckland and Christchurch, and some of the industrial programmes. This situation was maintained throughout the 1980s with only two major changes: the addition of two routine monitoring sites in Dunedin, and the development of a national lead survey based on sites in Auckland, Hamilton, Palmerston North, Lower Hutt, Wellington, Christchurch and Dunedin.

The early air pollution investigations in Auckland and Christchurch were carried out under the auspices of the Auckland Air Pollution Research Committee and the Christchurch Air Pollution Advisory Committee. Both of these bodies were established by the various local and regional authorities at that time. From the mid-1960s, much of the above work was carried out either by, or at the request of, staff of the Department of Health. The Department funded the operation of three long-term air monitoring sites, to provide data for the World Health Organisation's Global Environmental Monitoring System (GEMS). Two sites were located in Auckland (Penrose since 1964 and Mt Eden since 1983) and one in Christchurch (at Packe Street in St Albans since 1987).

With the passing of the Resource Management Act in 1991, the day-to-day responsibility for air pollution control has now been transferred from the Department of Health, and city and district councils, to regional councils. This is leading to a resurgence of interest in air quality monitoring as regional councils implement their responsibilities to monitor as required by Section 35 of the Act.

A consequence of the new regime is that, despite the increased interest, air quality monitoring has been very uncoordinated (Fisher, 1996). Even so, both central government and regional authorities do have a few valuable monitoring programmes that gather data on the common pollutants identified in the ambient air quality guidelines developed by the Ministry for the Environment (see Table 6.1).

During 1995–96, the Ministry for the Environment's National Environmental Indicators Programme set up a working group to develop national indicators of air quality. The group involves representatives from regional councils, industry, universities and community organisations. The indicators are being developed to assist councils in defining their air monitoring needs and to also meet the needs of central government in tracking changes in environmental quality.

**Emission inventories**

As the monitoring of air quality begins to improve, attention is also turning to the monitoring of actual emissions. Air quality management would be enhanced if emissions data existed because the impact of sources would be more readily determined. This would enable air quality managers to assess how air quality may change with time, and develop cost effective control strategies.

The Christchurch Regional Council conducted a vehicle emissions testing programme from 1993 to 1995. Prior to this initiative, a number of surveys of fuel usage had been carried out in Christchurch in the previous 30 years, but the methodology was not particularly rigorous. Similar surveys were carried out in Auckland and Hamilton over 20 years ago. A reasonably comprehensive emission inventory was conducted in Auckland in 1976, and a more limited one was carried out in 1988. None of these allow us to make any definitive statements about the changes in total emissions over time.

The research on vehicle emissions has not been matched by similar research on household fire emissions. Although the Resource Management Act makes regional councils responsible for monitoring air quality, nobody is undertaking basic research on home heating emission rates. Typical emission factors have yet to be identified for given types of solid fuel and fireplace and, in addition, it is hard to obtain accurate data on firewood use.

**Table 6.1**
**Air quality monitoring programmes by region in New Zealand[1].**

| Location | $PM_{10}$ (Particulate matter under 10 microns) | $SO_2$ (Sulphur dioxide) | CO (Carbon monoxide) | $O_3$ (Ozone) | $NO_2$ (Nitrogen dioxide) | Pb/Fl/$H_2S$ (Lead/Fluorine/ Hydrogen sulphide) | Meteorological | Other |
|---|---|---|---|---|---|---|---|---|
| *Northland* | *$PM_{10}$ Hi-vol (1 site) 92* | *Passive survey 3 months in 96* | *Survey 6-9/94 Survey 1 month in 96* | *Passive survey 3 months in 96* | *Passive survey 3 months in 96* | | | |
| *Auckland (includes two GEMS sites)* | *TSP Hi-vol (6 sites), 64➔ $PM_{10}$ TEOM Takapuna 1/95➔ $PM_{10}$ Hi-vol Penrose 4/94➔ $PM_{10}$ 3/95➔ TSP Hi-vol Penrose 64➔ Surveys 94/95* | *Penrose 77➔* | *Queen St. 91➔ Dominion Rd., 4/94-2/96 Surveys with student during 94/95 Takapuna 3/96➔ Penrose 86➔ Surveys with student 95/96* | *Mangere 8/95➔ Passive sampler survey 95/96 Occasional since 95 (City, Newmarket) Musick Pt. 12/95➔* | *Dominion Rd. 4/94➔2/96 Passive samplers 94/95 Penrose 86➔ Mt Eden 89➔* | *Pb Filters (6 sites) some since 64<br>Mt Eden 89➔* | *Onehunga 8/94➔ Takapuna 11/94➔ Henderson 11/94➔ Wiri 5/95➔ Acoustic sounder 94➔96 Climate database* | *Visibility programme<br>Hydrocarbon monitoring<br>Vehicle testing programme 94➔* |
| *Waikato* | *TSP 83➔ Survey 7/96* | *Passive survey 3 months 3/96* | *Survey 1 month in 96* | *Passive survey, 3 months 3/96* | *Passive survey 3 months 3/96* | *Pb Filters 83➔* | | *Vehicle testing 96➔* |
| *Bay of Plenty* | *Smoke 92➔ Survey 1 month in 96* | *Survey, TS & $SO_2$ Tauranga 9/94 ➔12/94 Passive survey 3/96 Ambient TS 9/95➔ 4/96* | *Survey Tauranga 10/94➔12/94<br>Survey, 1 month in 96* | *Passive survey, 3 months 3/96* | *Survey Tauranga 9/94➔12/94 Passive sampler 94 Passive survey 3/96* | *Fl Survey Tauranga 9/94➔12/94 $H_2S$ Surveys Aug/Sept 93, 94, Rotorua Jan-Jun 96* | *Full stations (2) Edgecumbe and Te Teko* | *Hydrocarbon and oxidant surveys 92* |
| *Gisborne* | *$PM_{10}$ 93➔ Deposition (6 sites) 93➔ Smoke surveys➔* | *Survey 94* | *Survey 93 & 94* | | *Survey 4-5/94* | *Pb Filter analysis 93 & 94* | | *Formaldehyde 94 Landfill gases 95* |
| *Hawke's Bay* | *$PM_{10}$ 95➔ Deposition* | *Passive survey 3 months in 96* | *Survey 94 Survey 1 month in 96* | *Passive survey 3 months in 96* | *Survey 94 Passive survey 3 months in 96* | | | |
| *Taranaki* | *TSP 73➔ Particulate and deposition* | | *Survey 1 month in 96* | | | | | *Video monitoring Biomonitor* |
| *Manawatu/ Wanganui* | *TSP 94➔* | | *Survey 1 month in 96* | | | | | |
| *Wellington* | *TSP survey 93/94 Particulate type and size* | | *Survey 1 month in 96 Background 72➔* | *Survey* | | *Pb Filters 83➔* | *Full met site* | *Global monitoring* |

## THE NATURE OF NEW ZEALAND'S AIR

While visitors to New Zealand are impressed by the clean air and absence of haze, they are sometimes less impressed by the strong winds they encounter in many parts of the country. Yet the two things are related. The prevailing and largely unpolluted westerly winds which often buffet New Zealand have a cleansing effect, dispersing air contaminants before they can become too concentrated (see Figure 6.2).

When the winds die away, however, serious air pollution can occur in some places. Christchurch, which is very prone to air pollution problems, is a good example. The city is situated in a geographical 'basin' on the east coast of the South Island. The Port Hills lie on one side, and the Canterbury Plains slope up towards the Southern Alps on the other. In winter, the city often experiences what is known as a 'temperature inversion' with a layer of warm air trapping cooler air—and the pollution from cars and domestic fires—underneath.

Another reason for New Zealand's generally clean air is the relative sparseness of its human population and the small number of 'smokestack' industries compared to European countries. The country's main revenue comes from outdoor industries such as agriculture, horticulture, forestry, fishing, and tourism. Except for isolated incidents of spray drift or controlled burn-offs, air pollutants generated by these industries are generally low and localised. By world standards, then, New Zealand has low concentrations of most urban air pollutants such as smoke, photochemical smog, and sulphur dioxide.

**Table 6.1**
**Air quality monitoring programmes by region in New Zealand[1] (continued).**

| Location | $PM_{10}$ (Particulate matter under 10 microns) | $SO_2$ (Sulphur dioxide) | CO (Carbon monoxide) | $O_3$ (Ozone) | $NO_2$ (Nitrogen dioxide) | Pb/Fl/$H_2S$ (Lead/Fluorine/ Hydrogen sulphide) | Meteorological | Other |
|---|---|---|---|---|---|---|---|---|
| *Nelson* | *Survey 1 month in 96* | | *Survey 1 month in 96* | | | | | |
| *Marlborough* | *Deposition (6) $PM_{10}$ (2 sites)* | | | | | | | |
| *Tasman* | *Smoke 92→* | | | | | | *Met site 92→* | |
| *Canterbury (includes one GEMS site)* | *TSP (10) 64→ TEOM (2) 94→ Beta (1) 93→ TSP 89→* | *Cont (2 sites) since 70s Cont (1) 87→ Passive survey 3 months in 96* | *Cont (2) since 80s Local surveys Cont (1) 87→ Passive survey 3 months in 96* | *Passive survey, 3 months in 96* | *Cont (2) since 70s Cont (1) 87→ Survey, optical, 1995 project* | *Pb Filters (7) and surveys Fl Filters (5) and surveys* | *Wind (3 sites) Met and model studies Full met site Temporary towers 5/95→9/95* | *Vehicle emissions data - testing station 93→ Nephelometers (2)* |
| *West Coast* | *TSP 92→* | *Bubbler survey 93→95* | *Survey 1 month in 96* | | | | | |
| *Otago* | | *Passive survey (14 sites) 7/95→ 10/95* | *Survey 1 month in 96* | | *Passive survey (14 sites) 7/95→ 10/95* | | | *$NH_3$, Passive sampler (3) 7/95→10/95* |
| *Southland* | *Smoke 71→* | *Bubbler survey 83, 92 Passive survey 3/96* | *Survey 1 month in 96* | *Passive survey, 3 months in 96* | *Passive survey 3 months in 96* | | | |

**Abbreviations**

| | |
|---|---|
| Beta | Beta Gauge (an instrument which uses Beta radiation to monitor particulate matter) |
| Fl | Fluorine |
| GEMS | Global Environment Monitoring System |
| Hi-vol | High volume |
| $H_2S$ | Hydrogen sulphide |
| $NH_3$ | Ammonia |
| Pb | Lead |
| $PM_{10}$ | Fine particulates (less than 10 microns diameter) |
| $SO_2$ | Sulphur dioxide |
| TEOM | Transverse Element Oscillating Microbalance (an instrument to monitor particulate matter) |
| TS | Total sulphur |
| TSP | Total Suspended Particulates |
| 77→, 92→ | 1977 onwards, 1992 onwards, etc. |

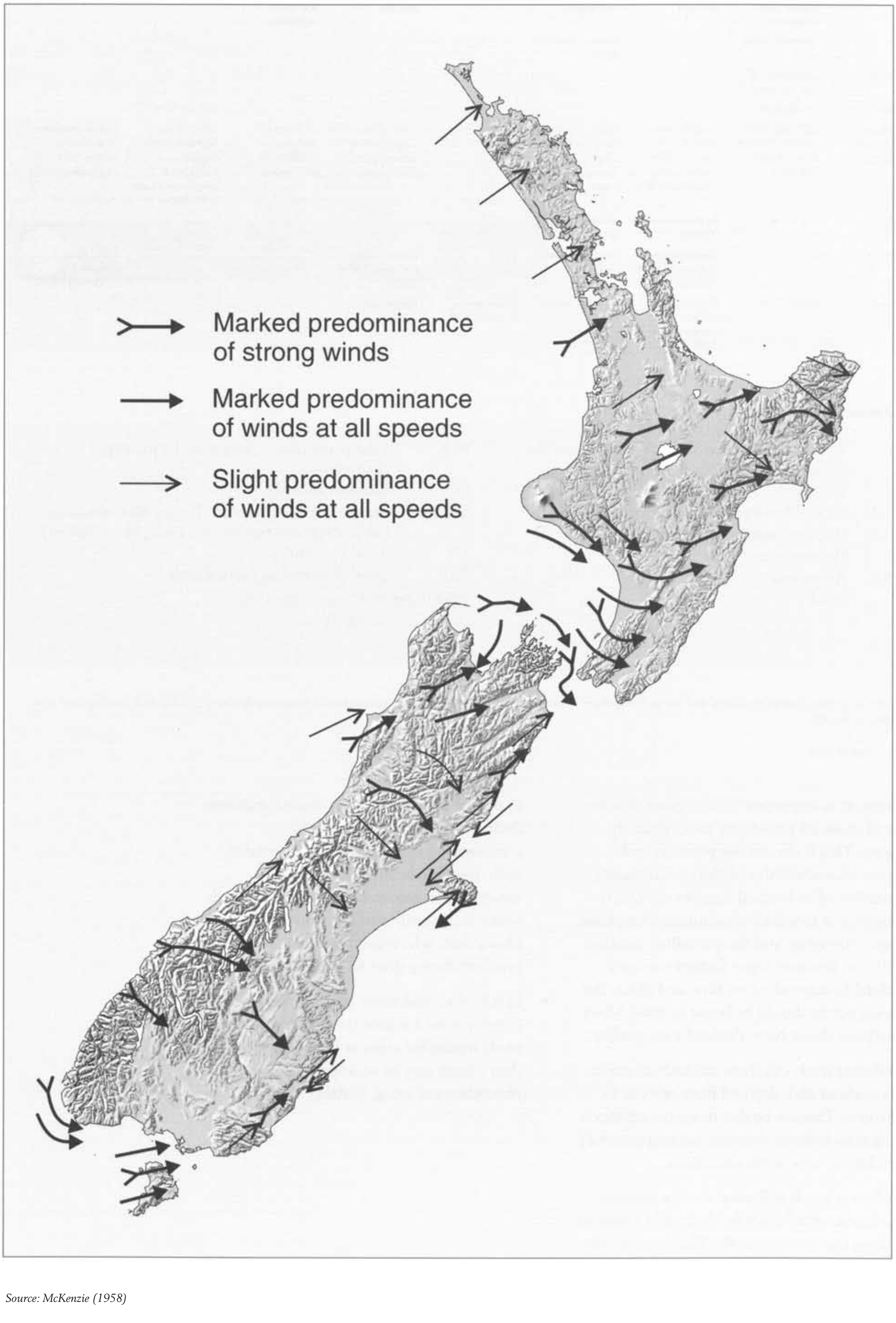
[1] *Includes three sites (two in Auckland and one in Canterbury) monitored for UNEP's Global Environmental Monitoring System (GEMS) with funding from the Ministry of Health.*

*Source: Fisher (1996)*

However, it is important to recognise that the levels of most air pollutants are constantly changing. This is due to the physical and chemical characteristics of the contaminants, the location of individual sources relative to the observer or monitoring instrument, variations in source strengths, and the prevailing weather conditions. Because these factors can vary considerably, depending on time and place, the following points should be borne in mind when generalising about New Zealand's air quality:

- Pollutant levels can show marked variations throughout each day, and from one day to the next. This can be due to source variations (e.g. vehicle flows, domestic heating patterns) or changes in weather conditions.
- Pollutant levels will often show a seasonal variation, with higher levels usually recorded during the winter months. This is partly due to poorer atmospheric dispersion conditions during winter and the increased combustion-related pollutants associated with domestic heating. The seasonal variation also applies to ozone, which needs warm temperatures to form, and wind-blown dust, which is often more of a problem during drier summer months.
- Levels of air pollutants generally decline with distance from a source (i.e. distance from roads, residential areas, or factories). However, their effects may be widespread (e.g. photochemical smog, visibility).

**Figure 6.2**
**Prevailing wind direction and strength in New Zealand**




*Source: McKenzie (1958)*

The shape of the surrounding land and/or buildings can also influence air quality. For example, valleys often tend to trap air while flat or hilly locations allow it to disperse. In a city, air pollution from motor vehicles is often worst where dispersion is inhibited by a 'street canyon' effect. In New Zealand, therefore, areas such as Christchurch, Dunedin, and the Hutt Valley experience periods of relatively high air pollution because of their locations, local topography, and prevailing weather conditions, particularly during the winter months.

Most parts of Wellington, and areas such as New Plymouth and Invercargill, are thought to be less affected because of their frequent and higher average wind speeds throughout the year. Auckland should be less vulnerable because of its maritime location, but this is offset to some extent by the much greater numbers and densities of pollution sources, especially motor vehicles.

Taken together, these factors mean that any summary of air quality can only be made in fairly general terms. Individual results may also depend on the specific methods used for measuring, collecting samples and averaging results over different time periods (e.g. 1, 8, or 24 hours).

## PRESSURES ON NEW ZEALAND'S AIR QUALITY

Apart from volcanic eruptions, such as the recent emissions from Mount Ruapehu, there are few natural pressures on air quality. Although natural forces, such as wind and temperature inversions can influence the dispersion or concentration of air pollutants, the source of those pollutants is nearly always human activity.

### Pressures from motor vehicles

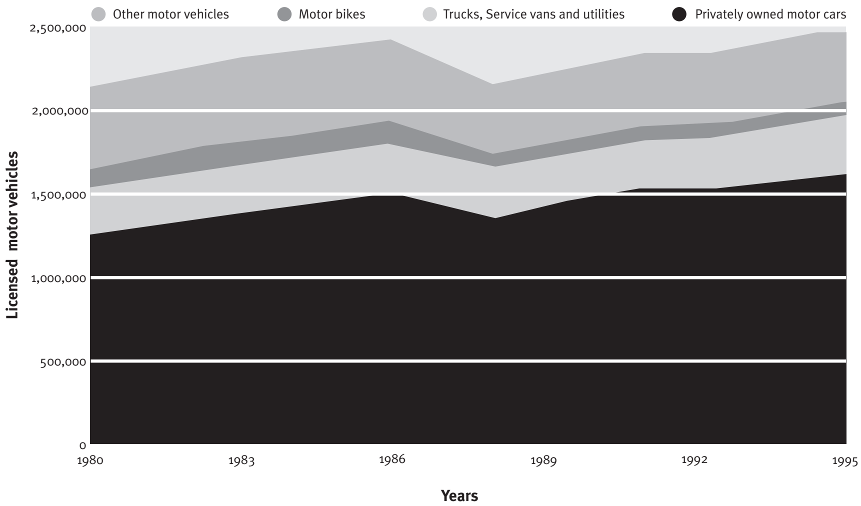
Motor vehicles are responsible for air pollution in heavily used traffic corridors and are secondary contributors to winter-time ambient pollution which is primarily caused by domestic fires and is enhanced, in Christchurch, by the temperature inversion layer which prevents pollutants from dispersing (see Box 6.1). New Zealand, along with Australia, Japan, North America, and the countries of northwest Europe, has one of the highest vehicle ownership rates in the world. We have 46 cars for every 100 people, approximately one for every two persons (Statistics New Zealand, 1996). When trucks and other vehicles are included, our vehicle ownership rises to 69 vehicles per 100 people. This compares to a world average of 11 vehicles per 100 people, and continental averages of 2 per 100 in Africa, 3 per 100 in South America, 9 per 100 in the former Soviet Union, and 33 per 100 in Europe, 50 per 100 in Canada, and 100 per 100 in the United States (World Resources Institute, 1994).

The number of licensed vehicles in New Zealand has grown at more than twice the rate of the human population since 1972.

While human numbers have increased by 18 percent, car numbers have gone up by 46 percent. The number of licensed vehicles peaked in 1986 at just over 2.4 million, then dipped slightly following the 1987 economic crash. By 1995, they had risen to a new peak of just under 2.5 million (see Figure 6.3).

**Figure 6.3**

**Trends in motor vehicle numbers**




*Source: Statistics New Zealand, 1996*

**Box 6.1**

### *Motor vehicles—New Zealand's main air polluters*

In many of the world's largest cities, emissions from motor vehicles are a significant source of air pollutants. In New Zealand cities, motor vehicles seem to play a secondary role to domestic fires but they can cause or contribute to pollution incidents, particularly in busy traffic corridors when wind speeds are low and traffic density exceeds 1,500 cars per hour (see Figure 6.9). The role of vehicles varies according to the pollutant. In Christchurch winters, for example, motor vehicles contribute roughly 50 percent to high carbon monoxide levels, but only about 4 percent to suspended particulate pollution.

All motor vehicles pollute to some degree, but the worst offenders are vehicles that have been poorly maintained, tampered with, or heavily used. In fact, in the United States, about half of all vehicle emissions come from just 10 percent of vehicles - namely, those whose engines are most poorly tuned (Calvert *et al.,* 1993; Beaton *et al.,* 1995). Until recently, lead was the most notorious air pollutant emitted by motor vehicles. Its residues were detectable even on country roadsides (Collins, 1988). With leaded petrol no longer sold in New Zealand, lead emissions are no longer a problem (see Box 6.7). Dioxin emissions from halogenated lead-scavengers are also likely to have declined. There is no evidence that other emissions have fallen, and, with the growth in New Zealand's vehicle fleet, it is likely that non-lead emissions have increased.

Emissions of concern to health researchers include: carbon monoxide (which can cause death from respiratory failure); dioxins (which have been linked to cancers); nitrogen oxides (possibly associated with asthma); fine particulate matter (linked to respiratory and cardiac deaths); 1,3-butadiene (linked to cancer in laboratory animals); and benzene (linked to leukaemia). Although the main source of exposure to benzene is tobacco smoke, a 1995 study estimated that benzene emissions from vehicles would go up slightly following the introduction of unleaded Super 96 octane petrol (M. Bates, 1996).

Petrol is not the sole cause of pollution from vehicle exhausts. Diesel fumes also emit high levels of fine particulate matter and cancer-causing chemicals (Bown, 1994b). Since 1990, diesel-powered vehicles have increased, accounting for 75 percent of new commercial vehicle registrations and 11 percent of new cars registered (McChesney, 1996). Even electric cars may not be as clean as they appear. According to one controversial estimate, if they replaced the petrol fleet in the United States, the smelting and recycling of lead for their batteries would cause an overall rise in lead emissions—though this view is contested (Lave *et al.,* 1995a, 1995b; Allen, 1995; Stempel and Ovshinsky, 1995; Gellings and Peck, 1995; Gaines and Wang, 1995; Hwang, 1995; Rubenstein and Austin, 1995; Socolow, 1995; Sperling, 1995).

At present, petrol vehicles are responsible for 84 percent of the kilometres travelled in New Zealand (Kuschel, 1996). Of the more than 40,000 vehicles that went through the Canterbury Regional Council's Emission Testing Programme in Christchurch from 1993 to 1995, more than 17,000 (41 percent) were so poorly tuned that they failed to meet the programme's emission guidelines (Ayrey, 1996).

Many countries have combated vehicle emissions by imposing design rules on vehicles (engine controls and catalytic converters) and programmes of inspection and maintenance of vehicle emissions. Catalytic converters are devices that are fitted to the exhaust of a motor vehicle. They use chemical catalysts to convert some pollutants, such as carbon monoxide and nitrogen oxides, into less toxic forms, such as carbon dioxide, nitrogen and water. Over the life of a car, a catalytic converter can reduce emissions of carbon monoxide and volatile organic compounds (VOCs) by about 85 percent, and nitrogen oxides by about 60 percent. Catalytic converters have been the most important tool in controlling vehicle emissions in Japan and the United States through the 1980s (Calvert *et al.,* 1993). However, they are only a partial answer. They can only be fitted to more modern petrol-driven cars, they cannot reduce particulate matter ($PM_{10}$) and they actually increase the output of carbon dioxide (Kuschel, 1996). It is becoming clear that behaviour change, public transport systems and strategic urban planning have as great a role to play as technical solutions.

The trend in vehicle numbers is reflected in the increasing percentage of workers who drive to work and the falling numbers taking public transport. This information is gathered by the Census every five years. In 1971, 44 percent of full-time workers drove to work. By 1986 that figure had risen to 57 percent, and in 1991 it stood at 65 percent. (Department of Statistics, 1990; Statistics New Zealand, 1993). (The 1996 Census figures were not available at the time of writing.)

Conversely, the percentage taking public transport has plummeted from 14 percent in 1971 to 10 percent in 1986 and 5 percent in 1991. The percentage walking to work also declined from 11 percent in 1971 to 7 percent in 1986 and 1991. Those taking bicycles remained at 5–6 percent between 1986 and 1991.

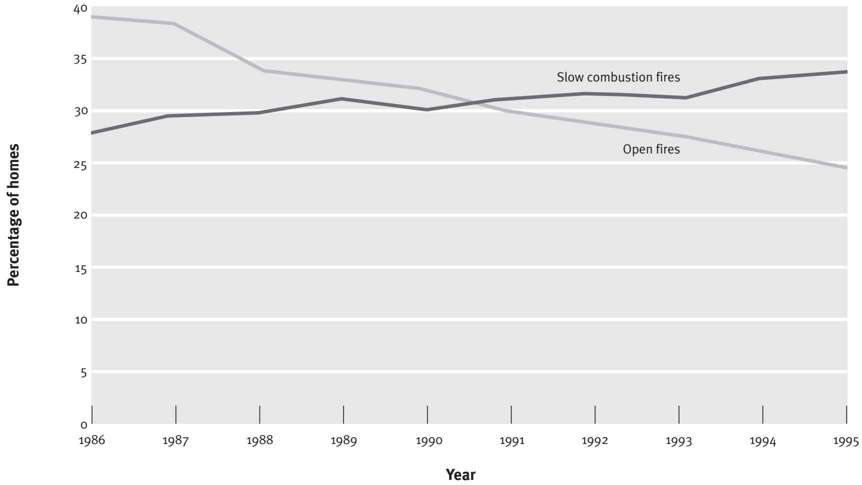
New Zealand has no laws requiring vehicles to be fitted with pollution control devices or to meet emission standards. The only laws targeting air pollution from motor vehicles are the Petroleum Products Specifications Regulations 1995, issued pursuant to the Ministry of Energy Abolition Act 1989, which ban the sale of leaded petrol (see Box 6.7) and Traffic Regulation No 28, issued pursuant to the Transport Act 1962, which makes it an offence to emit smoke from a vehicle to such an extent that it obstructs the visibility of other drivers.

**Pressures from home heating**

Home heating is the major cause of ambient urban air pollution because of the emissions from burning solid fuels (i.e. coal and wood). Both these fuels emit a range of contaminants. While coal emits twice as much particulate matter, wood emits twice as much as carbon monoxide. In absolute terms, though, most emissions come from wood fires as these are much more common than coal fires. Nationally, the number of homes with open fires has been declining, so that now only one-quarter of homes have them. Meanwhile, the proportion of homes with slow-combustion fires (e.g. woodburners) has been increasing (see Figure 6.4). This trend is not uniform, with wide variations from place to place.

**Figure 6.4**

**Changes during the past decade in the percentages of homes with open fires**




*Source: Statistics New Zealand (1996)*

A recent study of 14 Christchurch suburbs found that the percentage of homes using coal or wood fires ranged from 17 percent in one suburb to 57 percent in another (Kuschel and Foster, 1996). The suburb with the highest household air emissions was the one with the greatest number of open fires. The study also found that, for all suburbs, emissions were low in the morning and peaked between 4 and 10 pm on a typical winter's evening (which coincides with the onset of temperature inversion conditions in Christchurch).

Recent unpublished work by the Canterbury Regional Council suggests that about 90 percent of Christchurch's wintertime pollution from particulate matter comes from home fires, with coal fires, open wood fires and woodburners each contributing about a third of this. Motor vehicles contribute only about 4 percent. An earlier study estimated that up to 29 deaths a year and 80,000 lost work hours could be related to the fine particles in smoke (Foster, 1995). Household fires also contribute to about about 50 percent of Christchurch's wintertime carbon monoxide pollution. The Canterbury Regional Council has been developing plans to phase out open fires and bring in tougher emission standards for new woodburners.

**Pressures from industrial sources**

Large industrial installations, such as factories and power stations, can generate considerable quantities of air contaminants from a single source. This is often more visible than the diffuse haze which arises from cars and domestic chimneys. But, although they burn more than half the solid fuels consumed in New Zealand and sometimes emit heavy metals and other chemical contaminants, their overall impact on air quality may not be so dramatic. New Zealand has relatively few large industrial emitters; these are often located at some distance from heavily populated areas and are subject to local authority rules which prohibit high emissions.

Under the Resource Management Act 1991, large emitters are controlled through air discharge permits issued by a regional council.

The permit specifies the amount that may be discharged in a given period and usually requires emissions to be monitored. Because the system is relatively new, it is not yet possible to assess the significance of industrial emissions in contributing to ambient air quality problems. In principle though, the system ought to ensure that emissions do not significantly reduce air quality.

Some of the country's biggest emitters are the Huntly power station, the Glenbrook steel mill, and the pulp and paper industry. One of these, the Tasman Pulp and Paper mill at Kawerau in the Bay of Plenty, became subject to an air discharge permit in 1994 after previously operating under a Clean Air Act licence. The mill produces 1 percent of the world's paper, 2 percent of New Zealand's export earnings, and 3 percent of our discharges of the 'greenhouse gas', carbon dioxide. Its smokestacks currently emit 450 tonnes of particulate matter per year using state of the art control technology, and approximately 1,000 tonnes of reduced sulphur compounds per year, including the 'rotten egg' gas, hydrogen sulphide, which creates a local odour nuisance. (Ninety percent of the sulphur emissions come from the plant's geothermal energy source.) Under its discharge permit, the mill is committed to reducing these emissions, and trying to eliminate the odour problem for the surrounding community.

**Pressures from agricultural sprays**

While the vast majority of pressures on air quality tend to occur in urban areas, spraydrift from agricultural chemicals is largely a rural problem, especially where residential communities and those on lifestyle blocks rub shoulders with those involved in rural activities. Numerous complaints about spraying are received every year by government agencies, health authorities, and district, city and regional councils (Gazely and Bird, 1993; Parliamentary Commissioner for the Environment, 1993). The principle concerns are the potential for damage to susceptible non-target crops, and the perceived risk to human health either directly through spraydrift or indirectly through environmental contamination (Sheridan, 1995). Aerial spraying appears to produce a larger number of complaints than ground-based spraying, perhaps because of the greater noise and visibility of aircraft and helicopters. Another factor cited in many complaints is the chemicals' odour, which can often contribute to a complainant's perception that their health maybe at risk (Baker and Selvey, 1992).

The most widely criticised chemical sprays have been the butyl ester formulations of 2,4-D (2,4-dichlorophenoxyacetic acid) New Zealand's most widely used weedkiller (Ansley, 1996a and 1996b; Parliamentary Commissioner for the Environment, 1993; Watts, 1995). The herbicide was developed in the 1940s to control broad-leaved weeds. Its effectiveness and low cost made it New Zealand's most widely-used pasture spray.

In response to public complaints about off-target plant damage, odour, and the perceived risk to human health, regional councils in areas of high usage considered introducing restrictions on the use of this particular form of the compound and promoting other, less drift-prone, alternatives, such as 2,4-D amine formulations which have lower vapour pressures (Northland Regional Council, 1995). In October 1996 the Pesticide Board decided to ask the manufacturers and marketers of the 2,4-D isobutyl ester formulation to withdraw it and replace it with the less volatile ester formulation. Those approached agreed to the request, and the product will not be procurable after 1 October 1997. The Ministry for the Environment's Sustainable Management Fund is currently supporting research on the use and impacts of 2,4-D.

### Pressures from other sources

Other sources of ambient (outdoor) air emissions include:

- lead-contaminated paint dust from old buildings (see Box 6.2)
- nuisance odours from agricultural or industrial activities (see Box 6.4)
- scrub fires and agricultural burn-offs
- dust from unpaved roads, ploughed fields, quarries, road construction and building sites.

## THE STATE OF NEW ZEALAND'S AIR

The air quality indicators which are commonly measured throughout the world have all been monitored in New Zealand at some time or other. Only a few have been monitored systematically, however, and these are summarised here.

Levels of air pollution are commonly reported in two different types of units which are not interchangeable because one measures volume while the other measures weight. They are:

i. parts per billion (ppb) or parts per million (ppm)

   This is a volumetric measurement and refers to volumes of the pollutant (gas) per billion, or million, volumes of air. For example, a concentration of 50 ppm carbon monoxide is equivalent to 50 millilitres of the gas in 1 million millilitres (1 cubic metre) of air.

ii. micrograms per cubic metre ($\mu g/m^3$) or milligrams per cubic metre ($mg/m^3$)

   These are mass measurements and refer to the weight of pollutant (gas or particles) in 1 cubic metre of air.

   Most of the air quality measurements presented here were taken over the last 10 to 20 years. Where appropriate, the most recent data have been given greater emphasis. More detailed air quality data have been published by the Ministry for the Environment (1994a) and Graham and Narsey (1994). Although Box 6.3 contains a brief discussion of indoor air quality, the substance of this chapter deals with outdoor air. The pollutants discussed are those which commonly present problems in ambient (outdoor) air, namely, particulate matter, sulphur dioxide, carbon monoxide, oxides of nitrogen, hydrocarbons and ozone, and lead.

**Box 6.2**

### *The hazards of lead-based paint dust*

Lead is a heavy metal which is widespread in the environment. When absorbed into the human body, lead mimics calcium and tends to accumulate in the bones and teeth. Its half-life in the human skeleton (i.e. the time taken for its concentration to halve) is about 18 years (Atherley, 1978). At natural levels lead accumulation in the body seems to have no effect on human health. Comparisons of modern and prehistoric human bones reveal that our bodies now contain 500–1,000 times more lead than the natural levels of our forebears (Patterson, 1982). Even at this level the lead burden seems to have no effect on us. However, at three or four times the current 'normal' level, lead becomes increasingly toxic. Early symptoms of lead poisoning include anaemia, loss of appetite, gastric pain and constipation. Since Roman times the signs of acute lead poisoning have been well known, beginning with the tell-tale blue or black 'leadline' around the gums (Nriagu, 1983). The Romans had very high lead levels because they ate and drank from lead plates and cups.

The poison affects the entire body, most notably, the brain (in severe cases causing coma, convulsions, blindness, deafness, and severe mental disorder); the gut (causing acute stomach ache or 'lead colic', loss of appetite, nausea, vomiting and constipation); the peripheral nerves (causing weakness of fingers and toes, drooping of wrists and feet, and ultimately paralysis or 'lead palsy'); and the blood (causing anaemia and possible kidney problems) (Atherley, 1978). At lower doses, elevated lead levels in children appear to be associated with impaired learning ability and behavioural disorders, such as hyperactivity and irritability (Fergusson, 1992; Hay and de Mora, 1993; Rutter and Russell-Jones, 1983; Tong *et al.*, 1996).

Until the 1950s, a quarter of all brain-damaged lead poisoning victims died, and about half the survivors were mentally impaired. Today, early efforts are made to identify children who may be at risk from lead poisoning so that the hazards can be minimised or avoided before serious exposure occurs. Lead can be gradually removed from the tissues through lengthy treatment with substances containing calcium salts, but recovery is seldom complete. Doctors who diagnose blood lead levels above the statutory maximum values in an individual are required to notify the local Medical Officer of Health, but no statistics are kept in New Zealand on the incidence of lead exposure or lead poisoning. The average number of hospitalisations declined steadily from 14 per year in 1970–74 to 10 in 1985–89 (Public Health Commission, 1994). More than half the hospitalisations involved children aged one to four years. Most of the rest involved people in high risk environments (e.g. rifle ranges, battery factories) or handling high-risk products (e.g. lead pipes, lead-based paints).

Leaded petrol in cars has been the main source of airborne lead for most of us, but for people with lead poisoning, this 'normal' lead load has been topped up by additional lead sources. These include occupational sources, such as those already mentioned, and domestic sources, especially leaded paint flakes and dust in old houses. Children are particularly at risk of absorbing lead by inhaling dust or fumes (from the sanding or burning off of old paint) and by swallowing dust, paint flakes, or contaminated soil. Swallowing leaded surface dust (settled dust) is the most common cause of elevated lead concentrations in young children. Accessible dust contaminates the child's hands during play, and is transferred to the mouth via repetitive hand-to-mouth activities, such as thumb sucking and nail biting (Ministry of Health, 1996a).

Until 1965, many paints sold in New Zealand had high levels of lead. After that date, some lead-based paints continued to be sold, but in much smaller quantities. White lead was extensively used as a paint pigment until 1945 when it started to be phased out in favour of titanium dioxide. Nonetheless, white lead remained on sale in white undercoat until the mid-1960s. Lead sulphate was also the pigment used in pink primer until the mid-1960s. Lead chromate (yellow pigment) remained an ingredient in domestic paint until the late 1970s. Red lead steel primer is known to have been used as a wood primer until the 1980s. Calcium plumbate has been widely used as a coating for iron roofs from 1958 until the present day, but it is now no longer made, and limited stocks remain (Department of Labour, 1995).

Thus, although the concentration of lead in domestic paints has declined dramatically in the past 30 years, it may be assumed that pre-1970 interior or exterior domestic paintwork is almost certainly lead-based, whilst pre-1980 paintwork may be lead-based. An estimated 251,000 New Zealand houses may have lead paint on or in them, and each year some 5,000 of these undergo work to remove old paint (Jansen, 1984). Unfortunately, it is not possible to identify lead-based paint by its appearance, but it can be identified by simple spot tests. If sufficient care is not taken when removing it, people may be exposed to dangerous levels. 'Do-it-yourselfers' often overlook the dangers associated with preparing the family home for painting. Very young children and pets, especially dogs, run an even greater risk of contamination because they are more likely to ingest lead particles directly and in larger quantities. The Occupational Safety and Health Service (OSH) of the Department of Labour, and the Ministry of Health and public health units of Crown Health Enterprises (CHEs), are able to provide information on the health and environmental hazards linked to lead-based paint. The Ministry of Health (1996a) has issued guidelines for managing children's lead exposure.

**Particulate Matter**

The term 'particulate matter' refers to any airborne material in the form of particles, and encompasses pollutants we commonly refer to as dust, smoke, or aerosols. Particles less than 10 microns in size are generally known as $PM_{10}$. $PM_{10}$ is an important health determinant because of its ability to penetrate deeply into the respiratory tract and lungs. Airborne particulate matter can arise from a wide variety of sources including domestic fires (especially coal and wood), power stations (coal or oil), motor vehicle emissions, rubbish burning, agricultural activities, quarries, road construction, building construction, and numerous industrial processes as well.

Natural sources of particulate matter include volcanoes (such as Mount Ruapehu's recent eruptions), sea spray, plant and animal matter (e.g. pollens and fungal spores), and wind-blown dust and dirt. High concentrations of airborne particles can have various effects, including reduced crop production, when large amounts of dust are deposited in rural areas.

To humans, airborne particles can be both a nuisance and a health hazard. The nuisance effects of particulate matter include the deposition of dust and grime on vehicles, buildings and other surfaces, and reduced visibility. Large quantities of particles can make the air look hazy or dirty. When combined with sulphur dioxide emissions, particulate matter can not only also cause soiling of building surfaces, but also corrode them.

The health hazard arises when wind-blown dust irritates the eyes, and when small particles are drawn deep into the respiratory tract. Long-term exposure can seriously impair the performance of the lungs. Those most at risk are people with chronic lung diseases, asthmatics, the elderly, and very young children. In fact, an increasing number of overseas studies have shown that the fine particulate matter which comes from vehicle exhausts causes increased death rates in people with lung and heart ailments (D. Bates, 1996; Anderson *et al.*, 1996; Dockery and Pope, 1994; Health Effects Institute, 1995; Department of Health, 1995). One British estimate put the number of increased deaths in England and Wales at 10,000 per year (Bown, 1994a; Hamer, 1995). The strength of the medical evidence has persuaded the British Department of the Environment to recommend a new air quality standard for $PM_{10}$ of 50 micrograms per cubic metre (50 $\mu g/m^3$) for a 24-hour period (Department of the Environment, 1995).

The current New Zealand guideline for 24 hours is 120 $\mu g/m^3$ (Ministry for the Environment, 1994a). The typical background level for rural areas in New Zealand is less than 1 $\mu g/m^3$ and for an urban neighbourhood 25–30 $\mu g/m^3$. Readings of more than 300 $\mu g/m^3$, well in excess of the New Zealand guideline, are comparable with cities in other parts of the world (Fisher and Thompson, 1996).

Airborne particulate matter can be measured in different ways to reflect some of the effects noted above. The most commonly measured indicators of particulate pollution are:

- dust deposition
- suspended particulate
  - total suspended particulate(TSP)
  - inhalable particulate ($PM_{10}$)
- smoke.

***Dust Deposition***

Dust deposition is the amount of dust settling over a fixed surface. It was monitored at more than 40 sites around the country during the 1970s at a variety of locations including Auckland, Waiuku, Meremere, Paeroa, Kawerau, Karamea and Christchurch.

Most of these measurements were directed at specific industrial sites, and most had been discontinued by the end of the decade. The only significant monitoring in recent times has been carried out by various mining companies in areas such as Huntly, Waihi and Central Otago.

Complaints about dust fallout generally occur when deposition levels exceed 4 grams per square metre over 30 days (4 $g/m^2$/30 days). The Ministry for the Environment's *Ambient Air Quality Guidelines* do not set a guideline for dust deposition because it is regarded as more of a nuisance than a health issue. At what point a nuisance becomes an environmental issue is a matter for local authorities and their communities to judge.

Monitoring has shown that the levels of dust deposition vary widely. It is difficult to interpret some of the more extreme results without detailed knowledge of the individual monitoring programmes. However, some general observations can be made from the data:

- Background deposition levels in relatively clean environments are generally less than about 1 gram per square metre over 30 days (1 $g/m^2$/30 days).
- Deposition levels in urban areas not affected by specific industries, are typically around 1 to 3 grams per square metre over 30 days (1–3 $g/m^2$/ 30 days).

***Suspended Particulate***

*Total suspended particulate (TSP)* refers to particles floating in the air. It is measured by drawing an air sample through a filter and weighing the amount of particulate collected.

*Inhalable particulate ($PM_{10}$)* which is the measure preferred by public health authorities, is similar to TSP but only refers to particles with a median diameter of 10 microns or less which can be absorbed into the lungs.

**Box 6.3**

### *The State of our Indoor Air*

Although air pollution is generally perceived as an ambient (outdoor) issue, indoor air quality can also cause serious problems and increase vulnerability to outdoor air pollution. A wide range of indoor environments exist. Workplaces and households are where most people spend most of their time, and the most common air contaminant in these environments is probably smoke from cigarettes, and also from malfunctioning gas appliances, wood burners and open fires. There is clear evidence that coal and wood fires increase the risk of upper and lower respiratory tract infections (Larson and Koenig, 1994). However, it is also known that children in homes with coal and wood fires are less likely to develop asthma and hay fever (von Mutius *et al.,* 1996).

Alone, or in combination, cigarette, coal and wood smoke contain many toxic substances which increase the risk of cancers, bronchitis, emphysema, and heart attacks. Among the substances are particulate matter, dioxins, and carbon monoxide. Cigarette smoke also contains benzene, which is associated with acute non-lymphocytic leukaemia in children and adults. No studies have been done on the levels or concentrations of tobacco smoke in work and home environments. However, the Ministry of Health found in 1996 that nearly 20 percent of workers were exposed to tobacco smoke in their workplace, with approximately 35 percent of those exposed during tea breaks. The exposure rate in homes may be higher, particularly for children, because 23 percent of the adult population were regular tobbaco smokers in 1996. One-quarter of households with children aged under 5 years contained regular smokers. Nearly 85 percent of non-smoking adults live in households where nobody smokes. Thirty-two percent of smokers do not smoke in their own home. The smoking rate for the Maori population (38 percent) is much higher than for the Pacific Island population (22 percent) and Europeans and others (19 percent) (Ministry of Health, 1996b).

The Smoke-free Environments Act, which took effect in 1990, bans smoking in those indoor workplaces to which the public has access, and in most office areas, and encourages a smoke-free working environment. It bans smoking on public transport, and requires that at least half the space in restaurants must be 'non-smoking'. Trends in tobacco sales and public survey responses show that tobacco consumption is declining, though only a small number of smokers are actually giving up the habit. Between 1976 and 1993 New Zealand's consumption of tobacco declined faster than any other OECD country. Smoking rates fell from 34 percent of the population to 27 percent. The decline was confined almost entirely to the European population, with Maori and Pacific Island smokers showing little change (Public Health Commission, 1994). The trend continued in 1994 and 1995, with total tobacco consumption declining a further 6.5 percent in the year, but few people quitting. The average smoker had 102 cigarettes a week, compared to 107 in 1995. The 1996 Ministry of Health survey shows that 21 percent of New Zealanders are smokers.

Smoke is not the only indoor air pollutant, however. Emissions from gas appliances and kerosene heaters may also affect respiratory health. Nitrogen dioxide, for example, a by-product of combustion (see Box 6.5), has been suspected of worsening asthma. Although British studies have found no link to asthma in humans (Bown, 1993), recent US research has found that very high levels of nitrogen dioxide (about ten times the normal human exposure) does aggravate asthma in rats (Kaiser, 1996). A recent survey of 40 New Zealand homes with unflued gas appliances found nitrogen dioxide levels close to or above the World Health Organisation (WHO) guideline of a one-hour average of 160 parts per billion (ppb) (Bettany *et al*., 1993). Levels were higher for homes with wall convective gas heaters than for those with portable conductive or portable radiant gas heaters or gas cookers. Homes with flued gas appliances, or none at all, had nitrogen dioxide levels similar to ambient air.

All homes and some school classrooms with unflued gas appliances sometimes exceeded the New Zealand indoor standard for carbon dioxide, indicating inadequate fresh air supply. There were sporadic instances of high carbon monoxide. On two occasions this was associated with flued gas appliances, reflecting either poor maintenance or faulty flue installation. Six of the 40 houses had high levels of formaldehyde, in two cases above the WHO level of concern of 0.1 ppm. Indoor sources of formaldehyde include composite wood products, furnishing fabrics, carpets, and gas appliances. Five of these six houses were less than 6 years old, and one had had recent renovations (Bettany *et al*., 1993).

Other indoor environments which are likely to have some air problems are industrial worksites where dust, fumes or odour are generated as part of the production process. Because workplaces are legally subject to occupational health and safety requirements, air problems in these locations are dealt with by employers and employees on a case by case basis. The overall extent of workplace air problems is unknown.

**Box 6.4**

### *Perceived Air Quality*

Although the unaided eye or nose can sometimes detect polluted air, this is not an infallible method for assessing air pollution. Lead, carbon monoxide, and many other pollutants are invisible and odourless. Special instruments are therefore required to measure them. Instruments are also needed to determine the seriousness of a pollution episode. Sometimes air may look quite clean when, in fact, a serious problem exists. At other times it may look polluted when the levels of harmful contaminants are low.

In Auckland, for example, people often comment on the polluted appearance of the air above the city even when objective measurements sometimes reveal no problems. There are several reasons why perceived air quality may seem worse than measured air quality. For one thing, pollution is most likely to be seen during relatively short peak periods, while measurements are generally averaged over periods of 1, 8, or 24 hours. Also, measurements are often taken at single sites at ground level, while observed pollution is often well above the ground and spread over several kilometres.

The most commonly perceived air problems, however, are those detected by the nose rather than eye. In a country as sparsely populated and as windy as New Zealand, complaints about offensive odours should be quite rare. Such is not the case, and of all the issues relating to air quality, few are more likely to raise public interest—and anger—than strange and offensive smells. The Auckland Regional Council estimates that approximately 80 percent of all air pollution complaints it receives relate directly to odour (Allen, 1993). Other councils report a similar experience. The problem is not confined to the city. The bad smells come mainly from sites such as piggeries, mushroom farms, meat works, and wastewater. They often occur sporadically, depending on weather conditions and wind direction, and are difficult to assess. Odour from agrochemical sprays is also a common source of complaints in some rural districts.

The Ministry for the Environment has released a discussion document and a practice guide on odour measurement and management (Ministry for the Environment, 1994b and 1995). However, monitoring the problem is notoriously difficult because smell is a subjective sensation which cannot be objectively measured by instruments other than the human nose. Although it is possible to measure some odours from concentrated emission sources (e.g. smokestacks), the quality assurance procedures needed to get reproducible measurements are very difficult to implement.

Some councils have recorded the number and form of complaints about offensive smells (and noise), raising the possibility that complaints could be considered as an environmental indicator. However, complaint-based indicators are very subjective. An indicator of odour nuisance which is not based on complaints has been developed in the Netherlands where questions about the extent of odour nuisance are included in national social surveys dealing with a wide range of issues. By not placing undue emphasis on offensive smells, this provides a more balanced measure of the true extent and distribution of the problem.

Public perceptions of air quality problems are not always confined to things that can be seen or smelt. Extremely low frequency (ELF), or radio frequency (RF), electromagnetic radiation is invisible and odourless but public concern has grown in recent decades about whether it can cause cancer or other health problems in humans (Parliamentary Commissioner for the Environment, 1996). RF radiation is emitted by various sources, ranging from power lines and radio and television transmitters through to a whole array of household electrical appliances, such as microwave ovens, electric kettles, cellphones, computer screens and TV receivers.

RF radiation travels in waves which radiate out from the electric current like the ripples generated by a pebble dropped into a pond. The space the waves occupy as they radiate out is referred to as an electromagnetic field. The amplitude, or strength, of the field is determined by the strength of the electric current, but it weakens rapidly as it spread out from the source. The RF radiation in homes is mostly leakage from low-powered appliances (a TV, for example, uses 300 watts). However, large radio and TV transmitters are designed to carry signals over large distances and therefore have strong RF electromagnetic fields.

Cellphone transmitters use low levels of power (normally between 20 and 150 watts, or roughly light bulb strength). However, the increasing number of cellphone transmitters being erected in residential areas, and the uncertainty over whether there is a causal link between RF radiation and health problems, has stimulated public concern. For example, an application by a mobile phone company to erect a cellphone tower on a building next door to a Christchurch primary school was challenged in court. The case was lost, but it served to highlight the public's perception of the problem.

Scientists have yet to find clear evidence that RF radiation is harmful. A number of overseas studies have failed to agree on the effects, with some finding no effects at all. As scientists debate the issue, the World Health Organisation is recommending that high priority be given to further research.

Suspended particulate matter has been measured at more than 80 sites throughout the country over the last 30 years. Locations include Whangarei, Auckland, Waiuku, Waihi, Huntly, Hamilton, Kawerau, New Plymouth, Hutt Valley, Wellington, Christchurch and Dunedin.

Measuring for more than 2 years has occurred at only about one-quarter of these sites. About half the sites could be considered as area monitors, with the remainder directed at specific industries. Most of the latter are still being maintained by the companies concerned.

The equipment used for most of these measurements was designed in New Zealand, and the results cannot easily be compared with measurements from many other countries. The New Zealand equipment gave results 25–50 percent lower than the standard equipment (high-volume samplers) used overseas (Graham and Narsey, 1994). Similarly, the results should not be compared directly with the *Ambient Air Quality Guidelines* for New Zealand. The guideline pollutant is $PM_{10}$, whereas the New Zealand monitors measured TSP.

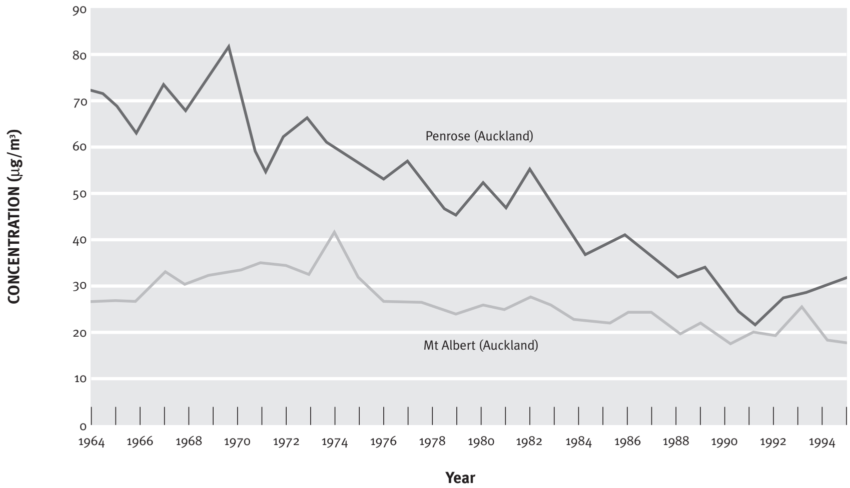
Most measurements taken using the local equipment have been evaluated against an unofficial standard of 60 micrograms of TSP per cubic metre (60 $\mu g/m^3$) averaged over 7 days. More conventional monitoring methods will have to be adopted in future, however.

Some typical results for suspended particulate measured under various situations in New Zealand are summarised below, using 7-day averages. All of the data are for total suspended particulate:

- Background levels of suspended particulate are typically below the unofficial standard, falling in the range of 20 to 50 $\mu g/m^3$. Urban areas unaffected by any specific sources fall within the same range. (A notable exception to this is Christchurch, where wintertime levels are typically in the range of 40 to 80 $\mu g/m^3$, with occasional excursions above 100 $\mu g/m^3$).
- Urban TSP levels in areas of significant industrial or commercial activity are typically in the range of 30 to 60 $\mu g/m^3$, although occasional excursions up to about 100 $\mu g/m^3$ can occur.

**Figure 6.5**

**Total suspended particulate matter (annual averages) measured in the Auckland suburbs of Mount Albert (residential) and Penrose (industrial), 1964-95**




*Source: Institute of Environmental Science and Research Ltd.*

Levels of suspended particulate matter have shown significant improvements over the last 2 to 3 decades at locations throughout the country. This applies both to general urban areas, and in the vicinity of major industrial sites. For example, at the Mount Albert (residential) and Penrose (industrial) sites in Auckland, the levels are now around half of their 1970 levels. Some of these changes are illustrated in Figure 6.5.

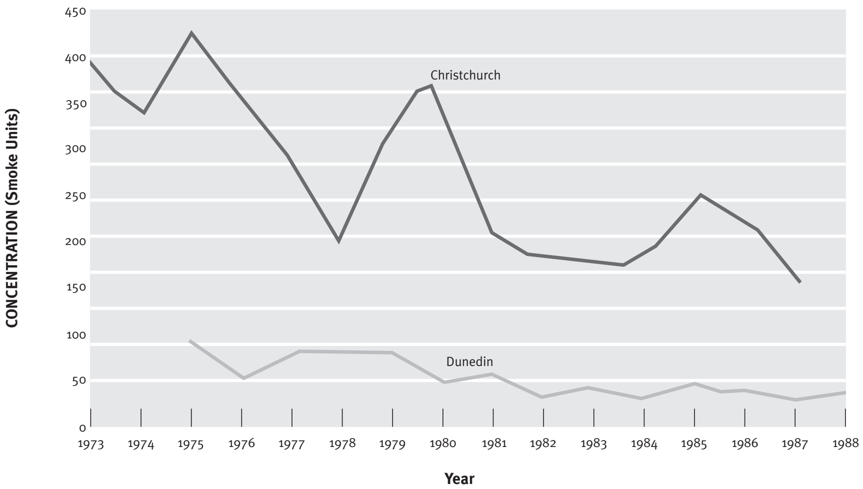
### *Smoke*

The darkness of particles collected on a filter is measured using light reflectance. This gives an indication of relative 'soiling potential' and was originally used for monitoring smoke from domestic fires. Measurements are highly dependent on the physical properties of the particles collected (especially size and colour or darkness).

The results of the measurements are converted to micrograms per cubic metre ($\mu g/m^3$) by means of a standard calibration curve, but this was originally derived from the United Kingdom and is really only applicable for communities where coal smoke from domestic fires is the predominant source.

**Figure 6.6**

**Smoke levels (annual averages) for Christchurch (Manchester Street, 1973-87, Dunedin (cnr. Princes and Rattray Streets), 1975-88**




*Source: Institute of Environmental Science and Research Ltd.*

The general practice in New Zealand has been to use this calibrating curve to convert the measured light reflectance into an estimate of smoke particle mass, but the results are expressed as 'smoke units' rather than micrograms per cubic metre. (One 'smoke unit' is equal to about 3 micrograms per cubic metre (3µg/m$^3$), with minor variations according to season, location, and fuel type).

Smoke levels have been measured at more than 60 sites over the last 20 or so years, although many of these were short-term projects, operating for periods of no more than about 6 months to 2 years. About two-thirds of all the sites were in Christchurch, with the remainder in areas such as Whangarei, Auckland, Huntly, Dunedin and Invercargill.

As with suspended particulate matter, smoke levels around the country have also shown some improvements over the last 10 to 20 years. In Christchurch and Dunedin, for example, wintertime levels of smoke have decreased—significantly in the case of Christchurch—especially over the last decade. These improvements are shown in Figure 6.6.

The results from the more recent monitoring programmes can be summarised as follows:

- Summer smoke levels throughout the country are typically less than 5 to 10 smoke units.
- Current wintertime smoke levels in areas other than Christchurch show daily maxima typically in the range of 30 to 50 smoke units. (By comparison, wintertime smoke levels in Christchurch over the period 1980–85, showed daily maxima of up to about 200 smoke units.) In recent years, this type of monitoring has been upgraded to measure TSP and $PM_{10}$, providing more useful information about health effects than smoke units do.

The above data cannot be compared directly with any air quality guidelines because of the nature of the measurements. Levels greater than about 30 smoke units would be visually assessed by most people as 'smoky' conditions, and results above about 100 smoke units would probably be cause for widespread concern. It is interesting to speculate on the reasons for this improvement in air quality. Quite clearly, if the change has occurred throughout the country in both residential and industrial locations, then it is probably not due solely to improvements in the control of individual pollution sources.

The most likely explanation for the improvements are changes in fuel use. Coal consumption has declined and use of electricity has increased. A rise in air pollution complaints to the Christchurch City Council in 1992 may have resulted from the greater use of domestic fires during the '1992 Hydro Power Crisis' (Brieseman *et al.*, 1992). [The increase in sulphur dioxide emissions during the 'Power Crisis' would seem to bear this out (see Figure 6.8).]

The Clean Air Act came into force in 1972 but this was primarily concerned with the control of industrial emissions. Although there have been controls on smoke emissions from domestic fires in Christchurch, this has not been the case elsewhere. Smoke is still the main wintertime air contaminant in other Canterbury urban areas (Canterbury Regional Council, 1993).

In Wairarapa, emissions from domestic fires can have greater impact on overall air quality than other sources, such as industry. The population density is low, but an estimated 80 percent of Wairarapa homes have some form of solid fuel heating. Climatic conditions can cause the emissions, especially smoke, to accumulate and reduce visibility (Gazely and Bird, 1993).

### *Sulphur Dioxide*

Many air pollutants belong to a group called the oxides, which are formed when oxygen combines with other substances (see Box 6.5).

Sulphur dioxide ($SO_2$) is an acidic gas which has a pungent odour in high concentrations. It arises from the burning of sulphur in coal and oil. Other carbon fuels, such as natural gas, petrol and wood, have insignificant amounts of sulphur.

The primary sources of sulphur dioxide are coal (typically between 0.5 percent to 3.0 percent sulphur, depending on type), fuel oil (ranging from 0.5 percent sulphur for light refined products, up to 4 percent for some heavy industrial types used in ships, power stations, and refineries), and diesel (0.3 percent).

Sulphur dioxide can also be emitted from a number of specific industrial operations, such as fertiliser and sulphuric acid manufacturing plants and oil refineries. It is also found in volcanic gases.

Sulphur dioxide is an irritant which can affect breathing and possibly harm the respiratory system. High concentrations can cause cell damage to plants. When combined with moisture in the air, sulphur dioxide forms sulphuric acid, a corrosive which can damage building and other materials.

Prolonged exposures to mixtures of sulphur dioxide and inhalable particulate matter may be linked to increased cases of respiratory diseases such as bronchitis, particularly in young children. When present in the air, there is usually particulate matter present as well. As a result, the effects of these two pollutants are difficult to separate, and their combined effects are worse than the effects of each individually.

Sulphur dioxide has been measured at more than 40 sites over the last 20 or so years, although about half of these were only for short periods. Much of the effort has been in Christchurch, with the remainder in Whangarei, Auckland, Huntly, Dunedin and Invercargill.

Prior to 1987, most monitoring was carried out using a wet-chemical procedure which gives a measurement of 'total acidity' as a 24-hour average result. Instrumental monitoring for sulphur dioxide has gradually taken over as the preferred method since that time in Auckland, Huntly, Christchurch, Dunedin, and Invercargill.

**Box 6.5**

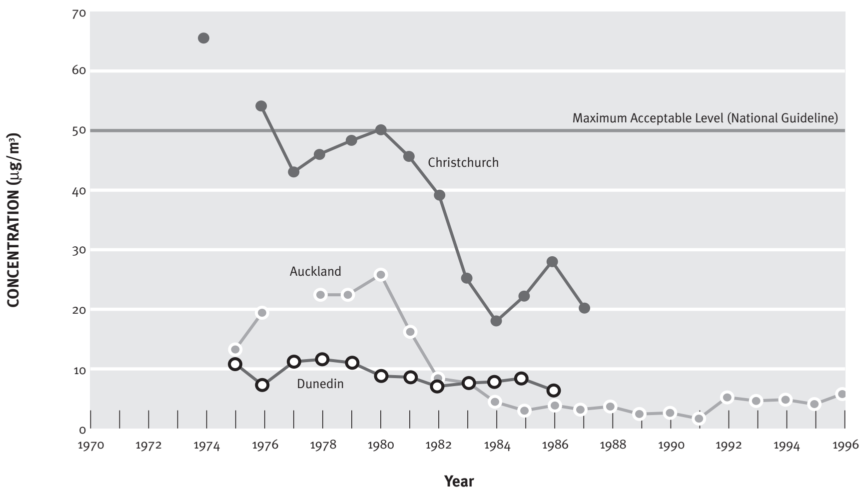
#### *How Oxides are Formed*

Oxidation is a simple but vital process that happens all the time. It occurs when iron rusts and organic matter rots. It happens when fires burn, and even when we breathe. It also happens quietly in the air around us. Basically, it occurs whenever an oxygen atom combines with another atom (such as carbon or nitrogen or sulphur or iron) to form a new molecule. The new molecule is called an oxide. Often oxygen creates oxides by tearing other atoms away from a pre-existing molecule, causing the latter to burn or rust or rot. When it happens to the food inside us, we call the process respiration. Carbon is torn away from food molecules by the oxygen we breathe and exhaled back into the air as carbon dioxide. The energy and remaining atoms released by the departing carbon can then be absorbed by our bodies.

Some oxides are formed by only one oxygen atom, e.g. carbon monoxide (CO) and nitric oxide (NO), while others are formed by two of them, e.g. carbon dioxide ($CO_2$), nitrogen dioxide ($NO_2$), and sulphur dioxide ($SO_2$). The shorthand terms for oxides of nitrogen and sulphur are $NO_x$ and $SO_x$. In our cars, homes, factories, and in power stations using oil or coal, oxidation occurs through combustion. When fuel or waste containing carbon is burnt, carbon monoxide (CO) and carbon dioxide ($CO_2$) are formed. Their relative amounts depend on the efficiency of combustion. More efficient processes create more $CO_2$ than CO. If trace levels of inorganic elements, like sulphur, are present in the fuel or air, these are also oxidised to produce sulphur dioxide ($SO_2$). Because air is 79 percent nitrogen, this also oxidises during combustion to produce oxides of nitrogen ($NO_x$). The newly-formed carbon dioxide and other oxides escape as fumes. Carbon monoxide is particularly dangerous because it is invisible, odourless, and toxic. With the rise of industrial society, and the heavy use of coal, oil, and petroleum, oxidation through combustion has increased dramatically and, with it, the levels of carbon, sulphur, and nitrogen oxides.

**Figure 6.7**

**Sulphur dioxide levels (annual averages) for Auckland (Penrose) 1975-76 and 1978-96, Christchurch (Manchester Street) 1976 and 1976-87, and Dunedin (cnr. Princes and Rattray Streets), 1975-88**




*Source: Institute of Environmental Science and Research Ltd.*

Monitoring in Auckland has mainly been based around 3 sites. These indicate that sulphur dioxide levels have declined significantly over the last 10 years or so. Prior to about 1980, sulphur dioxide levels averaged about 15 to 20 micrograms per cubic metre, (15 – 20 µg/m$^3$) with daily maxima of up to 75 µg/m$^3$. Levels in more recent years have been around 5 µg/m$^3$ or less, with daily maxima of up to 20 to 30 µg/m$^3$.

In Huntly, sulphur dioxide is monitored at 3 sites, with 2 of these operating since 1977. Once again, the levels have declined significantly over the last decade, with initial average levels of 10 to 15 µg/m$^3$ now dropping to 5 to 10 µg/m$^3$, and the daily maxima of up to 75 µg/m$^3$ now down to 15 to 20 µg/m$^3$. This monitoring is carried out by the Electricity Corporation of New Zealand (ECNZ).

In Christchurch, a total of 20 or more sites have been used for sulphur dioxide monitoring, although about two-thirds of these were only operated as short-term sites in the mid-1970s and usually over the winter months of each year. Since 1987, monitoring has been conducted at only one instrumental site, a GEMS/AIR site in Packe Street.

As with the other cities that have been monitored, Christchurch's sulphur dioxide levels have improved markedly over the last 10 to 20 years. Averaged across the year, sulphur dioxide levels in the mid 1980s were in the order of 15 to 30 µg/m$^3$, with maximum daily values in the range of 50 to 100 µg/m$^3$. Prior to about 1980, most Christchurch sites were recording results of about double these values. Since 1987, the suburban Packe Street street in Christchurch has shown annual averages of 3 to 7 µg/m$^3$, and maximum daily values of up to 30 µg/m$^3$. However, care is needed in comparing these results with the earlier ones because of the differences in methodology and location.

In Dunedin, monitoring for sulphur dioxide has been conducted mainly at two sites, although an additional six have been used for short-term studies. The results indicate annual average levels of 10 to 20 µg/m$^3$ with maximum daily values of 35 to 70 µg/m$^3$. Once again, these values are for data from the mid- to late 1980s, which are significantly lower than those for the previous decade.

In Invercargill, monitoring at two sites in the mid-1980s indicated relatively low levels of sulphur dioxide, with annual averages of 5 to 10 µg/m$^3$ and daily maxima of no more than 25 µg/m$^3$.

Sulphur dioxide levels have dropped significantly over the last two decades, and, when compared to the New Zealand *Ambient Air Quality Guidelines*, levels are generally very low in most urban areas. This is clearly illustrated in Figure 6.7 showing average annual levels for Auckland, Christchurch, and Dunedin.

It should be noted, however, that there are situations where sulphur dioxide emissions from specific local sources have caused concern in recent years. The area around Marsden Point in Whangarei where there is an oil refinery is perhaps the most widely publicised of these.

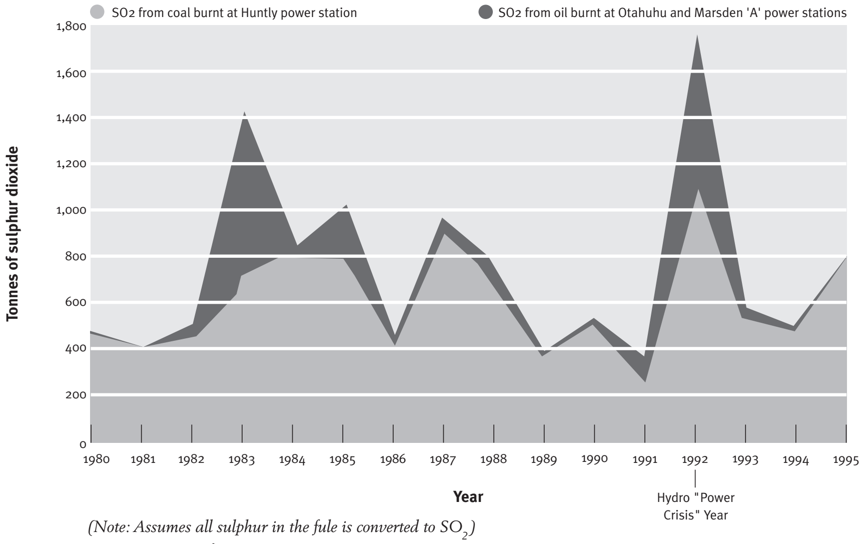
A 1994 survey also showed that in Greymouth, on still winter nights when coal with a high sulphur content is burned in domestic fires, sulphur dioxide levels exceed the 24-hour recommended levels (West Coast Regional Council, 1994).

The Greymouth survey shows that 2 sites were monitored, one for 97 days during which time the guideline level was exceeded 5 times (5.2 percent of time) and the other for 90 days during which time the guideline level was also exceeded 5 times (5.6 percent of time). (Although the United States has a less rigid guideline than New Zealand, exceeding the guideline more than once in a year would mean 'non attainment' and necessitate an extensive programme to clean up air quality within three years.)

During the 1992 winter power crisis when very low levels in the South Island hydro scheme lakes forced the Electricity Corporation of New Zealand to burn more coal and oil to maintain power supplies, there was a sharp jump in sulphur dioxide emissions (see Figure 6.8).

**Figure 6.8**

**Estimated sulphur dioxide emissions resulting from oil and coal-fired electricity generation, 1980-96**




*(Note: Assumes all sulphur in the fule is converted to $SO_2$)*
*Source: Ministry of Commerce (1995), Baines (1993)*

### Carbon Monoxide

Carbon monoxide (CO) is a colourless, odourless, highly toxic gas, which is formed by the incomplete combustion of fossil fuels. When inhaled, it binds to haemoglobin in the blood, displacing oxygen. Prolonged exposure at moderate levels can lead to symptoms such as headaches and dizziness, while at high levels it can lead to loss of consciousness and even death.

At the lower levels which are typically encountered in urban areas it can serve as a useful indicator of the influence of vehicle exhaust emissions on air quality. Vehicles are the main source of carbon monoxide in most parts of New Zealand. Carbon monoxide can also be present in the emissions from domestic open fires and backyard incinerators, industrial fuel use and some specific industrial processes, such as steel manufacture.

In the past, carbon monoxide was monitored on a fairly sporadic basis, using short-term studies over periods ranging from several weeks up to about 6 months. Permanent monitoring sites have only been established in Auckland and Christchurch over the last few years.

**Box 6.6**

### *Acid Rain— A Northern Hemisphere Problem*

Acid rain, which is a serious problem in some Northern Hemisphere countries, occurs when oxides of sulphur and nitrogen, which arise from the burning of fossil fuels, react with moisture in the atmosphere to produce a corrosive rain. Its worst effects are seen in Europe, Scandinavia and North America, where lakes and forests have been poisoned.

The acidity of rain is measured on the pH (powers of Hydrogen) scale which ranges from 0 to 14. Pure water has a pH value of 7, which is neutral. Values less than 7 are acid, and the stronger the acid the lower the pH. Orange juice has a pH of 4.5, vinegar has a pH of 3, and battery acid has a pH of 1. Values greater than pH 7 are alkaline. Rainfall is usually slightly acid with a natural pH of around 5.6. Acidification is only considered serious when the pH falls below 5. Rainfall with pH values of 5 to as low as 3 has been recorded in Europe and North America. In a comparatively unpolluted environment like New Zealand's, the pH of rain typically ranges between 5 and 6.

Only three sources of acid rain can affect New Zealand: the locally-produced sulphur dioxide from domestic and industrial sources; wind-blown imports from Australia; and the occasional belching of the North Island's volcanoes (e.g. Ruapehu). Holden and Clarkson (1985) estimated that, in an average non-volcanic year, the total fall-out of sulphur in New Zealand amounts to 42,000 tonnes, two-thirds of which blows over from Australia. This means an average loading of 0.15 grams of sulphur per square metre per year over the whole country—barely 13 percent of Sweden's level and less than 3 percent of Germany's (see Table 6.2). Holden and Clarkson concluded that acid rain is not a significant problem in New Zealand and is unlikely to become one at current levels of industrialisation and fuel combustion. In light of this, rainfall chemistry monitoring by the National Institute of Water and Atmosphere Research (NIWA) was terminated in favour of other research priorities.

However, on the rare occasions that significant volcanic activity does occur, the question of acid rain is inevitably revived. Until 1995, Mount Ruapehu had been relatively inactive for half a century. In September and October of that year it erupted, and did so several times in 1996 as well. In just two weeks in October 1995, the mountain spewed sulphur dioxide into the air at a rate of between 1,900 and 17,000 tonnes per day—three years' worth in a fortnight (Bell, 1995). Two vast ash falls sprinkled to the ground as far as Gisborne and Waipawa and a large sulphurous cloud stretched from Hawke's Bay down over the Wairarapa and Wellington, and out to sea between Christchurch and the Chatham Islands.

Vulcanologists did not expect any significant harm to the environment but predicted that vegetation away from the mountain could be affected if acid rain fell over a long period or gas emissions increased drastically (Bell, 1995). They cited the example of Hawaii where crops and natural vegetation were damaged over nine years of repeated eruptions. Soil scientists who analysed the ash falls concluded that they had useful amounts of sulphur and magnesium for fertiliser, "but heavy falls may have nuisance levels of sulphur and high soil acidity associated with them." (Cronin *et al.*, 1996).

**Table 6.2**
**Non-volcanic sulphur depositions in New Zealand and other countries (grams of sulphur per square metre)**

| Location | Average deposition ($gS/m^2/yr$) | Maximum deposition ($gS/m^2/yr$) |
|---|---|---|
| *Germany* | *6.5* | *>10* |
| *England* | *4.3* | *7* |
| *Norway* | *0.9* | *3* |
| *Sweden* | *1.2* | *4* |
| *Australia (four states only)* | *0.2* | *?* |
| *New Zealand* | *0.15 (model)* | *0.7 (estimated)* |

*Source: Holden and Clarkson (1985)*

The first significant studies of carbon monoxide were carried out in Auckland and Christchurch in the early to mid-1970s. These indicated that this pollutant could accumulate to undesirable levels for significant periods of time in some inner city streets.

Measurements inside a shop in Queen Street (the main street through Auckland's central business district) during 1974 showed that the World Health Organisation (WHO) 8-hour guideline of 10 milligrams per cubic metre ($mg/m^3$) was exceeded about 35 percent of the time (World Health Organisation, 1987). Similar results were reported for a short-term monitoring exercise in Hamilton during 1978.

Only a limited amount of carbon monoxide monitoring was carried out in Auckland and Hamilton during the 1980s, but this indicated that the situation was probably much the same as before. A new site was established in Auckland in 1990, again located in Queen Street, but well away from major intersections.

The levels of carbon monoxide now being recorded are much lower than in the past, partly due to the new site and partly due to the fact that traffic flows in and near Queen Street are now lower than those in the 1970s. During 1993–94, however, the guideline was exceeded 4 times at the new Queen Street site.

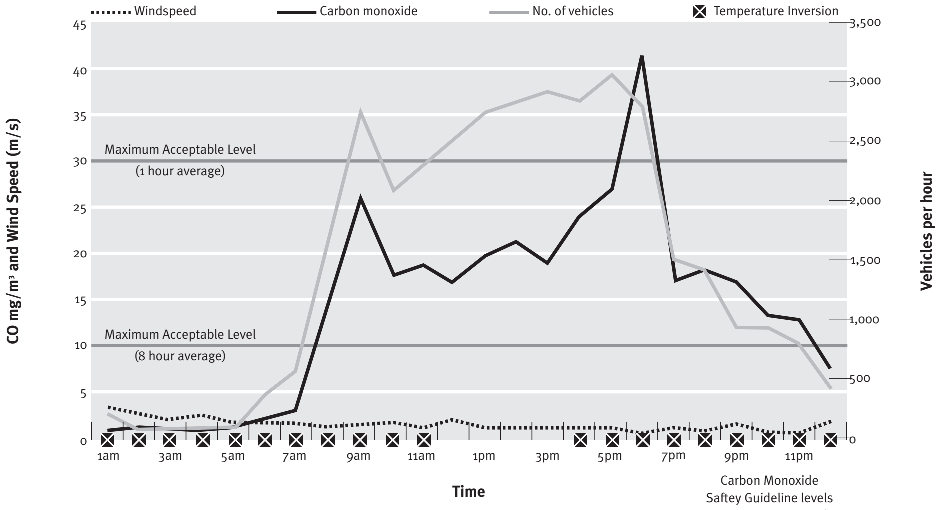
The regional council placed a second carbon monoxide monitor on Dominion Road in April 1994. During the 8 months it operated, the WHO guideline of 30 $mg/m^3$ for 1 hour, or 10 $mg/m^3$ over an 8-hour period, was exceeded 16 times. Traffic flows on this road are roughly 3 times the volume on Queen Street.

Carbon monoxide monitoring was also carried out in Christchurch during the mid-1980s. However, this was at a suburban site, rather than in the inner city area, and the carbon monoxide levels were relatively low.

The new monitoring site, in the suburb of St Albans, is also away from the city centre. Even so, the WHO guideline has been exceeded between 4 and 17 days per year at this site since 1988, generally on winter nights, suggesting that domestic fires may be partly responsible. During 1993, the regional council monitored carbon monoxide along Riccarton Road, a location with high traffic flows, for 61 days. The guideline was exceeded 56 times during this period (see Figure 6.9).

**Figure 6.9**

**Carbon monoxide (CO) levels (static hourly average) in Riccarton Road, Christchurch, showing typical variations for traffic move ment on days of low wind speed**




*Source: Foster (1994)*

At present there is no reason to believe that carbon monoxide levels near busy inner city intersections in New Zealand will be any lower than those recorded in the past. Increases in vehicle numbers are more likely to raise levels than to lower them.

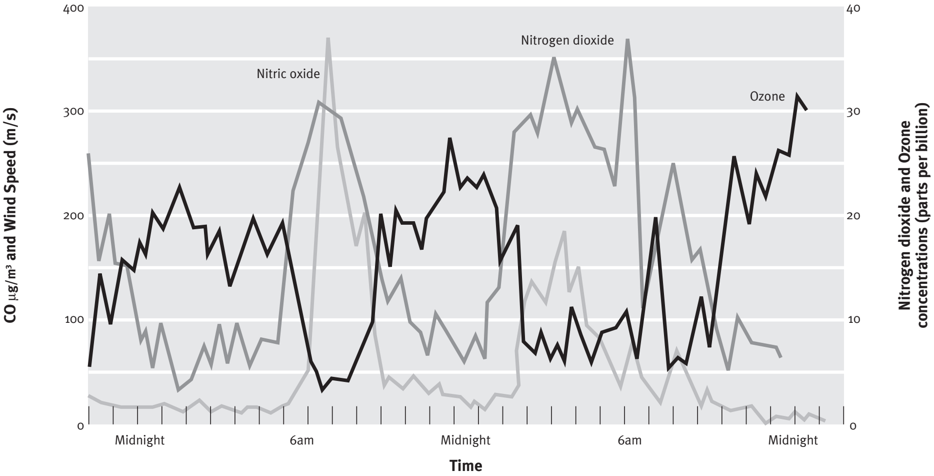
This is borne out by some recent measurements in Gisborne and Whangarei which showed that carbon monoxide levels in the central business district could be moderately high even in cities of this size (Gisborne 31,000; Whangarei, 44,000) (Gisborne District Council, 1993; Northland Regional Council, 1994).

Monitoring in Gisborne showed that for 25 percent of the time over 20 sample days, carbon monoxide levels were unhealthy. In Whangarei, high levels of carbon monoxide occurred at one of two sites monitored for 9 percent of the time over 90 sample days.

Recent studies in Auckland and Christchurch have found that carbon monoxide levels in busy traffic corridors can exceed the ambient

**Figure 6.10**

**Sample measurements of nitric oxide (NO), nitrogen dioxide ($NO_2$), and ozone ($O_3$) from Christchurch, 6-7 July 1996**




*Source: NIWA (1996)*

**Safety Guidelines**
Nitrogen dioxide: 1 hour 300 µg/m³; 8 hour 100 µg/m³
Ozone: 1 hour 150 µg/m³; 8 hour 100 µg/m³
No guideline has been set for nitric oxide because it converts to nitrogen dioxide.

air guidelines in both summer and winter, whenever wind speeds are low and traffic density is high (e.g. Foster, 1994). Motor vehicles are the dominant source. However, ambient air pollution away from the traffic corridors occurs only in winter when emissions from household fires combine with those from motor vehicles. In Christchurch, for example, motor vehicles and domestic fires contribute about equally to ambient wintertime carbon monoxide pollution.

### Oxides of Nitrogen

Oxides of nitrogen ($NO_x$) is the term used to describe a mixture of two gases, nitric oxide (NO) and nitrogen dioxide ($NO_2$). These are formed in most combustion processes by the oxidation of the nitrogen present in the air (see Box 6.5). Nitric oxide is the primary product but this can then be further oxidised in the ambient air to form nitrogen dioxide.

As with carbon monoxide, motor vehicles are the major source of the oxides of nitrogen in most parts of the country, although power stations and other large combustion units may be significant localised sources as well.

The main health impacts of the oxides of nitrogen come from nitrogen dioxide which is a respiratory irritant. At high levels it can corrode materials such as metals, and damage plants. Nitric oxide is believed to be quite harmless at the levels normally encountered in urban air.

The oxides of nitrogen are an important air pollutant because of their role in the formation of photochemical smog and of nitrates which take the form of fine particles and impair visibility. In the Northern Hemisphere, they also contribute to the problem of acid rain by converting to nitric acid in the atmosphere.

Most monitoring of the oxides of nitrogen ($NO_x$) has been carried out in Auckland and Christchurch, and to a lesser extent, Dunedin. Two monitoring methods have been used: wet-chemical (bubbler) systems, which generally yield a 24-hour average result, and instrumental monitoring, which gives continuous data. Both systems produce results for both nitric oxide and nitrogen dioxide, although our primary interest here is with nitrogen dioxide.

Oxides of nitrogen were monitored using wet-chemical systems at 5 sites in Auckland over the mid- to late 1970s, at 10 sites in Christchurch for variable periods through most of the 1970s and 1980s, and at 2 sites in Dunedin in the late 1970s. Most of the sites were located either within or near the central business districts, or in suburban areas with significant motor vehicle activity.

The results can be summarised as follows, with all $NO_x$ data quoted in terms of nitrogen dioxide ($NO_2$) equivalents:

- In Auckland, maximum daily values for $NO_x$ were typically in the range of 100 to 300 micrograms per cubic metre (100–300 µg/m³), with annual means of 40 to 60 µg/m³.
- In Christchurch, maximum daily values for $NO_x$ ranged from about 200 to 500 µg/m³, with occasional excursions above this limit. Annual means were in the range of 50 to 100 µg/m³ in most locations.

- In Dunedin, maximum daily values for $NO_x$ were typically in the range of 150 to 300 µg/m$^3$, with annual means of 50 to 60 µg/m$^3$.
- The ratio of nitric oxide to nitrogen dioxide in the above data was normally in the range of about 1:1 to 3:1. In other words, nitrogen dioxide normally accounted for between 25 percent and 50 percent of the total $NO_x$. The main factor here is proximity to the sources, in that the ratio tends to drop with increasing distance as nitric oxide is converted to nitrogen dioxide in the atmosphere.

Monitoring for $NO_x$ was carried out in a fairly sporadic fashion from the mid- to late 1980s, although there are now two permanent sites operating in Auckland and one in Christchurch.

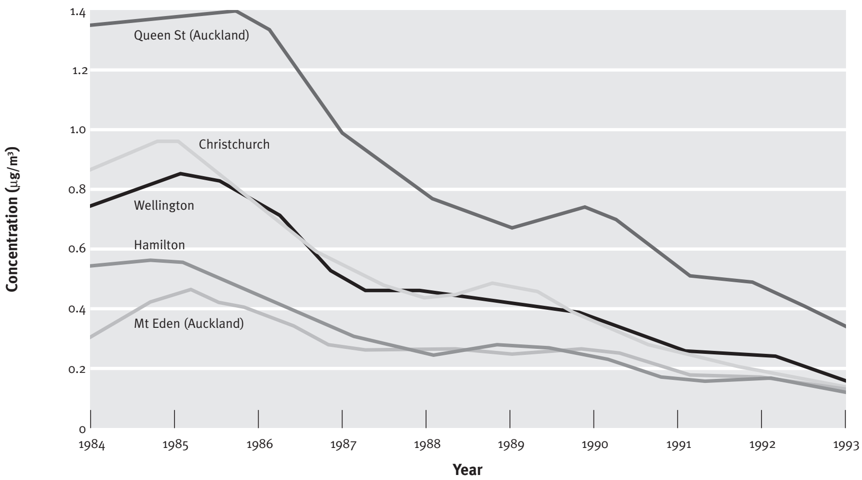
Generally speaking, the instrumental data indicates slightly lower levels of $NO_x$ compared to the wet-chemical information given above. This may be due to the improved sensitivity of the instrumental method or to a difference in location.

The above monitoring indicates there may be cause for concern at some sites in both Auckland and Christchurch for a small percentage of each year. However, because observations are based on levels of total $NO_x$, more work is needed to determine whether nitrogen dioxide levels actually approach the guideline values.

Unlike some of the other pollutants mentioned in this report, levels of $NO_x$ do not appear to have changed significantly over the last 20 years. However, as with carbon monoxide, increasing vehicle numbers and use in recent years may change this.

**Figure 6.11**

**Atmospheric lead levels (annual averages) from five monitoring sites (two in Auckland, and one in Hamilton, and Christchurch) 1984-93**




*Source: Institute of Environmental Science and Research Ltd.*

### Photochemical smog and tropospheric ozone

Photochemical smog is a dense brown haze which occurs in many large cities. It consists of a complex mixture of chemical gases, including ozone ($O_3$). Although ozone is a vital radiation screen in the upper atmosphere, at ground level it is one of the main components of smog. Ozone is part of the mix of pollutants in photochemical smog, and is formed from reactions between other pollutants.

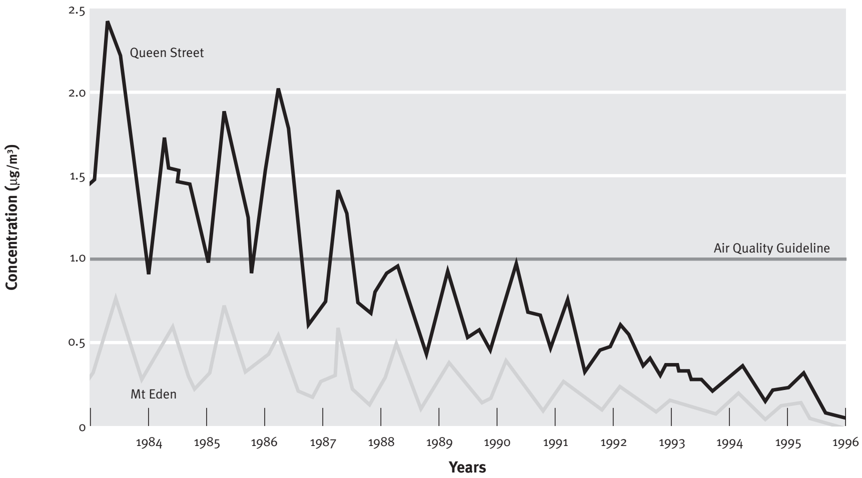
Photochemical smog results from the reaction of sunlight on the complex chemical mix of oxides of nitrogen ($NO_x$)(which come from the oxidation of atmospheric nitrogen during and after the process of burning), and volatile organic compounds (VOCs) (emitted mainly from car exhausts, and to a lesser extent from industrial solvents).

Photochemical smog has recently been shown to increase death rates in big cities. A recent study in London found that ozone levels were associated with significant increases in respiratory and cardiovascular deaths (Anderson *et al.*, 1996). This effect was quite independent of the effects of other pollutants (e.g. $PM_{10}$). The mixture of chemicals present in smog is also extremely irritating to the eyes, nose, throat and lungs, and can cause breathing difficulties, particularly in susceptible people.
It also causes deterioration of materials such as rubber, damages sensitive plants, and seriously reduces atmospheric visibility.

Because ozone is one of the main components of photochemical smog it is usually monitored as a simple indicator of smog conditions.

**Figure 6.12**

**Airbourne lead concentration (3-monthly moving averages) at two Auckland montitoring sites (Queen Street and Mt Eden), 1983-96**




*Source: Institute of Environmental Science and Research Ltd.*

The only monitoring for ozone and/or photochemical oxidants in New Zealand, however, was carried out in Auckland almost 20 years ago. The city, then, was considered the only place where there were enough of the major emission sources (especially motor vehicles) and sufficient sunlight for smog to be a potential problem.

Photochemical smog received particular attention in the late 1970s and early 1980s when proposals were made to build a number of large power stations in and around the Auckland area. Most of the monitoring was carried out in joint studies by the Department of Health, the New Zealand Meteorological Service, and the New Zealand Electricity Division of the Ministry of Energy.

The results can be summarised as follows:

- There is a natural background level of ozone which is normally in the range of 0 to 30 ppb.
- Periods with higher levels of oxidants were observed in Auckland on 5 to 10 days of any year. These 'incidents' were generally in the range of 40 to 80 ppb (80 to 160 μg/m$^3$), and usually occurred over periods of 2 to 3 hours in early to mid-afternoon during the summer months.

These results indicate that 20 years ago our cities had comparatively fewer smog 'incidents' relative to cities in other parts of the world. Although there has not been any recent monitoring for smog, the main contributors, particularly motor vehicles, have definitely increased, especially in Auckland. However, reliable evidence can only be obtained through renewed monitoring.

**Lead**

Lead is one of the group of so-called 'heavy metals' which also includes elements such as mercury, cadmium, and zinc. It is the most prevalent of these as far as air pollution is concerned. Leaded petrol was a widespread source of lead in the air in New Zealand, with the lead being emitted as fine particulate matter from motor vehicle exhausts. A few industrial sources, such as lead smelters and scrap metal recovery operations, may also contribute to local lead concentrations in the air. Although the main cause of lead-related illness in New Zealand is dust and lead-based paintwork in older buildings (see Box 6.2), lead in petrol has caused most of the widespread accumulation of lead in the environment.

Particulate lead has been monitored at more than 25 locations throughout the country, with sites in Auckland, Hamilton, Palmerston North, Hutt Valley, Wellington, Christchurch, and Dunedin. Two of these sites (Mount Albert and Penrose in Auckland) have been monitored since 1961, while many of the others have run for periods of 5 to 10 years.

The monitoring sites cover a variety of locations, including suburban, inner-city, and alongside major motorways, with most of them directed at observing the effects of motor vehicle emissions.

Prior to 1986, when lead levels in petrol were reduced, concentrations in most urban areas were typically in the range of 0.1 to 1.0 μg/m$^3$. In areas of high traffic densities or significant congestion the levels were generally higher than this, with values at times in excess of 2 to 3 μg/m$^3$.

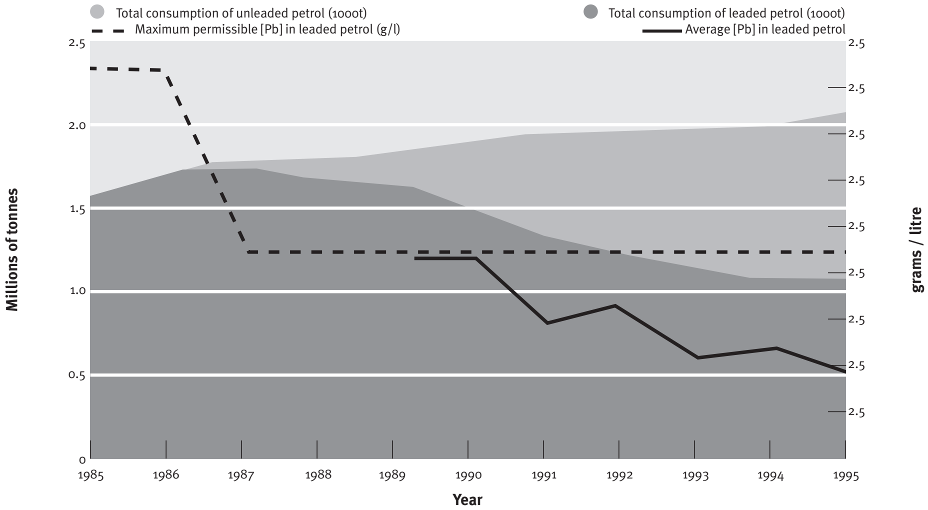
Since 1986, the lowering of the lead content in petrol has resulted in a marked reduction in atmospheric lead levels (see Figure 6.11 and 6.12).

Although the annual average statistics in Figure 6.11 clearly show the downward trend in atmospheric lead levels over recent years, they do not reflect marked seasonal variations recorded at the monitoring sites and shown in Figure 6.12. The data are presented for two Auckland sites as 3-monthly running averages for comparison against an air quality guideline of 1.0 µg/m$^3$ (3-monthly average).

The seasonal changes reflect variations in weather conditions. The highest lead levels are recorded in midwinter, probably because of the increased frequency of early morning temperature inversions in the winter months when air is trapped at ground level, below cloud or a warmer layer of air.

**Figure 6.13**

**Petrol sales following the introduction of Unleaded 91**




*Source: Ministry of Commerce (1996)*

(From January 1996 the maximum permissible lead content was reduced to 0.013 grams per litre)

## SOCIETY'S RESPONSES TO AIR POLLUTION

Until the early 1970s, responses to air pollution were localised and limited. In Christchurch, for example, local councillors could do little to reduce the build-up of traffic fumes and household smoke beneath the inversion layer that formed a frequent umbrella over the city. Auckland also had problems with odours, traffic fumes and some industrial emissions. As public concern grew, the matter was finally taken up by central government and, in 1972, the Clean Air Act was passed.

### Clean Air Act 1972–1991

The Clean Air Act regulated emissions of pollutants from industrial and trade processes, and classified pollution sources according to their type and rate of heat release. Major polluters were required to obtain licences from the Department of Health which were effective for anywhere between 1 and 5 years. For each licence, Health Department officers determined the 'Best Practicable Means' (BPM) of pollution control (Ministry for the Environment, 1994a). Under this BPM approach, large industrial sources of air pollution were instructed to operate in specific ways and to install particular control technologies to minimise emissions.

City and district councils were empowered to operate a similar licensing system for smaller air polluters. The controls imposed by these authorities were varied and were based on site-specific considerations and the Health Department's BPM guidelines. To deal with air pollution arising from dispersed sources (e.g. households), the Clean Air Act allowed local authorities to establish Clean Air Zones, in which emissions were controlled through by-laws rather than licenses. The only place ever declared a Clean Air Zone was Christchurch. The Christchurch City Council took the step to control the smoke pollution caused mainly by open fires. Within the Christchurch Clean Air Zone, grants were made available for homeowners to replace open fireplaces with approved non-polluting heating appliances, and restrictions were imposed on the types of fires which could be installed in new houses and on the types of coal and other fuels that could be burned in them.

One effect of the Clean Air Act was an upsurge in monitoring activity both regionally and at specific sites. However, this fell away in the late 1970s as emissions improved at some sites and as monitoring was considered unnecessary at others. Routine monitoring continued mainly in Auckland and Christchurch, the two centres with the greatest potential for problems. As a result of these monitoring programmes, we know that sulphur dioxide pollution and particulate matter decreased following the introduction of the Clean Air Act. However, this may have been coincidental rather than causal, with the Act merely spurring along a process of declining coal use that was being driven, in large part, by the aggressive promotion of electricity.

Another significant change in air quality occurred quite independently of the Clean Air Act. This was the progressive reduction of lead emissions from motor vehicles. It took place in a series of steps from 1986 to 1996 (see Box 6.7). Concern about lead in petrol had started to emerge in the 1970s as scientists overseas began connecting low level exposure to lead with developmental disorders in children. Leaded petrol, leaded paint, and lead-lined pipes and containers were identified as the main culprits, with petrol being the most widespread of these, and the hardest to avoid.

Both the Super grade (high octane) and Regular grade (lower octane) petrol on sale at the time contained high amounts of lead. New Zealand was slower than many other countries in responding to the concern about leaded petrol, but eventually measures were introduced and lead levels in air began to decline from the mid-1980s (see Figure 6.11). In the original data this effect could be detected by about October 1986, or three months after the first reduction in the lead content of Super petrol. The lag probably reflects the time taken to purge the petrol distribution system of the older high lead supplies. The reduction in air lead levels for mid-1987 compared to 1986 was around 40 percent.

In summary, although the Clean Air Act may have prevented some situations from getting worse, it cannot be credited with bringing about the main improvements in air quality which occurred during the 1970s and 1980s. It also proved to be inadequate to the task of reducing emissions from industrial and trade sources. The Best Practicable Means (BPM) approach, which was meant to strike a balance between the level of emission reduction and costs of control, offered few incentives for innovation. Air pollution was managed in a programme which did not include water and soil; there was little opportunity for the public to give its views and the BPM system did not require the evaluation of the effects of total emissions from several sources in a given area.

**The Resource Management Act 1991**

The Clean Air Act was repealed when the Resource Management Act (RMA) took effect in 1991. In promoting the sustainable management of natural and physical resources, the Resource Management Act seeks to safeguard the life-supporting capacity of air, water, soil and ecosystems, and to avoid, remedy, or mitigate any adverse effects of activities on the environment. Under the new Act, the management of air pollution from all sources is the responsibility of regional councils and unitary authorities.

The Act does not set air quality standards or pollution thresholds, but leaves that for each authority to determine. However, the Act does require the Ministry for the Environment to provide guidance to councils including, where necessary, either binding standards or non-binding guidelines. Given the variable conditions around the country, the Ministry has opted to issue guidelines (Ministry for the Environment, 1994a). These show 'safe' levels for human health of the most commonly known and widespread air pollutants (see Table 6.3). The guidelines are based largely on the World Health Organisation (WHO) Guidelines for Europe, supplemented by more recent information from the United States Environmental Protection Agency (EPA) and the Victoria (Australia) EPA.

**Box 6.7**

### *Lowering the lead in petrol*

Lead was first added to petrol in the 1920s as a cheap and convenient method of boosting octane (which enhances fuel combustion) and reducing engine 'knock' (caused by faulty combustion). The General Motors research engineer who made the discovery, Thomas Midgley, went on from this triumph to develop a non-toxic, non-flammable alternative to ammonia as a refrigerant—chlorofluorocarbon or CFC (Taylor, 1988). Today, both of these substances are recognised as major pollutants. When leaded petrol is burnt in the engine of a car, 75 percent or more is emitted from the exhaust as particulate matter, both large particles which fall rapidly to the ground, and finer particles ($PM_{10}$) which can stay airborne for considerable periods of time. The result is significant contamination of street dust and adjacent soil, and elevated levels of lead in the air near busy roads.

The first step towards removing lead from New Zealand's petrol was taken in 1984 when the Ministers of Health, Environment and Energy announced that the Government intended, in two years' time, to reduce the lead content of 96 octane 'Super' petrol and to follow this with the introduction of an unleaded 91 octane 'Regular' petrol. These changes had to await the completion of the Marsden Point oil refinery expansion. Until the changes were made, New Zealand had a higher level of lead in petrol than most OECD and other developed countries (0.84 grams per litre compared to 0.15 grams). This was more in line with the less developed Asian countries, and most of Africa, South America, and the Caribbean.

In July 1986 the lead content of Super (96 octane) petrol was reduced from 0.84 to 0.45 grams per litre. By world standards this was still high. Most of Europe, including Britain, had reduced to 0.15 grams per litre and the United States limit was just 0.026 grams per litre (Taylor, 1988). In January 1987, Regular petrol was replaced by Unleaded 91. Despite the name, it was not strictly 'unleaded'. Contamination by leaded petrol sometimes occurs in pipes and tankers, even though no lead is intentionally added. Allowing for this, the maximum permitted lead content of unleaded petrol has been 0.013 grams per litre since 1 January 1992. However, a Ministry of Commerce survey of service stations in 1992–93 found that actual contamination levels are much lower, ranging between nil and 0.003 grams per litre.

The switch to unleaded petrol was not an easy one (see Figure 6.13). Regular petrol had accounted for only about 7 percent of the total market. This fell to a mere 4 percent immediately after the change because many drivers feared that Unleaded 91 was unsuitable for their vehicles, an impression that the oil and motor industries did little to reverse. Following a $500,000 promotional campaign by the Ministry for the Environment, the market share quickly recovered to 7 percent but was slow to increase after that, even though 20–25 percent of vehicles could run on the unleaded fuel (Taylor, 1988). Eventually, in 1991, a 'lead tax' of 8 cents per gram was imposed on Super petrol. This made the price about 5 cents higher than Unleaded. It also spurred a further 'voluntary' lowering of the lead in Super petrol to about 0.35 grams per litre. The 1992–93 Ministry of Commerce survey found that a number of samples even had even lower levels—less than 0.1 gram per litre.

The final step in the transition from leaded to unleaded petrol was taken in June 1995 when the Government announced that the New Zealand petrol market would become lead-free. In January 1996 it became illegal to add lead to petrol and in September it became illegal to sell leaded petrol. A new higher octane petrol, Super Unleaded 96, was introduced but immediately ran into controversy when it was accused of causing fuel system leaks, engine fires and performance problems in some cars. In all, oil companies received several thousand complaints in the five months from March to July 1996. Of these, 2,636 complaints were investigated for possible compensation payment, among them 94 involving engine fires, and 1,213 involving fuel system problems (Ministry of Commerce, 1996).

One aspect of the controversy that has implications for air quality was the revelation that the new fuel has elevated levels of aromatic hydrocarbons (e.g. benzene). Aromatics in petrol do the same job as lead—they boost the octane rating. One imported batch of the new unleaded petrol contained a particularly high level of aromatics (56 percent), particularly toluene (54 percent). At the time a maximum benzene level of 5 percent by volume was permitted in all petrol. After the controversy, the Government introduced regulations which were based on a voluntary industry standard to control the levels of aromatics. These set a maximum specification for total aromatic content of 50 percent by volume from 20 March 1996, and 48 percent from 18 April 1996. The 5 percent maximum content of benzene remains unchanged. The net effect of the switch to lead-free petrol has been the virtual elimination of airborne lead from our environment, and a slight increase in emissions of benzene and other aromatics of about 1 percent (M. Bates, 1996).

Because they do not take into account the effects of air pollution on visibility, sensitive species (e.g. lichens), or corrodible structures such as monuments and historic buildings, they are not environmental guidelines in the true sense. However, regional councils may set more stringent air quality thresholds if they choose, having regard to their responsibility under the Resource Management Act to consider ecological, cultural, and intrinsic values in the environment. Research to assess which levels of air pollution are ecologically or culturally tolerable has not, to date, been a priority in New Zealand.

Apart from assisting with guidelines, the Ministry for the Environment has also been collaborating with regional councils and the National Institute of Water and Atmospheric Research (NIWA) to coordinate the development of indicators for air monitoring. These include a national set of core indicators to be monitored routinely at a selection of urban and rural sites. Among the recommended priority indicators are: carbon monoxide (CO); inhalable particulates ($PM_{10}$); nitrogen dioxide ($NO_2$); sulphur dioxide ($SO_2$); ozone ($O_3$); and a measure of visibility (Fisher and McMillan, 1996).

Under the Resource Management Act, regional councils can set down statutory plans with air quality standards that must not be breached. These standards must take into account all pollution sources, both large and small. Whether a council has developed a plan or not, large emitters, such as factories, are controlled through air discharge permits, in which the council specifies the maximum amount of a particular pollutant that may be discharged over a given period. These permits do not dictate which particular equipment must be used to control emissions, leaving that decision to the manager of the installation. However, if emissions exceed the permitted levels, the polluter may be closed down.

Small emitters, such as motor vehicles and households, cannot be so easily managed through a permit system. Other measures are needed to control air pollution caused by them. These may include changing traffic flows, improving access to public transport, encouraging the adoption of cleaner forms of home heating and better insulation, encouraging drivers to install catalytic converters, or simply encouraging them to have their vehicles regularly checked and tuned.

This last option was tried in Christchurch from late 1993 to mid 1996 when the Canterbury Regional Council set up the country's first free vehicle emission testing programme. It found that 44 percent of vehicles tested were poorly tuned and emitting high levels of pollutants. However, just as other councils, such as Environment Waikato and Waitakere City, were establishing similar programmes in 1996, the Christchurch programme was discontinued because it did not appear to have actually reduced emissions (Lusby, 1996; Ayrey, 1996; McChesney, 1996).

### Recent initiatives

Emissions monitoring is still very undeveloped in New Zealand, though this is changing. The Ministry of Transport has undertaken several studies of vehicle emissions. These include: the Land Transport Pricing Study, which attempts to cost the environmental impacts of transport; the Vehicle Fleet Strategy, and the Vehicle Emission Testing Study. Home heating emissions have recently begun to be studied by the Canterbury Regional Council.

In October 1995, the Ministry for the Environment's Sustainable Management Fund approved a large three-year research project to provide guidance for regional councils on the elements of air quality management. During the first phase of the project, the National Institute of Water and Atmospheric Research ran a series of workshops in 1996 which brought together air quality professionals from central government, regional authorities, and the Crown Research Institutes. The project's other elements include several air monitoring surveys and the development of a prototype national air quality database.

Strategies will be developed for assessing visibility and for managing air toxics (with the main focus on motor vehicles and agricultural chemical sprays). The project will also develop guidance manuals on how to use computer programmes which model the dispersion of contaminants in the atmosphere, including what models to use in what situations and how to create local meteorological datasets to put into the models. Guidance manuals are also being prepared on how to develop emission inventories and record compliance monitoring information.

Several regional councils have begun to develop regional air plans which identify their issues, objectives, policies and methods for managing air quality. This process has been difficult however, due to lack of air quality information. Most of the plans set out the programme the council will follow to gather data to improve councils' ability to sustainably manage air quality. Canterbury Regional Council appears to be most advanced in its air quality programme having studied household heating and vehicle emissions and recently introduced tougher emission standards for new woodburners. Council officers are also working on plans for the gradual phasing out of open fires and older woodburners.

**Table 6.3**
**Ambient Air Quality Guidelines for New Zealand**

| Contaminant | Acceptable Average Level | Averaging Period |
|---|---|---|
| *Particulates ($PM_{10}$)* | *120 μg/m³*<br>*40 μg/m³* | *24-hour*<br>*annual* |
| *Sulphur dioxide ($SO_2$)* | *500 μg/m³*<br>*350 μg/m³*<br>*125 μg/m³*<br>*50 μg/m³* | *10-minute*<br>*1-hour*<br>*24-hour*<br>*annual* |
| *Carbon monoxide (CO)* | *30 mg/m³*<br>*10 mg/m³* | *1-hour*<br>*8-hour* |
| *Ozone* | *150 μg/m³*<br>*100 μg/m³* | *1-hour*<br>*8-hour* |
| *Nitrogen dioxide ($NO_2$)* | *300 μg/m³*<br>*100 μg/m³* | *1-hour*<br>*24-hour* |
| *Lead* | *0.5–1.0 μg/m³* | *3-month* |
| *Fluoride: Special land use* | *1.8 μg/m³*<br>*1.5 μg/m³*<br>*0.8 μg/m³*<br>*0.4 μg/m³*<br>*0.25 μg/m³* | *12-hour*<br>*24-hour*<br>*7-day*<br>*30-day*<br>*90-day* |
| *General land use* | *3.7 μg/m³*<br>*2.9 μg/m³*<br>*1.7 μg/m³*<br>*0.84 μg/m³*<br>*0.5 μg/m³* | *12-hour*<br>*24-hour*<br>*7-day*<br>*30-day*<br>*90-day* |
| *Conservation areas* | *0.1μg/m³* | *90-day* |
| *Hydrogen sulphide ($H_2S$)* | *7 μg/m³* | *30-minute* |

*μg - micrograms*
*mg - milligrams*
*AS - Australian Standard*
*Source: Ministry for the Environment (1994)*

## CONCLUSIONS

Air quality is important, not just for our tourist appeal, but for our quality of life, our ecosystems and our health. Visitors often comment on the clarity of New Zealand's air, especially in rural, coastal and wilderness areas. But most New Zealanders live in cities and towns where, sometimes, the air can be less appealing. Although some aspects of urban air quality (e.g. lead levels, and smoke levels in Christchurch and Dunedin) have improved over the past 20 years, recent surveys indicate that some others are still a source of problems (e.g. particulate matter from domestic fires and carbon monoxide from home fires and motor vehicles). The surveys also indicate that the problems are not confined to big cities but extend to some smaller urban areas.

The potential health impacts of ambient air pollution are amplified for people with lung and heart conditions, and, aggravated by indoor pollutants, such as tobacco smoke and malfunctioning fireplaces. A quarter of the population is addicted to tobacco, even though they now consume less than in previous years. In many homes non-smokers (often children) are also exposed to the smoke. Bronchitis and emphysema, as well as elevated heart and cancer risks, are common in older smokers, making them more vulnerable to the effects of ambient air pollution.

Domestic fires are still the main source of air problems, both indoors and out, particularly where high-sulphur, high-ash, fuels are burned in low-efficiency open fires. At this point, it is difficult to gauge whether industrial sources are also contributing to air quality problems as the process of issuing and monitoring air discharge permits is still relatively new.

Carbon monoxide pollution from motor vehicles may be a growing problem in inner cities, particularly where high traffic density and low wind speeds allow fumes to build-up. Motor vehicle numbers are rising, encouraged by the dispersed, low density, design of most of our cities. These cities have grown up around the availability of motor vehicles and their public transport systems are often under-utilised.

Air emissions homes and vehicles are harder to manage than those from industry. Under the Resource Management Act, regional councils can limit air emissions from industrial and trade premises to the extent they consider necessary and can set ambient standards for emissions. This new system is currently evolving but it has the potential to effectively manage all industrial and trade discharges. At present, some industrial emissions are still uncontrolled while the Act is in its transitional phase. Councils also have the ability to impose controls on domestic fires (such as banning open fires and only allowing certain low emission burners).

Apart from regulations that ban the sale of leaded petrol and make it an offence for vehicle emissions to obstruct visibility, there are no environmental controls on motor vehicle emissions. Use of the Resource Management Act by regional councils is unlikely to be the most cost effective way to manage vehicle emissions. Other possible management options are under study in the Vehicle Fleet Emissions Control Strategy that is being developed by government officials under the leadership of the Ministry of Transport.

For the quality of our air to be well managed, we need better information than we have relied on in the past. With New Zealand's history of generally good air quality, authorities in most parts of the country have not felt the need to invest in the programmes and equipment which are required to regularly monitor air pollutants and record changes over time. Most of our air quality monitoring has been sporadic and uncoordinated, and often triggered by specific problems.

As a result, the approaches used in the rest of the world for managing air quality have not yet evolved here. Inventories of emissions, regional models for atmospheric dispersion, and strategies for managing air quality are now in the rudimentary stages of development in Auckland and Christchurch. Little basic research has been undertaken on the health impacts of air pollution in New Zealand, and none at all on the non-health impacts, such as visibility and ecological implications.

Despite these limitations, however, the initiatives currently underway by central government, Crown Research Institutes and the regional councils are positive steps. The production of a national database and a national set of air quality indicators should enable us, for the first time, to identify the extent of our clean and dirty air. And the development of monitoring guidelines for regional councils should enable them to keep better track of the trouble spots and deal with them effectively.

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THE STATE OF

NEW ZEALAND'S

ENVIRONMENT

CHAPTER SEVEN

# THE STATE OF OUR WATERS

CONTENTS

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| **$BOD_5$** | Biochemical oxygen demand (the amount of oxygen consumed by micro-organisms in a water sample measured over 5 days at 20°C). |
| **cumec** | cubic metres per second |
| **DIN** | Dissolved Inorganic Nitrogen (NH) |
| **DO** | Dissolved Oxygen |
| **DoC** | Department of Conservation |
| **DRP** | Dissolved Reactive Phosphorus |
| **$NH_4$-N** | ammoniacal nitrogen, organic form |
| **NIWA** | National Institute of Water and Atmospheric Research |
| **$NO_3$-N** | nitrate nitrogen or nitrate-N |
| **NWQN** | National Water Quality Network |
| **ppb** | parts per billion |
| **SS** | Suspended solids |
| **TKN** | Total Kjeldahl nitrogen (organic nitrogen plus ammonia) |
| **TN** | Total Nitrogen |
| **TP** | Total Phosphorus |
| **WCO** | Water Conservation Order |

## KEY POINTS

- *New Zealand's abundant rainfall feeds thousands of streams, over 70 major rivers, more than 770 lakes, and numerous underground aquifers containing cool groundwater or hot geothermal water. The rain also provides 75–80 percent of our electricity by feeding some 80 hydro power stations. The rainfall is not distributed evenly, however, because of the impacts of mountains on weather patterns. As a result, some parts of the country are prone to water shortages.*

- *Droughts are common in 'rain shadow' areas of New Zealand, particularly along much of the east coast, and also in some inland and northern pockets of both the North and South Islands. Because many drought-prone areas tend to have high densities of livestock or people, dry spells can affect urban and rural water supplies and agricultural production. Hydro-electricity generation can also be affected.*

- *Floods can occur in any season, and in all regions of New Zealand. The rate of flooding increased 50–150 years ago following widespread replacement of forests, scrub and tussock with shallow-rooted pasture grasses. Despite extensive river and catchment control schemes, damage from flooding is estimated to cost at least $125 million a year.*

- *The main source of pressure on water is pastoral agriculture which has polluted many surface waters and some groundwater with sediment, animal waste and nutrients, and has also increased flooding and erosion in many areas by removing deep-rooted vegetation from hillsides and riverbanks. The use of irrigation water, mainly for pasture, is also a source of pressure on water levels in some South Island rivers and aquifers, as is land drainage for agriculture which has caused an 85 percent reduction in New Zealand wetlands.*

- *In urban areas, pressures on water come from increasing consumption and from sewage and stormwater discharges. Additional pressures on water flows or quality come from the damming of rivers for electricity and water supply, the impacts of pests and weeds, and the potential impacts of climate change.*

- *Pollution of rivers and coastal waters from point sources (i.e. specific sites such as dairy sheds, factories, sewer pipes) has declined over the last 20 to 30 years as treatment systems have been upgraded and alternative disposal methods are developed (e.g. onto land or into constructed wetlands).*

- *Pollution from non-point sources (i.e. diffuse sites such as paddocks and roads) is still a major problem, particularly on pastoral and horticultural land where organic matter, nutrients, and sediment wash into waterways or nitrates leach into groundwater.*

- *Urban stormwater causes serious problems in some areas (e.g. Auckland), polluting estuaries and harbours with sediment and toxic substances (e.g. heavy metals and hydrocarbons derived from motor vehicles) and, in some cases, infiltrating and flooding sewerage systems. Stormwater quality is often similar to that of secondary-treated sewage.*

- *The natural character and habitat quality of many freshwater and estuarine waters has been lost or degraded by drainage, construction of flood control channels and stopbanks, development, removal of riparian vegetation, waste disposal, urban stormwater and agricultural run-off.*

- *Invasive species of plants, fish and other animals pose a threat in freshwater ecosystems and in some parts of the coast where they have become established. Some of the toxic algal blooms which have recently become an intermittent problem in our coastal waters may involve exotic species introduced in ship ballast water.*

- *Water quality is high in mountain streams and in sparsely developed areas throughout much of the South Island and the upper reaches of most North Island rivers. It declines measurably in lowland streams and rivers, particularly in pasture-dominated catchments. At times some lowland rivers are unsuitable for swimming because of faecal contamination from farm animals, poor water clarity, and nuisance algal growths. The stream water in some intensive dairy farming areas is in such poor condition that it may be unsafe for livestock to drink. The lower reaches of some rivers are also polluted by discharges of industrial wastes, urban sewage and stormwater run-off.*

- *New Zealand's 30 or so large, deep lakes appear to be of high quality. However, more than 700 lakes are shallow and between 10 percent and 40 percent of these are nutrient enriched (eutrophic). Most of the eutrophic lakes are in the North Island and in pasture-dominated catchments. A number are subject to fish kills or are no longer capable of supporting fish life.*

- *The state of our groundwater is largely unknown. However, many shallow aquifers beneath dairying or horticultural land have elevated nitrate levels. The extent of contamination from seepage from landfills, other waste disposal systems, and contaminated sites is unknown. The extent of pesticide contamination in groundwater is also largely unknown. The few surveys to date have found pesticide traces, but at very low concentrations. In some coastal areas, seawater has contaminated groundwater after excessive use during dry seasons has reduced the groundwater level below sea level.*

- *New Zealand has 1,638 community drinking water supplies and these serve 85 percent of the population. Of these, 7 percent (serving 54 percent of the population) are considered safe, while a further 2 percent (serving 5 percent of the population) are of borderline safety. However, 19 percent (serving 18 percent of the population) have an unsatisfactorily high risk of contamination. The remaining 71 percent of water supplies (serving 8 percent of the population) have not been graded because they are in communities of less than 500 people. Approximately 15 percent of the population are not connected to community supplies.*

- *Many geothermal phenomena (e.g. geysers, hot springs, mud pools) have been affected by human activities. Between 1950 and 1990 the number of active geysers declined from 130 to 11 as a result of flooding for hydro dam construction, the draw-off (or abstraction) of steam for geothermally-powered electricity production, and the draw-off of hot water for household and commercial use. No geothermal fields are formally protected from abstraction, and no dormant geysers have been able to be restored.*

- *Wetland areas have been reduced by about 85 percent in the last century and a half, from nearly 700,000 hectares to about 100,000 hectares. Several thousand wetlands remain, including more than 70 which are deemed to be of international importance. Many of the surviving wetlands have been degraded by drainage, pollution, animal grazing and introduced plants.*

- *From the limited data available, the state of our sea water seems generally good, except near some river mouths and in some harbours and estuaries where sediment, heavy metals, nutrients, bacterial counts and marine debris levels have been elevated by urban stormwater, sewage and agricultural run-off. In addition, at least 100 oil spills occur each year in the major harbours.*

- *Sediment from rivers is a serious threat to some coastal ecosystems, particularly estuaries. Marine debris (particularly plastic wrapping and containers) is a significant health threat to marine mammals and seabirds and is associated with increasing population size in coastal areas. Waste from fishing and recreational boats has the potential to cause localised problems. Another threat comes from toxic algal blooms which occasionally irrupt in coastal waters.*

- *Management of natural water (i.e. freshwater, groundwater, geothermal water and coastal water) is the responsibility of Regional Councils which, under the Resource Management Act, are required to safeguard the life-supporting capacity of waters and ecosystems and ensure that water users avoid, remedy, or mitigate any adverse effects of their use on the environment. Council approval is required for abstracting, damming or diverting water, discharging pollutants into it, or placing structures on the beds of lakes, rivers and the coast. These approvals, and the environmental limits on use (e.g. water quality standards), are issued through policy statements, plans and water permits.*

- *Regional Councils are responsible for monitoring the environmental impacts of the water uses for which they have issued permits (consent monitoring) as well as broader monitoring of water and other resources (environmental monitoring). In addition to these planning and regulatory roles, Councils also have responsibility for flood control, civil defence and dealing with oil spills out to the territorial sea limit.*

- *Central government also has responsibilities for improved water management, including:*
  - *the 1986 National Wetlands Policy (Minister of Conservation);*
  - *the nation's coastal policy (Minister of Conservation);*
  - *managing water bodies on Conservation Department land (Department of Conservation);*
  - *approving Water Conservation Orders (Minister for the Environment);*
  - *producing water quality guidelines and standards (Ministries of Health and Environment);*
  - *monitoring drinking water supplies (Ministry of Health);*
  - *monitoring toxic algae in coastal waters (Ministries of Health and Agriculture);*
  - *funding research and development to improve water and soil management (Foundation for Research, Science and Technology, Ministry for the Environment, Ministry of Agriculture); and*
  - *safeguarding the Crown's property interests in freshwater fisheries and their habitats (Department of Conservation).*

- *Responses by industry and land user groups include the development of codes of practice (e.g. by the Forest Owners' Association), the development of farmers' landcare groups, and the adoption of improved forms of waste water disposal by farms and factories (e.g. constructed wetlands).*

- *Most information on the state of our water resources is collected for local use by regional councils and by territorial authorities involved with water supply and disposal. Some data are also collected, or collated from local authority collections, by Crown Research Institutes. Because the data are primarily for local authority use, the monitoring methods, and the parameters and indicators measured, may differ from one authority to the next. This makes it difficult to combine the data across regions to provide a national picture of the state of our water.*

- *Water management and monitoring will become easier as information systems become better integrated and standardised. A key part of this is the development of a core set of water quality indicators and an agreed methodology and programme for monitoring and updating them.*

## INTRODUCTION

Every day each New Zealander pours and flushes an average of around 350 litres of water down the sewer pipes (Hauber, 1995). This includes water used for drinking, cooking, cleaning, washing, showering, laundering and flushing the lavatory. It doesn't include the water used to sprinkle the lawn and garden, or the vast amounts used for processing and manufacturing, for irrigating pastures and crops, and for sustaining livestock. Some of this water evaporates as steam or respiration and re-enters the atmosphere. However, a large proportion is harnessed, transformed (i.e. made cleaner or dirtier), and discharged back into the environment.

New Zealanders, whether at home or at work, on the farm or in the factory, have long prospered from the consumption and harnessing of water, and from the discharge of wastes into it. Now, the new growth industries of tourism and recreation are finding prosperity in people's desire to visit unspoilt rivers and lakes. This trend stems from the growing appreciation of nature and the growing awareness that 'our' water resources also belong to the other species that depend on them and the future generations that will depend on them in centuries to come.

Maori culture has contributed to the new awareness. In Maori tradition, water is perceived as having a life essence (*mauri*) which is easily degraded if the water is diverted or polluted. Streams, rivers, lakes, estuaries and harbours are therefore seen not only as vital sources of fish and seafood but as living beings which have their own intrinsic value. Maori protests over the pollution of sacred waters and of fishing and food-gathering areas have played an important part in shifting the focus of water management from an exclusive emphasis on stocks and flows to a much greater concern for maintaining water quality and ecosystems.

New Zealanders' evolving views of water are reflected in the legislation changes of the last half century. The Soil Conservation & Rivers Control Act 1941 was primarily concerned with stemming erosion, sedimentation and flooding. The Water & Soil Conservation Act 1967 put greater emphasis on water quality and water allocation. The Wild and Scenic Rivers amendment to the Act in 1983 focused on the aesthetic and recreational aspects of rivers in their natural state. Now, under the Resource Management Act 1991, the intrinsic values of ecosystems, including their biodiversity and life supporting capacity, must be considered when managing water, and the emphasis has changed from multiple-use management to environmentally sustainable management.

This chapter outlines the main features of New Zealand's water environment, the main pressures that people impose on it, the state of the water as far as we can tell, and society's responses to the environmental problems affecting our water.

## THE STATE OF THE DATA

Water is probably the most monitored feature of the New Zealand environment. Even so, national data are rather limited. Information on the quantity and quality of groundwater, surface water and coastal water are collected by a diverse range of organisations, headed by regional councils and local territorial authorities (i.e. district and city councils) and the National Institute of Water and Atmospheric Research (NIWA).

From 1983 through to 1988, the Ministry of Agriculture and Fisheries summarised much of the existing information on a region by region basis in a series of reports entitled "Regional modifications to waterways" in the now defunct journal, *Freshwater Catch*. Each report was authored by a scientist attached to either a government department or local authority and gave an overview of the history and impacts of water and land use in each of thirteen 'water regions' (Hicks, 1983; Davis, 1984; Richmond, 1984; Richardson, 1985; Rodway, 1986; Eldon, 1987; Watson, 1987; Poynter, 1987; Jellyman, 1984, 1988; Porter, 1988; Haughey, 1988; Boothroyd, 1988).

Apart from this, there have been few attempts to provide a systematic overview of the state of our waters, particularly at the national level. No repetitions of the 1980s baseline surveys have been undertaken to report on trends. At present, water monitoring tends to focus almost exclusively on the quantity and quality of water, and little on its ecological properties. **Quantity** is measured as **stocks** and **flows** (e.g. areas and volumes of lakes, rivers and groundwater, their flow rates, volumes and rates of rainfall and run-off, evaporation rates etc.). **Quality** is measured in terms of water clarity and the presence and degree of contamination (e.g. nutrient, chemical, and sediment content, and the concentrations and activity of micro-organisms). Water quantity is generally measured by hydrologists, while water quality is generally measured by chemists and biologists.

The **ecological** attributes of streams, rivers, lakes and wetlands have been only lightly monitored to date, partly because of a lack of standardised methods and partly because the emphasis in the past has been on monitoring water for human uses, rather than its inherent life supporting functions. As awareness of the ecological dimension grows, however, various methods are being investigated. One is the **macro-invertebrate index** which measures changes in the diversity and composition of the larger invertebrates in an area. Several different indices have been developed, and a few regional councils are now using one or other of these, but none is yet in widespread use. Another method is the **indicator species** approach, which monitors changes in the abundance or distribution of one or two selected species. At present, criteria for species selection vary widely.

A problem with ecological indicators is that they are difficult to interpret without a fairly sound knowledge of the ecosystem being monitored. Normal population fluctuations or species changes can be misinterpreted as signs of ecological degradation. It is also difficult to tell whether ecological trends in a monitored area apply to other areas. As a result, the ecological indicators tend to be used more as indicators of physical water quality rather than ecosystem health. Efforts are underway to resolve some of the difficulties with ecological monitoring through the Ministry for the Environment's National Environmental Indicators programme. A draft set of water quantity and quality indicators is being developed and work is progressing on ecological indicators. For now, though, any assessment of the state of our water environment is largely limited to measures of quantity and quality (see Box 7.1).

**Data on water quantity (stocks and flows)**

Knowing how much water is falling, flowing, and stored in New Zealand is important for agriculture, forestry, electricity generation, flood and erosion control, drought impact management, urban water supply, recreational use of rivers, and maintaining the habitat and biodiversity of fish and other stream and river life. New Zealand has an extensive network of river flow recording sites. Monitoring of river flows, lake levels, and rainfall began around the turn of the century. With the establishment of catchment boards in the 1940s, monitoring was extended so that flood and erosion risk could be assessed and, in the 1960s, it was expanded still further so that water could be better managed to take account of its allocation and conservation. Between 1959 and 1989 the number of permanent water level recording stations increased from 109 to 915 (Waugh, 1992).

**Box 7.1**

***Common water pollutants and measurement parameters***

Several pollutants are of particular concern in New Zealand's surface and groundwaters. Suspended solids, micro-organisms, excessive nutrients, and chemical contamination can make water unsuitable for drinking, recreational use, or the health or survival of fish and aquatic ecosystems. Some pollutants can be measured directly, and some indirectly. Cost, ease of measurement, and degree of risk from particular pollutants are taken into account when deciding what to measure and where, when, and how. For example, micro-organisms can be measured directly by assessing the concentrations of particular algal and bacterial species in a sample of water, or indirectly by measuring biochemical oxygen demand ($BOD_5$) which indicates the amount of oxygen consumed by micro-organisms and other decomposition processes as organic matter rots.

**Suspended solids** are particles of matter which float in water. They include inorganic sediments from rock and soil as well as organic matter. They can ruin fish habitat by reducing light, depleting invertebrate populations and degrading spawning areas. They can also reduce the drinkability and recreational use of water. Parameters (things which can be measured) that are related to suspended solids include visual water clarity and turbidity. **Water clarity** decreases when suspended solids increase. It is best measured as the sighting distance (in metres) of a black disk lowered on a rope into a stream or river, or a secchi disk (a black and white coloured disk) lowered into a lake. **Turbidity** (or muddiness) calculations are derived from the light scattering properties of water and sediment. Unfortunately turbidity is difficult to measure in absolute units, and the same water sample can give different results in different analytical machines. Turbidity is also relatively poorly correlated with suspended solids so, in general, water clarity measurements are considered a better method of assessing the optical quality of water (Ministry for the Environment, 1994).

**Nutrients** are vital for plant and animal health. However, an abundance of nitrogen (N) and phosphorus (P) (often referred to as nutrient enrichment) can fuel excessive plant and algal growth in rivers and estuaries (often referred to as eutrophication). Eutrophication may degrade surface waters by making them aesthetically unpleasant, by depleting the water's oxygen, by changing the quantity and type of food available for fish and birds, and by altering the habitat for fish and invertebrates. **Dissolved reactive phosphorus (DRP)** and **dissolved inorganic nitrogen (DIN)**, which includes nitrate-nitrogen ($NO_3$-N) and ammoniacal nitrogen ($NH_4$-N), are most likely to cause excessive algal growths in waterways. In addition to nitrogen's eutrophication impact in waterways, ammonia can be toxic to fish, while nitrate can be toxic to humans and other animals that drink contaminated water.

**Micro-organisms** or **microbes** are minute organisms consisting of a single cell. They include simple bacteria (such as faecal coliforms, enterococci, and campylobacteria), and more complex one-celled organisms collectively known as protists (such as giardia, cryptosporidium, amoebae, and micro-algae). The micro-algae may be free-floating 'blooms' or slimy coatings (periphyton) on rocks. Fungi are also sometimes included among the micro-organisms although the true fungi are actually multi-cellular organisms, occupying their own large kingdom between the plant and animal kingdoms. Some fungi and micro-organisms can cause illness in humans who eat contaminated shellfish or who swallow contaminated water while swimming, boating, fishing etc. It is not practical to monitor all the potentially harmful organisms in water so a few indicator organisms are monitored instead.

**Faecal coliforms** are the most commonly used indicator of microbial contamination. Where concentrations of faecal coliform bacteria are high (measured as the number of faecal coliforms in 100 millilitres of water) the risk of harmful organisms being present is also assumed to be high. **Biochemical oxygen demand** ($BOD_5$) is another indicator of microbial contamination. It measures the amount of oxygen in a water sample that is consumed over a five-day test period by the micro-organisms and biochemical processes that break down rotting organic matter. $BOD_5$ increases with the amount of dead organic material in water, and indicates the potential for algal growths and depletion of dissolved oxygen. **Dissolved oxygen** (DO) is a direct measure of the amount of dissolved oxygen in water (expressed in grams of oxygen per cubic metre of water, or $g/m^3$). DO is particularly important to ensure the survival of aquatic animals. DO varies considerably and is usually lowest around day-break. Because of the variability of DO levels, sampling needs to be careful and interpretation of DO data requires caution.

**Chemical contaminants** in water are mostly metals and organic substances. **Metals**, such as arsenic, mercury, lead, zinc and copper can enter waterways from industrial sites, rubbish tips, motor vehicles and geothermal areas. Small amounts can accumulate to toxic levels in shellfish, fish and marine mammals, and large amounts can reach toxic concentrations in the water itself. Metal contamination in sediment and water is usually measured as the concentration of the particular metal in a volume of water (e.g. grams, milligrams or micrograms per cubic metre) or in a kilogram of sediment.

**Toxic organic substances** in water can include oil, petroleum products, pesticides (including wood preservatives), some plastic compounds and industrial chemicals, and their breakdown products. Some are carcinogenic, and others are suspected of being environmental oestrogens, interfering with the body's normal hormonal balance. They may enter water (including groundwater) through a variety of sources, such as spills, failures in pipes and storage facilities, as leachate or run-off from landfills or contaminated sites, through stormwater systems, and by inappropriate pesticide applications. Many petroleum and other oil products are insoluble and float on the surface of water and may stick to plants and animals. However, a proportion of toxic organic substances are soluble, and may become invisible once they enter the water.

**Units of measurement** vary considerably for the different water monitoring parameters. However, the unit that is most familiar to the general public, the litre, is rarely used. While it may be ideal for measuring small amounts of liquid, such as our daily supplies of petrol, oil, and milk, the litre is simply too small to cope with the quantities of water that hydrologists measure. Instead, they deal in **cubic metres ($m^3$)**, **million cubic metres ($Mm^3$)**, and even **cubic kilometres ($km^3$)**. One cubic metre is a thousand litres. A million cubic metres is a billion litres. And a cubic kilometre contains 1,000 billion (i.e. a trillion) litres. Water flow is often measured in **cubic metres per second ($m^3$/s)** or **cumecs**, which are equivalent to a 1,000 **litres per second (l/s)**.

The variety of measurement units increases when water quality is being monitored. Quality is often expressed as the amount of a given contaminant per measure of water, for example **parts per million (ppm)** or **parts per billion (ppb),** or **grams per cubic metre (g/ $m^3$)** which can also be expressed as **milligrams per litre (mg/l)** or **micrograms per millilitre ($\mu$g/ml)**. Water quality can also be measured in many other ways, however, such as biochemical oxygen demand ($BOD_5$) which is the amount of dissolved oxygen consumed over 5 days by the decomposition of organic matter (expressed, in water, as **grams per cubic metre**, or **$BOD_5$/g/ $m^3$**, or, in animal excrement, as **kilograms per day**, or **$BOD_5$/kg/day**); microbial concentrations (expressed as **organisms per 100 millilitres**); visual clarity range (expressed in **metres**); turbidity (expressed in **nephelometric turbidity units** or **NTUs)**; and acidity/alkalinity or softness/hardness (expressed as **pH** or proportion of hydrogen ions).

Today, most monitoring of ground and surface water levels and river flows is undertaken by the successors to the catchment boards—regional councils and unitary authorities. Some of this information is fed into the National Hydrometric Network, which is coordinated by NIWA. In 1994, this network collected data from 231 sites including sites monitored by participating regional councils. Although economic factors led to a 20 percent reduction in the number of sites between 1993 and 1994, efforts have been made to maintain representative coverage, and even improve it in under-represented areas such as rainfall and flow monitoring in the less accessible parts of the Southern Alps (Mosley, 1993).

**Data on water quality**

Knowing whether water is polluted is important for anyone intending to drink, swim, eat shellfish, or provide water for livestock. It is also important for ensuring the survival of fish and other aquatic life. Water quality monitoring began relatively recently, mostly within the past decade, as desk computers made it possible to store and analyse the information easily (Waugh, 1991). Now most regional councils have water quality monitoring programmes for both surface water and groundwater (including geothermal water where applicable).

Not all the monitoring is at the local level. Limited national data are available from the '100 Rivers Study' which surveyed a large sample of rivers from 1987 to 1990 (Close and Davies-Colley, 1990), and the National Water Quality Network (NWQN) which has conducted a monthly survey of 77 rivers and streams and 16 shallow lakes since 1990 (Smith and McBride, 1990; Burns, 1994). These surveys were initiated by the former Department of Scientific and Industrial Research (DSIR) and are now NIWA's responsibility. For cost and logistical reasons, the NWQN does not monitor water quality in large lakes. Nor does it monitor microbial water quality (see Table 7.1).

Another national monitoring exercise is the National Groundwater Monitoring Programme which was initiated in 1992 as a cooperative project between some regional councils and the Institute of Geological and Nuclear Sciences Ltd. Most regional and unitary authorities now participate in the programme. Every four months the participating local authorities supply groundwater samples to the Institute of Geological and Nuclear Sciences for analysis, the results of which are then collated into a database (see Table 7.2).

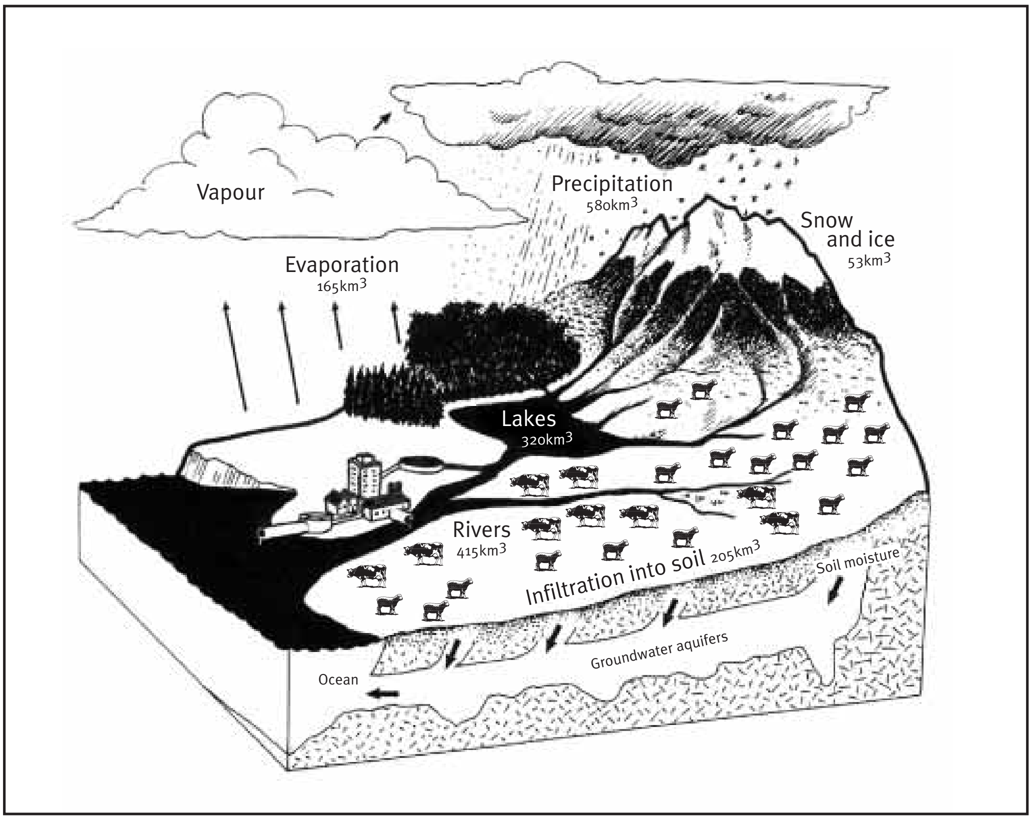
**Table 7.1**
**Parameters monitored by the National Water Quality Network.**

| Parameter | Where measured | River or lake | Why the parameter is monitored |
|---|---|---|---|
| *Dissolved Oxygen (DO)* | *field* | *R/L* | *Necessary for aquatic life; rapid indicator of pollution; indicator of lake trophic state.* |
| *Biochemical oxygen demand ($BOD_5$)* | *lab* | *R/L* | *Indicates decomposing organic matter by measuring the amount of dissolved oxygen used by micro-organisms and biochemical processes.* |
| *Conductivity* | *lab* | *R/L* | *Simple measure of dissolved inorganic chemical ions.* |
| *Temperature* | *field* | *R/L* | *Necessary to interpret dissolved oxygen data; mixing of lake currents; protection of aquatic life.* |
| *pH (acidity/alkalinity)* | *lab* | *R/L* | *Protection of aquatic life; pollution indicator.* |
| *Visual clarity*<br>*- Secchi disk*<br>*- Black disk* | <br>*field*<br>*field* | <br>*L*<br>*R* | *Descriptive standards; visual indicators of water quality effects of sediment, algae etc* |
| *Turbidity and Light Absorption coefficients* | *lab* | *R/L* | *Turbidity coefficient complements visual clarity measurements; light absorption coefficient relates to colour and organic content of water.* |
| *Total nutrients*<br>*- Total phosphorus (TP)*<br>*- Total nitrogen (TN)* | <br>*lab* | <br>*R/L* | *Nutrient status of water; potential for algal growth.* |
| *Dissolved nutrients*<br>*- Ammoniacal-nitrogen*<br>*- Nitrate-nitrogen*<br>*- Dissolved reactive phosphorus* | *lab* | *R/L* | *Drinking water standards; nutrient status of water; potential for algal growth.* |
| *Flow* | *field* | *R* | *To establish relationships between river flow and water quality.* |
| *Lake level* | *field* | *L* | *To establish relationships between lake level and water quality.* |
| *Chlorophyll a* | *lab* | *L* | *Indicator of algal density, showing nutrient status; indicator of water use change.* |
| *Benthic invertebrates* | *lab* | *R* | *Indicator of water use change.* |
| *Nuisance periphyton growth* | *field* | *R* | *Visual indicator of water quality.* |

**Table 7.2**
**Parameters monitored by the National Groundwater Quality Network.**

| Parameter | Where measured | Why the parameter is monitored |
|---|---|---|
| *pH (acidity/alkalinity)* | *field* | *Helps determine environmental influences (soil and rock types, source of water, pollution) on ground water chemistry.* |
| *Temperature* | *field* | *General description - helps assess significance of dissolved substances.* |
| *Conductivity* | *field* | *Simple measure of total quantity of dissolved inorganic chemicals.* |
| *Major cations (e.g. calcium, magnesium)* | *lab* | *General description of groundwater quality, to determine environmental influences (soil and rock type, water source, pollution) on groundwater composition; numerical drinking water standards.* |
| *Major anions (e.g. chloride, sulphate)* | *lab* | *General description of groundwater quality, to determine environmental influences (soil and rock type, water source, pollution) on groundwater composition; numerical drinking water standards.* |
| *Trace metals* | *lab* | *Indicator of source of groundwater (e.g. geothermal); numerical drinking water standards.* |
| *Dissolved nutrients*<br>*Ammoniacal-nitrogen*<br>*Nitrate-nitrogen*<br>*Nitrite-nitrogen* | *lab* | *Indicator of groundwater contamination; numerical drinking water standards.* |
| *Groundwater levels* | *field* | *To establish relationships between groundwater levels and water quality.* |

**Figure 7.1**
**New Zealand's water cycle.**




*Source: Adapted fom Mosley(1993)*

Most regional councils have, or are developing, coastal monitoring programmes which measure sediment movement and coastal erosion, water levels in coastal and estuarine areas, and bacterial concentrations in the water at bathing beaches, around sewage and stormwater outfalls, and around shellfish beds. In some places, limited monitoring of sediment quality has also been undertaken.

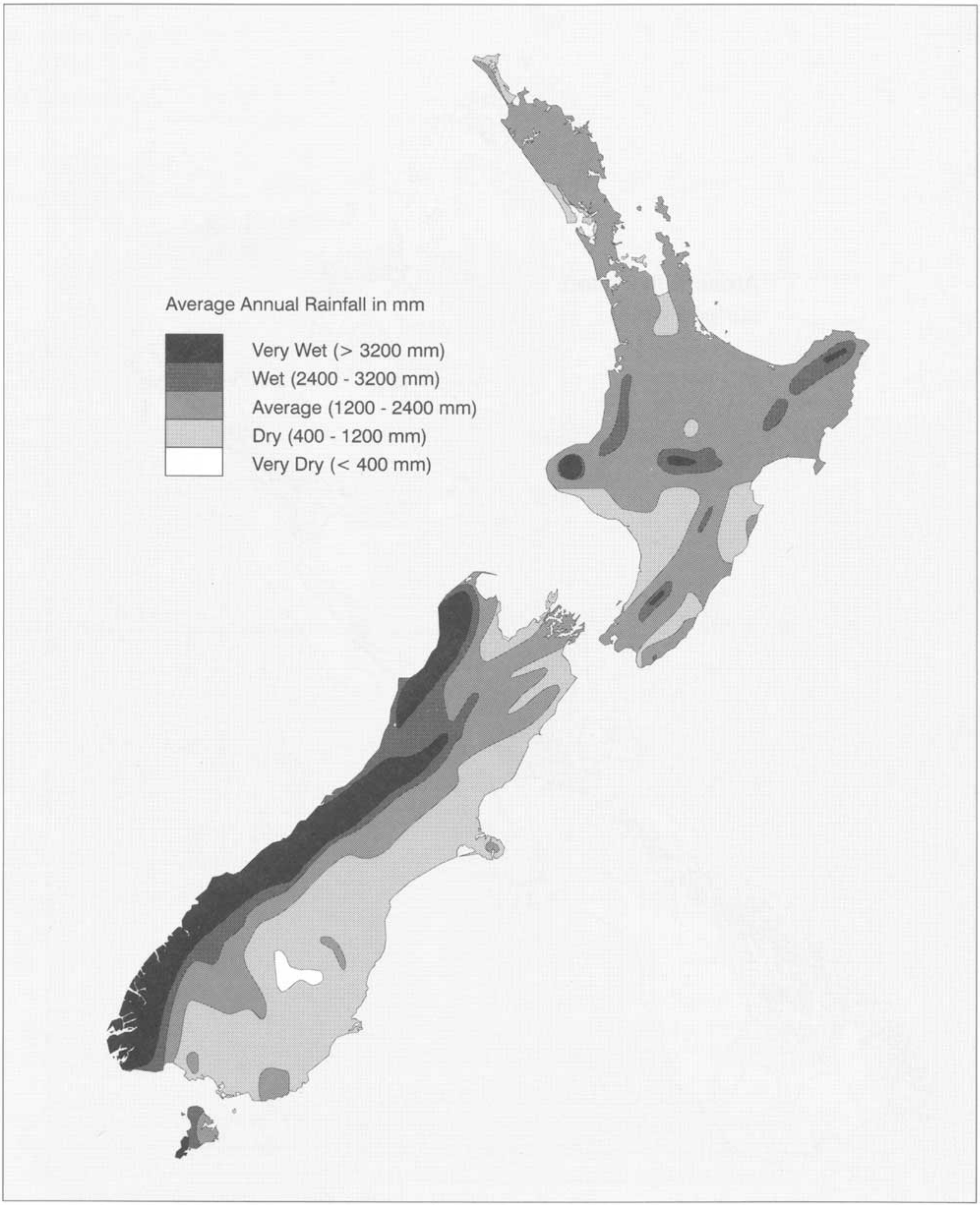
The Ministry of Agriculture's Marine Biotoxins Surveillance Unit, until its recent disbandment, monitored an average of 120 shellfish samples from sites around New Zealand each week for signs of contamination by toxic algae. The Ministries of Agriculture and Health now share responsibility for monitoring toxic algae. Limited environmental data on salinity, water temperature and clarity, daylight and sea conditions are also collected to help identify factors that may trigger toxic algal blooms.

Drinking water quality is monitored by the authorities in charge of water supplies and the results are collated through the Ministry of Health's Drinking Water Surveillance Programme

**Data on aquatic ecosystems**

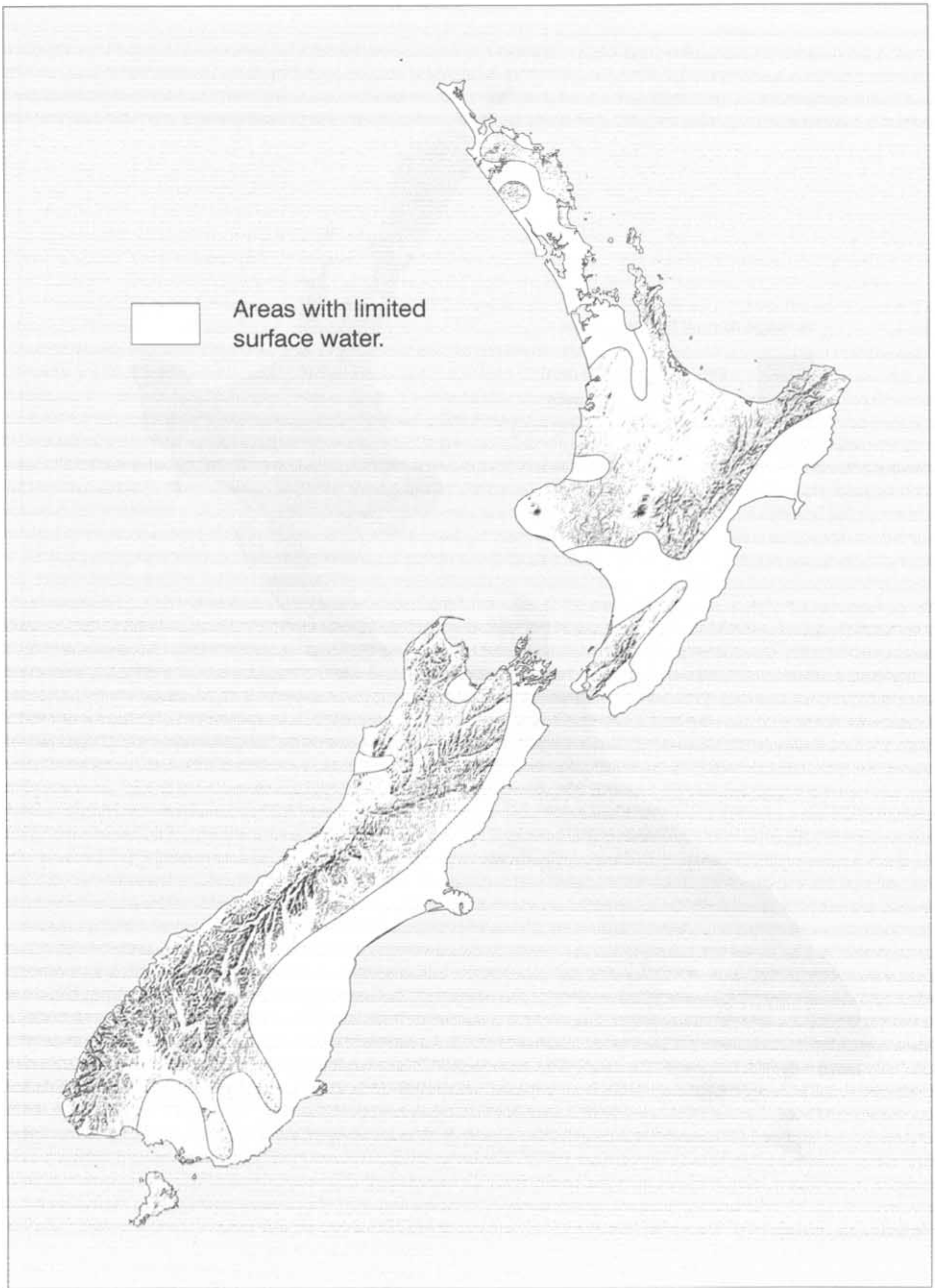
Marine and freshwater ecosystems have been widely studied but rarely monitored in a systematic way. The main databases on them are held by NIWA (e.g. the freshwater fish database, which is updated twice a year, and a large amount of marine biodiversity data, much of which has not yet been collated). The Department of Conservation also holds data (e.g. the WERI database on Wetlands of Ecological and Regional Importance, which is not regularly updated, and the Coastal Resource Inventory, which is more descriptive than quantitative). University scientists, and some regional councils, also hold data on aquatic ecosystems, though often the focus is limited to a particular species, location, or time period, making it of limited value in assessing national trends. Quantitative data on ecological processes are particularly rare.

**Figure 7.2**
**The distribution of rainfall in New Zealand.**




*Source: NZ Meteorological Service*

**Figure 7.3**
**Areas with limited surface water resources**




*Adapted from Pearson (1995)*

## THE NATURE OF NEW ZEALAND'S WATER ENVIRONMENT

Water flows in a constant cycle from ocean to sky and back again, often taking an overland route on its return journey to the sea (see Figure 7.1). In a complete cycle water evaporates from the oceans and is carried in moist air currents which are eventually forced up into cooler altitudes when they pass over landmasses. As it cools the air's moisture condenses into droplets that are visible as clouds. With further cooling the droplets become raindrops or snowflakes which are too heavy to remain in the air and fall to the ground as precipitation. In New Zealand, precipitation mainly occurs as rain, but snow is also common in mountainous areas.

Some precipitation is absorbed by plants and animals and is re-evaporated back into the atmosphere, some flows back to the sea through streams, rivers, lakes, wetlands and estuaries (known as surface waters), and some seeps down into underground sediments, rock fractures, and caves (known as groundwaters or aquifers). Groundwater may flow back into surface waters, lie immobile in confined aquifers, or flow underground through unconfined aquifers to the sea.

The main factors influencing New Zealand's water cycle are the prevailing westerly winds and ocean currents (which bring us our rain), the country's latitudinal position (which extends from warm subtropical waters to cool subantarctic waters), the size and position of our mountains (which determine where the rain falls and where the rivers run), and the amount of forest cover (which determines how much water is returned to the sky as evaporation and how much runs back to the sea as surface and ground water).

New Zealand's natural water environment, therefore, consists of four main components: **rainfall** (which also includes other forms of precipitation, such as snow and hail); **surface water** (which includes *streams, rivers, lakes* and *wetlands*); **groundwater** (which includes both *ambient* and *geothermal* underground water); and the **marine water** into which they all drain (which includes *estuaries*, *coastal waters* and the *open sea*). Interwoven with these is an unnatural, but highly important, fifth component - the piped (or reticulated) drinking water and drainage systems that supply clean water to, and remove dirty water from, most of New Zealand's households.

### Rainfall

The total annual amount of precipitation in New Zealand is anywhere between 300,000 million and 600,000 million cubic metres ($Mm^3$). No one knows for sure because yearly rainfall has not been evenly recorded throughout the country. In most parts of the North Island rainfall averages between 1,200 and 2,400 millimetres (see Figure 7.2). In the South Island rainfall shows greater regional variation. Generally, the west is wetter and the east is drier, with the most extreme variations in the far south.

The driest area, Central Otago, is east of the Southern Alps and has an average yearly rainfall of around 350 mm per year, sometimes dipping to 300 mm, while Fiordland and Westland, west of the Alps, have an average rainfall of more than 6,000 mm (or 6 metres) with some sites occasionally exceeding 13,000 mm. The record of more than 14 metres of rain was set in 1982 at Waterfall Creek in Westland (Statistics New Zealand, 1995).

The reason for the uneven rainfall is the high mountain backbone of the country. This forces the moist westerly winds from the Tasman Sea to rise, get colder, and release most of their moisture as rain and snow west of the main divide. The dried-out winds then sweep eastwards leaving a dry 'rain shadow' east of the mountains. One result of these differences in rainfall is that areas with the least population (e.g. Fiordland, Westland, and Tasman) have the most water, while areas with the greatest demand sometimes have water shortages.

Rainfall also varies with the seasons. Most areas receive more rain during winter and spring than during the summer and autumn. In many areas these variations can result in floods (see Box 7.2). In the rain shadow areas they can also result in prolonged dry spells which affect farmers and townspeople alike by reducing pasture growth, urban water supplies and hydro-electricity supplies (see Figure 7.3 and Box 7.3).

**Box 7.2**

### *Floods and drought in New Zealand*

Flooding has been the most common reason for declarations of civil defence emergency in New Zealand. In the 19th Century it was dubbed 'the New Zealand Death' (McConchie, 1992). Flooding can occur in any season and in all regions, although the steep, mountainous, catchments of the South Island's West Coast have the highest frequency. Even drought-stricken Auckland was afflicted by flood damage in the midst of its 1994 water supply crisis. It is likely that flooding increased after New Zealand's two main episodes of forest clearance following Maori and European settlement. Because most land clearance occurred before 1920, when few flood records were kept, the full impact on flooding is unknown. However, modern comparisons of forested and deforested catchments suggest that it must have been considerable (e.g. Dons, 1987; Smith, 1987; Duncan, 1994).

Flood trends since 1920 are also difficult to establish, partly because the definition of a flood event often depends on whether serious property damage occurred. Even if rainfall and river flows had been constant since 1920, we might expect the amount of property damage to increase simply because of population growth and urban and farm development in flood-prone areas. A recent review of river flow data found no overall trends in the frequency of high or low flows (Pearson, 1992). Nor has it been possible to draw a firm conclusion about national trends in damaging floods (Ericksen, 1986). A total of 820 damaging flood events were recorded from 1920 to 1953 (averaging 25 events per year), but only 118 were recorded from 1955 to 1985 (averaging 4 per year). The two sets of records are not comparable, however, because the latter refers only to floods affecting towns. The Ministry of Civil Defence has listed 10 major flood 'disasters' in the period 1986 to 1991, but these excluded floods affecting less than 100 people (Ministry of Civil Defence, 1994).

An indication of extreme flood trends in some catchments is available from historical records, such as those for the Wairau River in Marlborough in the north east of the South Island, and the Waipaoa River in Gisborne in the east of the North Island. The Wairau catchment was cleared and settled well before the end of the last century, and has had at least one damaging flood every decade since European settlement (Williman, 1995). Floods were so frequent in the early days that Blenheim was known as Beavertown. Prior to 1920, a total of 30 years were spent on the construction of river control works. Flood records from 1920 to 1990 show a decline in small floods but little change in the frequency of extreme floods. Eleven floods had flows greater than 3,000 cumecs (3 million litres per second). Six of these occurred in the 35 year period prior to 1955, and five occurred in the 35 year period since, two in 1983 (Williman, 1995).

Gisborne's Waipaoa River catchment, on the other hand, was still being cleared of forest up to the 1920s. Extreme floods in this catchment therefore became more numerous in the ensuing decades. Between 1900 and 1990 the Waipaoa river had 29 extreme floods, in this case defined as flows greater than 1,500 cumecs (1.5 million litres per second) (Kelliher *et al.*, 1995). Of these, 10 occurred in the 45 years up to 1945, and 19 occurred in the 45 years since. The six largest floods (i.e. those with flows greater than 3,000 cumecs) occurred in 1906, 1910, 1948, 1950 and March and September of 1988.

Across the nation, the yearly cost of flood damage was estimated in 1986 at $90 million (around $125 million in today's terms). In 1988 this doubled as a result of Cyclone Bola. These costs were in addition to the $30 million spent annually on flood protection, and millions more spent on insurance (Ericksen, 1986; Ministry for the Environment, 1992; Ministry of Civil Defence, 1994). The current national cost of flooding is unknown but is unlikely to have diminished. Typical flood damage includes erosion, deposits of sediment over vegetation, reduced farm production, and damaged crops, roads, bridges and buildings. Flooding also causes ecological damage, eroding river banks and depositing sediment which can destroy coastal seaweed and shellfish communities as well as freshwater fish habitat and populations (Jowett, 1992; McDowall, 1993). Flood control efforts also have ecological impacts. Channelisation and stopbanks have degraded the natural character of most lowland rivers and streams in New Zealand.

In 1941 the New Zealand Government passed the Soil Conservation and Rivers Control Act to limit soil erosion and the effects of flooding. This established catchment boards to coordinate erosion and flood control within regions and it also set up a national coordination and research body. A considerable amount of money was spent on flood protection and river control works, including the construction of flood protection embankments (or stopbanks) and drainage works. From 1941 to 1963, 25 large-scale river control schemes were initiated (Roche, 1994). This figure excludes the largest flood control scheme in New Zealand, the Waihou Valley Scheme in the Thames Valley, which was conceived in the 1960s with construction running from the 1970s into the 1990s.

Despite the legislation and massive investment in prevention measures, flood losses have continued to rise. Part of the reason is increasing urbanisation. Many studies have shown that paving and drainage systems in urban areas increase flooding, particularly as many urban areas are located on floodplains and former wetlands (McConchie, 1992). A study of Auckland's North Shore found that: average annual floods are nearly doubled by the provision of stormwater drains and sewers, which concentrate flows; the peak flow of a two-year flood increases by more than 4 times when a catchment is fully urbanised; the peak flow of large floods, such as 50 and 100-year events, more than doubles; floods rise to a peak and fall away more rapidly than in rural areas; and the number of bank 'overflows' increases—perhaps doubling where a fifth of the catchment has storm sewers and paving (Auckland Regional Authority, 1983).

The suggestion has been made that, in some areas, the river control works themselves have increased the amount of flood damage by attracting urban developers and farmers into flood-prone areas that are not safe from extreme events (Ericksen, 1986). Nearly 100 communities in New Zealand are currently prone to flooding. Of 17 urban areas flooded since 1970, most (80 percent) had some form of flood control. Two-thirds of our cities with more than 20,000 people have river flood problems. While entire urban areas are not likely to be inundated, a 1981 study of 18 communities found that an average of 20 percent of the built-up area lay within the historical flood zone (Ericksen, 1986; McConchie, 1992).

### *Drought*

Periods of low rainfall in New Zealand are shorter and less widespread than those experienced in such places as Australia or parts of Africa, but they can have significant impacts on urban and rural water supplies, hydro electricity generation, and agricultural production. The areas most prone to periods of water shortage are in the east of the country and in some 'rain shadow' enclaves on both main islands (see Figure 7.3). Over a dozen significant drought events occurred between 1978 and 1994. In some cases only 50 to 100 farms were affected. In others, thousands of farms and hundreds of thousands of urban households were affected. In one case, the entire country experienced electricity cuts. The impacts on farms are sometimes made worse by the style of farm management. Hill country pastoral properties in drought-prone areas, for example, can be severely affected because they tend to be marginally economic and so carry the maximum possible stock numbers.

Some dry spells are also made worse by the climatic phenomenon known as El Niño, which alters weather patterns over large areas of the Southern Hemisphere (see Chapter 5). El Niño brings more frequent south-westerly winds to New Zealand, intensifying the rain shadow effect so that eastern and northern parts of New Zealand become drier than normal, and the country as a whole becomes a little cooler. In the Southern Alps 'drought' of 1992, El Niño reduced precipitation on the eastern side of the Southern Alps, parching the headwaters of the South Island hydro lakes. The Electricity Corporation of New Zealand was managing the lake levels on the assumption that normal rainfall patterns would replenish them during the winter. When the rain did not come the result was a national power shortage which required 20 percent reductions in power usage. The Government introduced legislation to lower the water level in Lake Pukaki to increase hydroelectricity generation during this period.

In 1993 and 1994, it was Auckland's turn to be caught out by El Niño. Aucklanders' demand for water had increased steadily throughout the 1980s, putting strain on the available supplies. A successful water conservation strategy had begun to reduce water use, but it was based on the assumption that normal rainfall levels would keep the reservoirs topped up. By mid-1993, however, Auckland's rainfall had been below average for 15 of the past 18 months and the usual winter rains had not come. Lake levels peaked at 75 percent of their total capacity in September 1993, then started to drop.

In May 1994, Aucklanders were told they would have to reduce their water consumption by 25 percent. By early June, the lake levels were down to 31 percent of total capacity. In July a bill was introduced to Parliament which would allow water to be piped from the Waikato River without going through the normal consent process of the Resource Management Act. However, just as the politicians were debating the need for this, a late rainfall made the decision for them. The bill was withdrawn on 5 October 1994 as water storage climbed back to 78 percent of total capacity.

Auckland's reprieve is only temporary. Conservation measures reduced water consumption from the 1988 level of around 340 million litres per day to a 1995 level of around 300 million litres, but population and economic growth in the region are expected to force total consumption up. By the end of this decade, demand is expected to exceed supply, so plans are underway for a new pipeline. Water supply authorities in other drought-prone parts of the country are also anticipating future thirsty periods. Many are putting greater emphasis on water conservation and metering to reduce unnecessary water use. What is not known is whether El Niño-induced dry spells will become more or less frequent in future. Some scientists are now beginning to suspect that the El Niño phenomenon is a direct symptom of rising global temperatures and will become more frequent as the 'greenhouse effect' intensifies (Kerr, 1994; Wuethrich, 1995).

**Table 7.3**
**Flows of some of New Zealand's largest rivers.**

| River | Catchment area (hectares) | Mean annual flow (cumecs) |
|---|---|---|
| *Clutha* | *2,058,000* | *570* |
| *Buller* | *635,000* | *428* |
| *Waitaki* | *976,000* | *367* |
| *Grey* | *383,000* | *337* |
| *Waikato* | *1,140,000* | *327* |
| *Whanganui* | *664,000* | *224* |

*Source: Mosley (1993)*

## Surface water

Surface water includes streams, lakes, rivers and wetlands. New Zealand's rivers and lakes provide about 60 percent of the water we consume (the other 40 percent comes from underground). They also provide 75 percent of our electric power, and they are home to more than 30 species of native fish and 20 species of introduced ones, including trout and salmon, as well as freshwater invertebrates and plants.

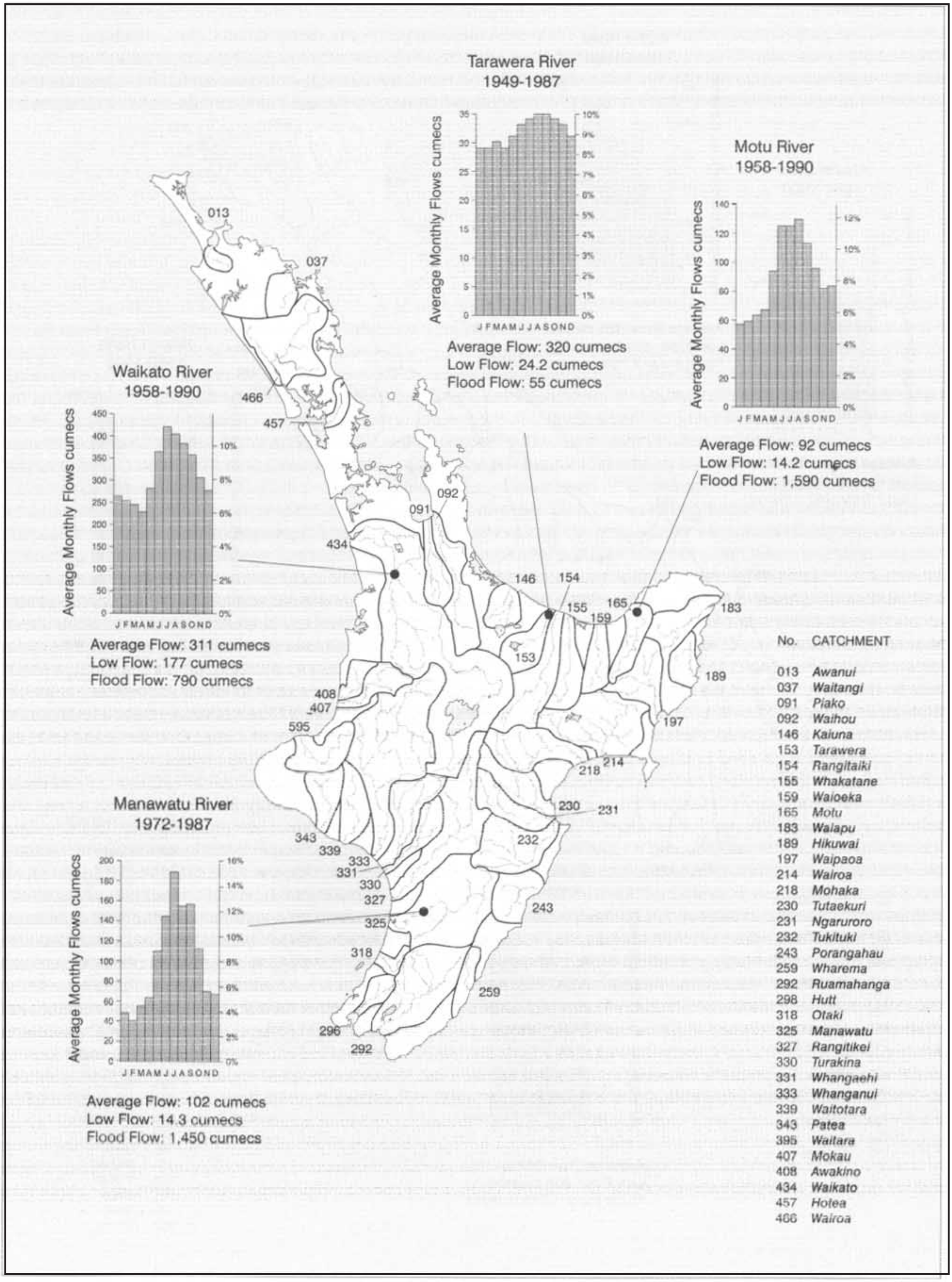
### *Rivers*

The mountainous terrain of both main islands has produced many comparatively small catchments with fast-flowing stony streams and rivers. The South Island has 40 major river catchments and the North Island has 30 (see Figures 7.4a and 7.4b). Over 180,000 kilometres of rivers have been mapped on 1:250,000 scale maps, but many tens of thousands of small streams are too small to be shown. The total area of riverbed has been estimated at 204,000 hectares (Molloy, 1980).

The largest river is the South Island's Clutha which drains a catchment area of 2,058,000 hectares (or 20,580 square kilometres). This is more than 13 percent of the South Island. The Clutha has an average flow of 570 cubic metres per second or cumecs (570,000 litres per second). The longest river, at 425 kilometres, is the Waikato River in the North Island. It has a catchment area of 1,140,000 hectares and an average flow of 327 cumecs (see Table 7.3).

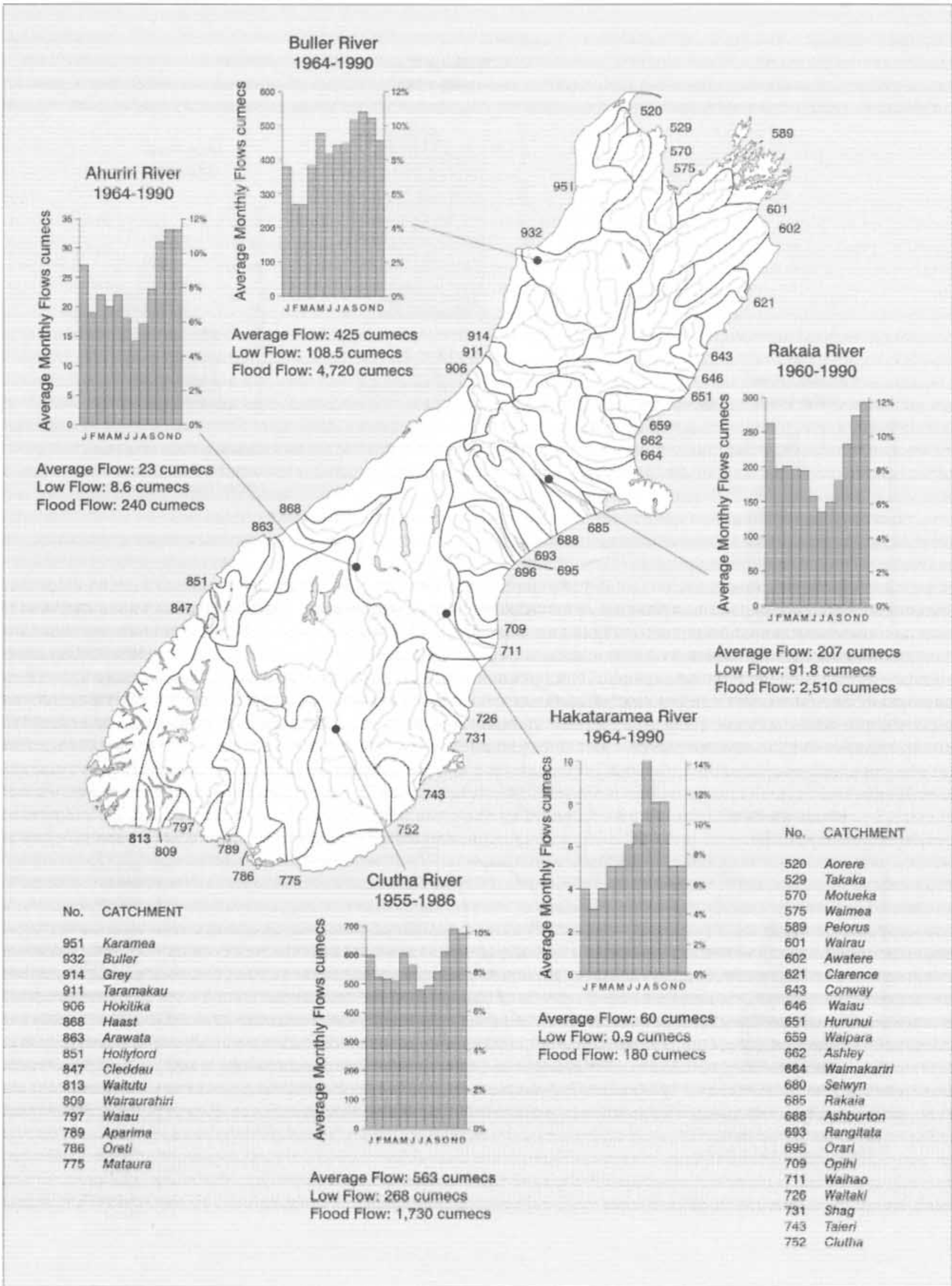
Seasonal variations in rainfall cause river flows to change through the year (i.e. lower flows in summer and autumn and higher flows in winter and spring). This variation is more extreme in the east coast of both islands where summers are relatively dry. In some snow-fed South Island rivers, however, the pattern is reversed, with the lowest flows occurring in the winter and early spring, before the snow melts, and increasing in late spring and summer (Figure 7.4b). In some rivers, such as the Rakaia and the Ahuriri, the summer flows are relatively high because water from the melting snow is augmented by increased rainfall from the seasonal northwest winds (Duncan, 1992).

**Figure 7.4a**
**Main river catchments and typical flow patterns in the North Island.**




*Adapted from Duncan (1992)*

**Figure 7.4b**
**Main river catchments and typical flow patterns in the South Island.**




*Adapted from Duncan (1992)*

In some places, river flow is also augmented by groundwater which may enter from springs and openings in hillsides and cliffs or seep from sloping ground. In some of the central North Island rivers, the contribution from groundwater is large enough to reduce the seasonal flow variation caused by rainfall, as is demonstrated by the relatively constant flow of the Hamurana Stream near Rotorua.

### *Lakes*

New Zealand has at least 770 lakes with a combined surface area of some 334,000 hectares (Molloy, 1980). The vast majority are small with surface areas of less than 50 hectares (or half a square kilometre). Most are shallow lakes only several metres deep and surrounded by farmland. Only 40 lakes have areas greater than 50 hectares (Lowe and Green, 1987).

New Zealand's lakes were formed by three broad processes. **Volcanic eruptions** created the hollows for most of the larger North Island lakes. **Glacial ice** gouged out the basins for most of the South Island lakes. **Land barriers** formed by accumulated sediment, sand bars, and earth movements, have blocked off river channels, creating a large number of shallow lakes in floodplains and coastal areas.

Lake Taupo in the North Island is New Zealand's largest lake, with an area of about 62,000 hectares and a maximum depth of 163 metres. Its size is the legacy of several vast ancient eruptions. The next largest North Island lake is the shallow Lake Wairarapa, with an area of almost 8,000 hectares and a maximum depth of less than 3 metres. Drainage for farmland has greatly reduced Lake Wairarapa's area. The deepest (and probably least modified) North Island lake is Waikaremoana, which formed when a landslide blocked a valley 2,000 years ago. Its maximum depth is 248 metres. Apart from Taupo and Waikaremoana, only one other North Island lake (Rotomahana) is deeper than 100 metres (Spigel and Viner, 1991).

The South Island's largest lakes are the glacial Lake Te Anau, with an area of around 35,000 hectares and a maximum depth of 417 metres, and Lake Wakatipu, with an area of 29,000 hectares and a maximum depth of 380 metres. The third largest South Island lake, Ellesmere (or Waihora), is also the country's largest shallow lake with an area of 18,000 hectares (reduced from 30,000 hectares) and a maximum depth of less than 3 metres. The deepest South Island lake, and also the deepest lake in New Zealand, is the glacial Lake Hauroko in Southland which has a maximum depth of 462 metres. Apart from Te Anau, Wakatipu and Hauroko, 12 other South Island lakes have depths greater than 100 metres (Spigel and Viner, 1991).

At least 16 **artificial lakes** have been created for hydro power stations, the largest of which is the South Island's Lake Benmore (6,900 hectares) and the smallest of which is the North Island's Lake Aratiatia (34 hectares).

### *Wetlands*

Wetlands are areas of shallow water containing specially adapted plant and animal communities (e.g. rushes, sedges, reeds, flax, water birds, eels, mudfish, aquatic invertebrates etc.). They occur on land-water margins, or on land that is temporarily or permanently wet. Although they are found at all altitudes, from coastal estuaries and sand dunes to alpine tarns, wetlands mainly occur in valley floors and on flood plains, often in association with former river courses and ponding areas, lake margins and dune hollows. In estuarine areas and in inland Otago's salt pans their water may be brackish or salty.

New Zealand's wetlands are as varied as the terrain that shapes them, but they can be grouped into three broad categories reflecting their water quality and typical vegetation. **Eutrophic mires** have high nutrient levels and are dominated by the native reed, raupo (*Typha orientalis*). **Mesotrophic wetlands** have moderate nutrient levels and are dominated by rushes, sedges and the native flax, harakeke (*Phormium tenax*). **Oligotrophic bogs** have very low nutrient levels and are dominated by spaghnum moss, rush-like sedges (e.g. S*choenus, Baumea*, and *Tetraria* spp.) and restiad rushes (e.g. *Empodisma* and *Sporodanthus*) (Newsome, 1987). The oligotrophic wetlands often have no significant surface water. Some wetlands were dominated by kahikatea forests, others by pukatea and swamp maire.

An additional category which is often not considered to be true wetland is pakihi, a term coined by West Coast miners last century to describe land which was formerly covered in tall podocarp forest but became water-logged when the water table rose after deforestation (Mew and Johnston, 1988). Pakihi areas are characterised by ferns, mosses and rushes, and sometimes manuka, gorse, and bracken (Newsome, 1987). Many have been sustained by fire and stock grazing and have shown no substantial changes in the last 100 years.

Wetlands are a major habitat for at least eight species of indigenous freshwater fish as well as frogs, birds and invertebrates. Coastal wetlands are more biologically productive than virtually any other ecosystem, providing habitat, breeding areas, and food for shellfish, crustaceans, inshore fish and birds. A fifth of New Zealand's indigenous birds use wetlands as their primary habitat. Wetlands also support other ecosystems by absorbing flood waters and filtering waste water. They regulate water flows, recharge ground aquifers, maintain water quality, and limit coastal erosion.

Freshwater wetlands covered at least 670,000 hectares before European settlement, but have now been reduced by drainage for pasture to around 100,000 hectares. Although several thousand wetlands still survive, most are very small and have been modified by human activities and invasive species. It is likely that, in the last 100 years, some characteristic New Zealand wetland types have been lost completely, while very few examples are left of others, such as kahikatea swamp forest and some kinds of flax swamp and salt marsh (Cromarty and Scott, 1996).

### Groundwater

After rainfall soaks into the ground as soil moisture it may seep into streams as delayed flow, it may be absorbed by plants, or it may seep further into the ground and become groundwater. The underground areas in which groundwater collects are called **aquifers.** Aquifers take many geological forms, including caverns, deep rock fissures, and porous gravel beds. The most extensive New Zealand aquifers are porous sediments lying on top of harder rock layers.

New Zealand's groundwaters range in temperature from less than 10°C to more than 300°C, depending on how close they are to active faultlines or volcanic zones. The Resource Management Act defines groundwater of 30°C or more as **geothermal**, whereas groundwater cooler than this is considered to be within the range of ambient land and surface water temperatures.

#### *Ambient groundwater*

Extensive aquifers of 'ambient' groundwater occur in many parts of the country, including the Canterbury Plains, Marlborough and Tasman Districts, Hutt Valley, Manawatu, Hawke's Bay, the Bay of Plenty, the Waikato and Hauraki Lowlands, and South Auckland. In areas prone to surface water shortages or seasonal fluctuations in river flows and rainfall, these groundwater reserves have become an important source of supply. Aquifers can satisfy heavy summer demand with water stored during the winter and can smooth out the effects of wet and dry years. Approximately 40 percent of New Zealand's freshwater supplies are now drawn from groundwater.

Aquifers vary in their depth and in the extent to which they are 'confined' or 'unconfined'. Unconfined aquifers are surrounded by porous rock or sediment, while confined ones are surrounded by impermeable materials. Water flows easily through unconfined aquifers, but is often trapped or reduced to very low flows in confined aquifers. Because they are more exposed to surface water and leachate, unconfined aquifers are more vulnerable to pollution, particularly if they are shallow and close to the land surface.

Places with unconfined aquifers include parts of the Aupouri peninsula in Northland, the Pauanui spit on the eastern Coromandel coast, the Hamilton basin, and much of the Wairarapa and Canterbury plains. Areas with confined aquifers include the Kaawa shellbeds between Manukau harbour and Pukekohe, the Rangitaiki Plain, and much of the Heretaunga Plain of Hawke's Bay (Thorpe, 1992).

#### *Geothermal groundwater*

Geothermal groundwater occurs where aquifers have been heated in volcanic zones, along faultlines, or in deep fissures (5 kilometres or more underground). These heated groundwaters are usually referred to as **geothermal fields** or **systems**. New Zealand's geothermal fields are classified as low temperature if they are below 100°C, and high temperature if they are above 100°C (Hunt and Bibby, 1992).

Low temperature geothermal systems are generally associated with faultlines or deep groundwater circulation (Cave *et al.*, 1993). They are found in the centre and north of the North Island from Taranaki and Hawke's Bay northwards. In the South Island they are associated with the Alpine and Hope faultlines, and so run in a band from Hanmer Springs to the Copland River in Westland and on down to western Fiordland. When low temperature geothermal systems breach the surface, they appear as hot springs. Often, however, they remain underground until discovered by drilling.

High temperature geothermal systems are associated with volcanic activity. All 24 high temperature fields are in the North Island, where their total surface area has been estimated at around 3,000 to 4,000 hectares (Cave *et al.*, 1993; Bibby, 1995). Nine have temperatures ranging from 100°C to 180°C, and most of the rest are in the 200°C to 300°C range. The high temperature fields display themselves at the surface in a variety of ways, ranging from warm ground to spectacular geysers of steam and boiling water. In between these extremes are hot springs, sinter deposits, fumaroles, and hot mud pools.

Except for one high temperature field at Ngawha, in Northland, which is not associated with recent volcanism, all the others occur in the Taupo Volcanic Zone. This zone extends from Mount Ruapehu in the centre of the North Island to the Bay of Plenty. It incorporates Lakes Taupo, Rotorua and Tarawera, the upper reaches of the Waikato and Tarawera Rivers, and the significant townships of Taupo and Rotorua.

**Coastal and marine waters**

New Zealand may have the eighth longest coastline of any nation, although its exact length is not known because of all the twists and turns it takes around inlets, headlands, spits, bays, harbours, fiords, sounds and estuaries. Depending on how detailed the map is, estimates range from 10,000 to as many as 15,000 kilometres. A more solid statistic is that we have the fourth largest maritime area, with an exclusive economic zone (EEZ) of some 483 million hectares. Only the United States, Indonesia, and French Polynesia have larger maritime areas.

The coastal marine environment forms three temperature-related bioregions: northern, central and southern (Tortell, 1981). The northern bioregion covers the north-east of the upper North Island, from Northland Peninsula through to East Cape. Its warm temperate shores are influenced by the subtropical East Auckland Current (see Figure 7.5). The central bioregion covers the large area from East Cape to Otago on the east coast and virtually all of the west coast from the western tip of Northland down to Fiordland. The cool southern bioregion is influenced by the Southland Current and the West Wind Drift.

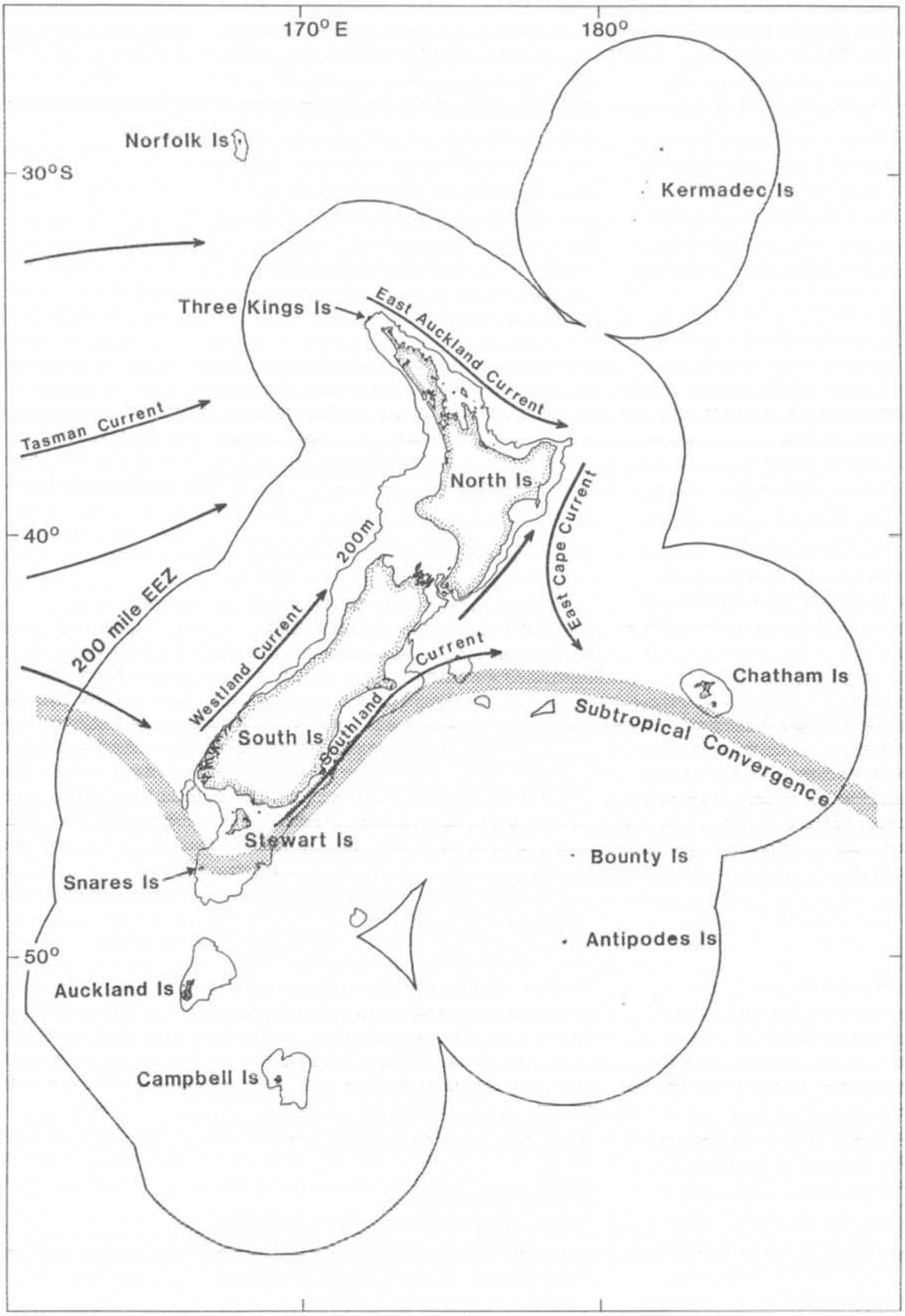
For these reasons, our coastal waters vary from warm, salty, sub-tropical currents in the north and west, to cold, less saline, sub-antarctic currents in the far south and south-east. The warmer currents come from the coastal waters around Australia. They swirl around most of the North Island and the northern and western part of the South Island and meet the cold sub-antarctic waters in a zone called the Sub-tropical Convergence, which extends from Banks Peninsula to Milford Sound. Summer water temperatures on the continental shelf range from about 21°C in the north to 14°C in the south. Although the typical seasonal range is 5°C, significant local variations occur from time to time as a result of upwelling caused by onshore winds and freshwater inflows.

Apart from the variations of current and temperature, the marine environment also varies in other ways. Underwater habitats range from monotonous plains of mud to occasional wonders, such as the volcanic vents near White Island, whose micro-organisms "breathe" sulphur rather than oxygen, or the great, coral-festooned, seamounts of the deep ocean (see Box 7.3) or even the rocky reefs of our coastal waters. However, the greatest variation is probably between the intermittently wet tidal environment along the shoreline and the sea environment beyond this.

***The tidal environment***

About two-thirds of our coastline is hard rocky shore while soft shores of sand or gravel cover about one third. Some 80 percent of the coast is directly exposed to the sea, with the remainder sheltered in harbours and estuaries. The rocky

**Figure 7.5**
**New Zealand's marine environment, showing the 200-mile Exclusive Economic Zone, the main ocean currents and the 200-metre depth contour.**




*Source: Francis (1996)*

shores contain three tidal zones: littoral; eulittoral; and sublittoral. The littoral fringe is well up the beach, beyond the reach of all but the highest spring tides. It is climatically harsh and sometimes dry for days at a time. Only a few well-adapted pioneer species are found there, such as yellow and grey lichens and periwinkles.

The much larger eulittoral zone is bathed twice daily by the tide and is home to acorn barnacles, mussels, and serpulid tubeworms (*Pomatoceros*). The lower third of the zone has a seaweed turf of the calcareous red alga *Corallina officinalis,* accompanied by the bladdered fucoid seaweed, *Hormosira banksii*, and sometimes by the green alga, *Codium convolutum*. The sublittoral fringe is underwater most of the time and is richly clad in half a dozen or more species of brown algae, better known to most people as kelp seaweed. It also supports a small but diverse assortment of bullies and other rockpool fish (see Chapter 9).

The soft shore beaches are made of gravel or sand or mixtures of these. Gravel beaches tend to be steep and tiered, but sand beaches have a low, gentle gradient. They are porous, firm underfoot, and the open beach sand is free of silt, even-grained, and subject to constant wave action. These conditions favour shellfish, such as the toheroa (*Paphies ventricosum*), which forms its zone in the mid-beach, and a profusion of other molluscs just below wave-break. The open beaches of the east coast are composed of relatively coarse to medium sand. Onshore surf, common on the west coast, is here confined to occasional periods of easterly wind. Toward low water the dominant bivalve mollusc is the tuatua (*Paphies subtriangulatum*).

Much of the coastline is made up of river-fed estuaries, whose wide, shallow, waters are permanently protected from ocean waves by sand or shingle bars or offshore islands (see Figure 7.6). Such shores include drowned harbours or, more generally, wide, level flats of sand (which are often miscalled mudflats). New Zealand's estuaries cover a total area of at least 100,000 hectares. Most have developed where coastal sand bars at river mouths have caused the rivers to spread out. In total, 164 estuaries are bar-built, 56 are drowned river valleys, 65 are lagoons and 16 are fiords (McLay, 1976).

The sandflats and wetlands associated with shallow estuaries are the most productive ecosystems on Earth, growing three or four times more plant and animal matter per hectare than the land or sea to either side of them (Knox, 1980). The rich assortment of burrowing sandflat animals includes many bivalve molluscs, notably pipi (*Paphies australis*) and crowded beds of the cockle (*Chione stutchburyl*), and a rich wealth of worm species, including the pencil-sized yellow proboscis worm (*Balanoglossus australiensis*). Various echinoderms are also common in the sandflats, such as the comb star (*Astrpecten polyacanthus*), the brittle star (*Amphiura aster*), the worm-like holothurian (*Trochodota dendyi*) and sometimes the burrowing urchins *Echinocardiun australe* and *Arachnoides novaezelandiae*.

In the upper reaches of estuaries, soft deposits accumulate and form habitat for both bivalve and gastropod (snail) molluscs. Tiny crustaceans called copepods are also common. Pauatahanui inlet, near Wellington, has the highest recorded density of copepods in the world. Though partially degraded by pollution and sediment, part of the estuary became a wildlife management reserve in 1985, in recognition of its importance to wading birds (Forlong and Kirkland, 1993).

Some estuarine ecosystems are based on plants. Seagrass (*Zostera*) can form wide green swards, such as in the Manukau Harbour where scallops (*Pecten novaezelandiae*) are abundant and form large beds around low water (Tortell, 1981). Mullets and flatfish (flounders and sole) share the rich feeding grounds with wading birds as the tide ebbs and floods. Another plant-based ecosystem is formed by the mangrove tree (*Avicennia marina resinifera*), which flourishes in the warm harbour and estuarine waters of the northern third of the North Island (Hackwell, 1989). Though low in species diversity, mangrove ecosystems are a haven for young flatfish and provide habitat for more than 30 fish species in all. The most common of these is the yellow-eyed mullet (*Aldrichetta forsteri*). The seagrass and mangrove ecosystems have declined this century as a result of widespread modifications to estuaries caused by such as activities as infilling for agriculture, rubbish disposal, and commercial land development.

***The sea environment***

The nature of our sea environment is determined by several factors, including our remote location in the South Pacific Ocean, the wide latitudinal range of our marine zone stretching from sub-antarctic to sub-tropical waters, the predominant westerly weather pattern, and the extensive continental shelf surrounding New Zealand which, at 24 million hectares, is only slightly smaller than New Zealand's total land area of 27 million hectares.

New Zealand's coastal waters support hundreds of fish species, a variety of marine mammals, and many marine invertebrates. Some of the unique marine ecosystems include The Gut, in Fiordland's Doubtful Sound, famous for its red and black corals and sea pens, and Nugget Point on the South Otago coast which is the only place on the mainland where New Zealand fur seals, New Zealand sea lions, and elephant seals co-exist (Forlong and Kirkland, 1993). Banks Peninsula near Christchurch was made a marine mammal reserve to protect the world's rarest and smallest marine dolphin, Hector's dolphin, while, in other parts of the coast, fur seals, dolphins and whales have become popular tourist attractions. The most popular of all are probably the sperm whales which feed in the deep water just off the Kaikoura coastline.

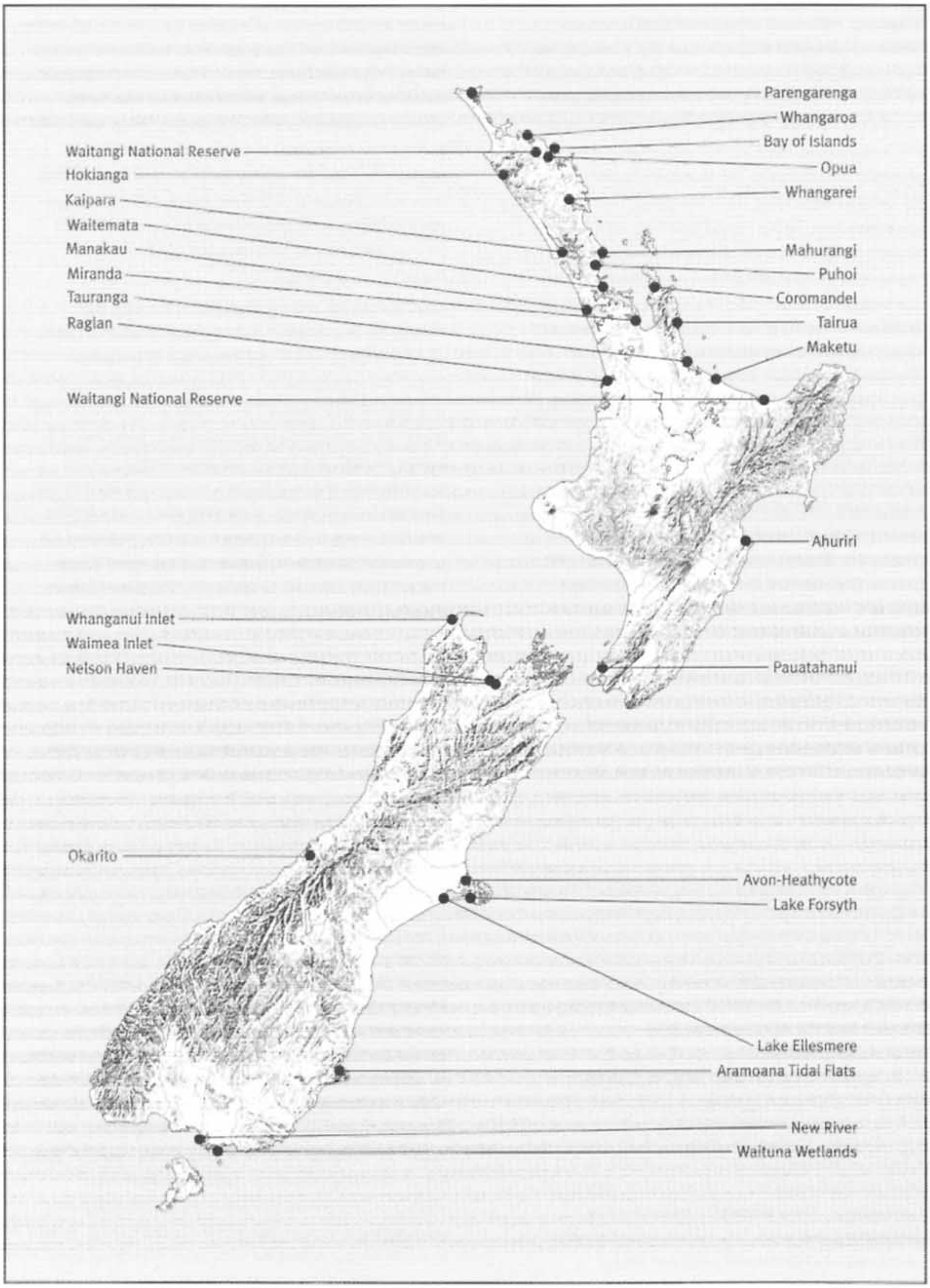
The waters around New Zealand have many temperate reefs. These are rocky ridges which range from warm temperate in the north through to cool temperate in the south. Warm temperate reefs are characterised by the kelp, *Ecklonia radiata*, or large, grazed areas of the urchin *Evechinus chloroticus*. Common fish include the seaweed grazers—butterfish (*Odax pullus*), parore (*Girella tricuspidata*), silver drummer (*Kyphosus sydneyanus*), marblefish (*Aplodactylus arcticdens*), and black angelfish (*Parma alboscapularis*). Other common reef fish include the spotty or paketi (*Notolabrus celidotus*), banded wrasse (*Notolabrus fucicola*), hiwihiwi or kelpfish (*Chironemus marmoratus*), red moki (*Cheilodactylus spectablis*), blue cod (*Parapercis colias*), goatfish (*Upeneichtys lineatus*), and snapper (*Pagrus auratus*).

The deeper reef areas are covered with sponges, ascidians and other colourful encrusting animals. In the cooler southern waters, butterfish and marblefish are the main seaweed grazers and blue moki (*Latridopsis ciliaris*), copper moki (*L. forsteri*), and tarakihi (*Nemadactylus macropterus*) feed on the sea floor. Generally, algal species diversity is greater in the cool temperate waters. The dominant kelp varies depending on exposure—the bull kelp (*Durvillaea willana*) is present in exposed conditions and *Macrocystis pyrifera* in more sheltered areas.

Seabed communities vary from those of the muddy shelves off Westland, Hawkes Bay and Wairarapa, to those of the sandy and gravelly shelves off Northland, Otago and Southland.

They include many species of true crab, hermit crab, sea snail, octopus, starfish and brittlestar, and two species of rock lobster, the commonest of which, the red rock lobster (*Jasus edwardsii*) is the basis of a commercial fishery. Seabed invertebrates are also important in the diet of many species of fish that live on or close to the bottom, such as dogfish, carpet shark, skate, elephant fish, gurnard, tarakihi, flatfish and our most commercially important inshore fish, snapper (*Pagrus auratus*), which eats a wide range of seabed invertebrates and small fish.

**Figure 7.6**
**Some of New Zealand's major estuaries and harbours.**




*Source: Crisp and Walsby (1986)*

**Box 7.3**

### *Seamounts: 'reefs' of the deep*

The great coral reefs found in shallow tropical waters are well known as gardens of marine biodiversity. Formed by the accumulation of coral skeletons over hundreds or thousands of years, these reefs support a wide variety of species within their nooks and crannies. A myriad of fish, invertebrates and seaweeds dwell there, some for their entire lives, others for key phases of their life cycle. The abundance of reef life is mainly fueled by algae living inside the corals. These capture energy from the sun shining overhead. New Zealand has no coral reefs and so is not directly affected by the fact that many of the world's reefs are now under threat. But we do have something similar—coral-dominated seamounts. Out in the deeper waters of our Exclusive Economic Zone, tall mountains rear up from the mud-covered abyssal plains which dominate 80 percent of the ocean floor. Living on their peaks and ridges, half a kilometre or more below the surface, are dense communities of marine invertebrates and fish. They receive their primary energy supply not from the sun, but from nutrient-rich water currents which well-up around them and a daily 'catch' of tiny invertebrate prey (zooplankton) that get trapped on the seamounts each morning as they descend from their night-time forages near the surface. The seamount communities are also fed by a constant 'rain' of detritus and faecal pellets from organisms which live closer to the surface.

The seamount ecosystems are complex and varied. Many harbour their own unique endemic species. As on the reefs, the dominant animals are corals–not the typical reef species, but groups such as black corals and horny corals (or gorgonians). 'Thickets' of tree-like and bush-like coral colonies festoon seamount ridges and pinnacles wherever they can find exposed rock surfaces to cling to. For them, the seamounts are like desert oases. The seamounts are also places of shelter or sustenance for other small marine animals, such as anemones, sponges, echinoderms (e.g. brittle stars, snake stars, sea stars), bryozoans, worms, molluscs (e.g. snails, bivalves) and crustaceans (e.g. crabs). These attract large congregations of fish, which, in turn, attract other species to the surrounding waters, such as sperm whales and sea birds.

The biodiversity of New Zealand's seamounts is just beginning to be understood. Most of the invertebrates found in a recent study of trawler bycatch on seamounts in the Chatham Rise had not previously been scientifically identified (Probert, 1996; Probert *et al.*, in press). But scientists are not the only ones to recognise the seamounts' high productivity. Many seamounts are targeted by trawlers seeking deep water fish, such as orange roughy. Anecdotal evidence from trawler crews and fishery scientists suggests that large numbers of corals and other marine invertebrates are killed when the trawlers first move onto a seamount and then populations decline markedly as fishing progresses (Jones, 1992). Scientific investigations are still at an early stage, but the Chatham Rise survey appears to confirm the anecdotal reports. Deep-water coral banks, large gorgonians, sea pens and sponges are particularly vulnerable as they are fragile and slow-growing. Once destroyed, coral formations appear to need 200-400 years to fully recover, and will never be quite the same if their endemic species have been lost (Probert, 1996; Probert *et al.*, in press).

Given the relative scarcity of seamount habitats, their biodiversity and their vulnerability, some marine scientists are now voicing concern about their lack of protection (Jones, 1992; Probert *et al.,* in press). The scientists are also beginning to wonder if seamounts play key roles in the life cycles of commercially important deep water fish (e.g. orange roughy). It is known that some coastal fish use bryozoan mats and coral thickets as spawning grounds and nurseries for their young. If the seamounts play a similar role, their destruction may have a long-term impact on our commercial fisheries. Until more is known about this, a precautionary approach to seamount fishing would seem the safest strategy.

To date, the conservation of marine ecosystems has focused on shallow water ecosystems (the Marine Reserves Act 1971 applies to areas within the 12 mile limit). Although the Territorial Sea and Exclusive Economic Zone Act 1977 provides for measures to protect and preserve the marine environment throughout the Exclusive Economic Zone, it has not been used to protect any deep water areas from trawling. The recently passed Fisheries Act 1996 requires the Minister to (among other things) avoid, remedy or mitigate any adverse effects of fishing on the aquatic environment, maintain the viability of associated or dependent species, maintain aquatic biodiversity, and protect any habitat which has particular significance for fisheries management. While the Fisheries Act does not empower the Minister to establish reserves as such, it does enable him to impose a range of 'sustainability measures' to stop environmentally harmful fishing. The Marine Reserves Act enables the Minister of Conservation to establish such reserves for scientific purposes. The recent extension of the Wildlife Act to the 200 mile limit also enables the Minister of Conservation to prepare Population Management Plans for protected coral species which may be at risk of 'fishing related mortality'. With the passing of these measures, and the adoption of an ecosystem management approach in the Ministry of Fisheries' proposed Fisheries 2010 strategy, the infrastructure now exists to ensure that our fascinating 'reefs' of the deep do not go the same way as the ill-fated reefs of tropics.

Some of the least known parts of the marine environment are the deep water ecosystems beyond the continental shelf. Two thirds of New Zealand's Exclusive Economic Zone (EEZ) consists of deep water, much of it barren of fish and extending over vast areas of featureless, muddy, seafloor. Compared with coastal waters, the deep sea is a constant environment. Even the effect of latitude is relatively small, so that whereas many marine organisms of surface waters occur only in the north or south of our Exclusive Economic Zone, those of the deep sea (e.g. orange roughy) are often found throughout the EEZ.

The expanses of ocean mud are inhabited by a variety of marine invertebrates, such miniature worms, crustaceans, and molluscs, but their total biomass is believed to be relatively low—even compared to desert ecosystems on land. However, the deep oceans are not total deserts. On the Chatham Rise, for instance, at depths of about 400 metres, small spiny nodules projecting from the mud are festooned with bonsai-like colonies of soft corals and bryozoans. And marine life flourishes on and around the great mountain ranges and peaks which occasionally rear up from the muddy plains. These seamounts, as they are called, are very rich fishing grounds and are also havens of marine biodiversity (see Box 7.4).

## PRESSURES ON OUR WATER ENVIRONMENT

We tend to under-estimate how much water we use directly and indirectly simply to get through an average day. The total amount harnessed each year for electricity production, crop and livestock production, industrial production, and normal household activities has been estimated at almost 102,000 million cubic metres (Table 7.4.). Broken down to a scale we can deal with this comes to some 82,000 litres per person per day. When the huge amount used for hydroelectricity generation is subtracted, the total still exceeds 1,500 litres per person per day. Much of this is used by agriculture and industry in providing the products and services which are an integral part of our economy and lifestyle, but about 160 litres are used by each of us personally in the home and at the workplace. In addition to this we use large amounts of unharnessed water, such as the rain that falls on our gardens, crops and pastures, and the natural waterways that nurture the fish we eat and provide us with recreational opportunities.

With such a variety of water uses, it is not surprising that people have had an impact on New Zealand's water flows and water quality. Some of the heaviest impacts, however, have not come from water use, but from land use. By changing the vegetation cover we have altered the amount of rainfall that runs off the land into streams and rivers. The greatest single source of pressure was probably the removal of our hill and riparian (riverbank) forests for **pastoral agriculture**. This caused an increase in the scale

**Table 7.4**
**Yearly use of harnessed water in New Zealand.**

| Water Use | Quantity ($Mm^3/y$) | |
|---|---|---|
| *Electricity generation* | *100,000* | |
| *Irrigation* | *1,100* | |
| *Livestock consumption* | *350* | |
| *Industry consumption* | *260* | |
| *Household consumption* | *210* | |
| *Bathroom (assuming one 5-minute shower a day)* | | *55* |
| *Lavatory (assuming five 11-litre flushes a day)* | | *50* |
| *Washing machine (varies from 70-240 litres per cycle)* | | *40* |
| *Kitchen (7 litres per half-sink, 24-45 litres per dishwasher cycle)* | | *20* |
| *Outdoors (summer hosing for 30 minutes per day)* | | *45* |
| ***Total yearly use*** | ***101,920*** | |

*Sources: McConchie (1992); Mosley (1993)* of erosion, sedimentation and flooding. Most of the deforestation occurred before 1920 (see Chapter 8), but the continuing use of deforested hill and riparian areas for livestock production is a persistent source of pressure on streams and rivers, causing pollution from animal waste, sediment and fertilisers.

New Zealand's water has also come under heavy pressure from urban populations and industry. Many are situated on estuaries and in former wetlands where drainage and urban development have destroyed or modified the aquatic ecosystems. The increasing urban demand for water has reduced the levels of some rivers and aquifers, and the demand for electricity has led to river flows being disrupted by dams. In some areas, the increasing consumption of water by households and industry has led to water shortages and costly pipeline and reservoir extensions. In some areas, too, the increasing production of human and chemical waste has led to water pollution from sewage, leachates, and stormwater run-off.

Several surveys in recent years have asked local authorities to identify and rank the pressures on water quality in their areas. One survey covered local authorities, the Department of Conservation, and Fish and Game Councils (C.M. Smith, 1993), while another concentrated on regional councils (Hoare and Rowe, 1992). The most serious pressures identified in both surveys were:

- sedimentation and nutrient enrichment (eutrophication) of surface waters by agricultural run-off and urban stormwater;
- point source pollution in some lower reaches of streams and rivers; and
- nitrate contamination of groundwater.

In a similar survey by the Ministry of Agriculture and Fisheries, regional officials ranked agriculture as the greatest source of pressure on water quality, closely followed by urban sewage (see Table 7.5). Below these, the officials ranked urban stormwater, industrial wastes and agricultural processing as important sources of pressure, and, further below these, mining and forestry. The main agricultural impacts were identified as sedimentation, nutrient and microbiological contamination, altered physical characteristics of surface waters, and nitrate contamination of groundwater (Sinner, 1992).

**Table 7.5**
**Impacts on water quality as ranked by regional officials.**

| Sources of impacts on water quality | |
|---|---|
| **Source** | **Average rank[1]** |
| *Agriculture* | 4.9 |
| *Human sewage* | 4.8 |
| *Urban storm water* | 3.9 |
| *Industry* | 3.8 |
| *Agricultural processing* | 3.7 |
| *Mining* | 2.6 |
| *Forestry* | 2.6 |

| Agricultural impacts on water quality | |
|---|---|
| **Type of Impact** | **Average rank[1]** |
| *Sedimentation* | 6.4 |
| *Nutrient contamination* | 6.2 |
| *Alteration of physical characteristics* | 5.6 |
| *Faecal contamination-surface water* | 5.4 |
| *Nitrate contamination-ground water* | 4.6 |
| *Pesticide contamination-surface water* | 2.8 |
| *Faecal contamination-ground water* | 2.8 |
| *Pesticide contamination-ground water* | 1.6 |

*Source: Sinner (1992)*
*[1] Ranked on a scale from 0 = no damage to 10 = severe damage*

In summary, the various pressures on water can be grouped as: **agricultural pressures** (including vegetation clearance, land drainage and channelling, draw-off for irrigation and stock watering, and run-off and waste discharges from farms and agricultural processing facilities); **urban pressures** (including sewage and industrial waste, stormwater run-off, draw-off for household and industrial uses; and urban expansion into wetlands and estuaries); **dams** (including hydro-electric and water supply dams); and **forestry** and **mining**. In addition to these pressures, concern has also been expressed about the impacts on natural waterways from introduced **pests and weeds** and from the potential impacts of **climate change**. A brief discussion of each of these pressures follows.

**Agricultural pressures**

Agriculture outranks other sources of pressure on water largely because of the scale of pastoral farming. Pasture grass and farm animals dominate more than half of New Zealand's land surface, and affect nearly all catchments. The livestock populations excrete about 40 times more organic waste than New Zealand's human population. The treeless pastures are a constant source of run-off, washing some of this waste, as well as sediment and fertiliser residues, into waterways. The animals and irrigated plants consume three times more water from rivers and aquifers than all the country's households and industrial sites combined. Pastoral products are also a major source of organic waste discharges from processing industries such as meatworks and dairy factories.

In recent decades some of these pressures have improved noticeably as the agricultural sector has become more aware of the problems and as waste water treatment technologies have improved. Economic conditions and soil conservation initiatives have also brought trees and scrub back to some of the steeper pastures. The extent of these trends has not been measured, however, and on current evidence, pastoral agriculture remains a significant source of pressure on New Zealand's water.

Other forms of agriculture also consume water and generate pollutants (e.g. horticulture, cropping, pig and chicken factory farms). These may have significant impacts in a particular locality, but their national impact is small compared to pastoral agriculture. Pasture covers 14 million hectares of land, whereas crops and horticulture cover barely 400,000 hectares (see Chapter 8). The estimated daily $BOD_5$ loading from the organic waste of 9.3 million cattle, 48.8 million sheep, 0.3 million farm goats, and 1.2 million farm deer comes to over 10,000 tonnes, compared to a daily $BOD_5$ loading of less than 5 tonnes from the nation's 430,000 pigs, and about 380 tonnes from the 54 million chickens, most of which is removed as dry waste.

This calculation assumes an average daily $BOD_5$ load for individual animals of 980 grams for pasture-fed cattle, 32 grams for sheep and goats, 10–12 grams for pigs, and 7 grams for chickens (Vanderholm, 1984). The comparable human load is about 70 grams, although the discharge of industrial waste into domestic sewers increases the daily $BOD_5$ per person to 100 grams (Hauber, 1995). $BOD_5$ varies considerably with size and diet, but these averages provide a basis for comparing the waste load of different species.

***Agricultural pressures on water stocks and flows***

The three main pressures which farming exerts on water flows are **pastoral land use** (which determines the dominant vegetation cover in most catchments and hence the amount and quality of rainwater that runs off into streams and rivers), **irrigation** (which takes water from rivers and aquifers and thereby affects their volumes and flows), and **land drainage** (which continues to exert major effects on the extent and depth of wetlands, and the volume of groundwater resources in most lowland floodplains).

*Deforestation pressures on water flows*

Before people arrived here, New Zealand was a forested country. The forests acted as natural sponges for much of the rainfall, with tree leaves and mosses intercepting the rain as it fell, and tree roots sucking the water out of the soil. Indigenous forests, plantation pine forests and, to a lesser extent, the native tussock grasses, all have a similar effect on the water cycle, absorbing a sizeable proportion of rainfall and allowing it to evaporate and transpire back into the atmosphere. Exotic pasture grasses also intercept and absorb water, but not to the same extent as forests and tussock. The result is greater water run-off in pastoral catchments than in forested or tussock-dominated ones.

Vegetation change began with Maori settlement. Large areas of forest were burnt off causing considerable sedimentation and flood flows in some areas, though not in others (McGlone, 1989; Trustrum and Page, 1991). Dry naturally erodible areas, such as the South Island high country, were heavily affected, but wetter areas, such as the East Coast of the North Island were relatively unscathed because of the the quick regrowth of deep-rooted bracken fern and small shrubs which held the soil. Following European settlement, however, large areas of forest, tussock and scrub were replaced with short, shallow-rooted, pasture grasses (see Chapter 8). This wholesale vegetation change increased the amount of water running off the land, causing higher river flows, more frequent floods, increased erosion rates and increased water sedimentation. The removal of streambank vegetation contributed to the loss of water quality and destruction of aquatic habitat (see Box 7.4).

**Box 7.4**

### *Banks in crisis*

Before humans arrived, New Zealand's stream banks, or riparian zones, were also biodiversity banks. Most lowland streams were bordered by dense native forest teeming with at least 50 species of vascular plants and many species of mosses and fungi. The riparian zones provided key habitat for half our native land birds, many of which are now extinct or threatened (e.g. the blue duck, brown teal and even the takahe). The stream banks were also home to native frogs, skinks and lizards, slugs, snails, flatworms, earthworms and nematodes, and many insect species, including half the world's *Taenarthus* carabid beetles and many species of Tanyderidae crane flies (Collier, 1995). The overhanging vegetation and falling leaves and branches provided shade, food and habitat for native fish such as the extinct grayling, the banded kokopu, the short-jawed kokopu and the koaro. Mudfish dwelt in the holes around tree roots and in the moist earth of the stream banks and wetland edges. The shade also kept algae at low levels and maintained cool water temperatures, even through summer. The tree roots limited bank erosion, keeping the water clear of sediment (Gilliam *et al*., 1992).

Today, most stream banks have been cleared of their vegetation to create pasture. Where hundreds of species once dwelt, there are now just a few species of exotic grass accompanied by some sheep or cattle and the occasional thistle, sedge or lone clump of cabbage trees. Loss of shade has increased light levels in many lowland streams, driving the native fish away and leading to the proliferation of algae and introduced weeds. The situation has been made worse by the increased amount of run-off containing nutrients from animal waste and fertilisers and sediment from eroding hillsides and collapsing streambanks (Collier, 1995).

Awareness of these problems has led to riparian protection measures in some parts of the country, notably the streams draining into Lake Taupo which became riparian protection zones in the 1970s. In most cases, however, riparian protection has been undertaken by landowners only where significant bank erosion has demanded it. Where collapsing banks have caused serious pasture loss introduced willow and poplar trees have been planted. Because of their fast growth rate, these species can quickly restore bank stability but have done little to restore biodiversity. Some species (especially the crack willow, *Salix fragilis*) invade channels and destroy habitat for aquatic life (Collier, 1995).

Protecting the natural character of rivers and their margins is among the matters of national importance set down in the Resource Management Act and, as a consequence, a number of district and regional councils are now actively promoting riparian retirement planting and conservation. Taranaki Regional Council, for example, has adopted a riparian management strategy whose key elements are education, advocacy and free technical advice to interested landowners. Between 1993 and 1996, the council prepared 45 personalised riparian management plans for individual landowners (Taranaki Regional Council, 1996). To assist councils and private landowners, the Department of Conservation commissioned NIWA to develop guidelines for the management of riparian zones (Collier, *et al.,* 1995). These have been published as a two volume set and have become an unexpected 'best seller' for DoC. By April 1996, copies had been sent to more than 600 locations (Green, 1996). The riparian guidelines outline techniques for retaining or restoring bank stability and biodiversity through: protecting remnant vegetation; planting trees and shrubs; maintaining a vegetated ground cover; protecting wetlands; controlling livestock, and planting and maintaining native riparian plants. Otago Regional Council has also recently published a report called *Riparian Management* which is a set of local guidelines for different types of land activity in Otago.

Although no native plants can match the vigour and protection of willows, several show promise for bank stabilisation where erosion is less severe, or where willows have already stabilised a bank. Some also provide food for birds. These plants include makomako (*Aristotelia serrata*), kotukutuku (*Fuschia excorticata*), kawakawa (*Macropiper excelsum*), mahoe (*Melictus ramiflorus*), karo (*Pittosporum crassifolium*), pate (*Schefflera digitata*), kowhai (*Sophora* spp.) and pohutukawa (*Metrosideros excelsa*). The popularity of the guidelines suggests a growing interest in stream and river bank conservation. Although it appears to involve only a fraction of the country's 80,000 or so farms at present, it is a much needed step toward improving stream quality and bringing biodiversity back to the farm.

Evidence that vegetation change significantly affects river flows has been obtained from several catchment studies in various parts of New Zealand, including Berwick Forest in Otago (Smith, 1987), Glendhu Forest in Otago (Fahey and Watson, 1991), Moutere near Nelson (Duncan, 1994), Tarawera in the Bay of Plenty (Dons, 1986; Pang, 1993) and Purukohukohu near Rotorua (Dons, 1987).

In the Purukohukohu study several small catchments with different vegetation covers were compared (Dons, 1987). One catchment was predominantly covered in pasture, one was covered in pine forest, and one was covered in indigenous forest. In the forested catchments 70-75 percent of rainfall was absorbed by vegetation compared to only 55 percent in the pasture catchment (see Figure 7.7). Run-off from the forested catchments was only half to two-thirds that of the pasture catchment. As a result, the pasture catchment had higher average stream flows and flood flows.

More dramatic results were obtained from a 30-year study of a small catchment at Moutere, Nelson, where pine forest replaced pasture (Duncan, 1994). Average stream flows, flood flows, and low flows were reduced by between 50 percent and 80 percent. Extreme floods were reduced to such an extent that even a 50-year flood would now produce only half as much flow as before.

A study of vegetation changes in the much larger catchment surrounding the Tarawera River came up with similar results (Pang, 1993). In this 90,000 hectare catchment, some 25,000 hectares (28 percent of the catchment) were converted from a light cover of regenerating forest (40 percent) and scrub (60 percent) to pine forest. This caused a drop of about 13 percent (4.5 cumecs) in the average yearly flows of the Tarawera River (Pang, 1993). Declining rainfall caused a further flow reduction of 6.4 cumecs, making a total reduction of about 11 cumecs (see Figure 7.8). The impact of afforestation at Tarawera was similar to that found in Glendhu forest where 67 percent afforestation caused a flow reduction of 25 percent, and where complete afforestation of the catchment could reduce flows by 45 percent (Fahey, 1994).

These experiments corroborate the evidence from sediment studies suggesting that the deforestation of New Zealand has had a considerable impact on river flows (McSavaney and Whitehouse, 1989; McGlone, 1989; Trustrum and Page, 1991). They also suggest that an increase of tree cover on pasture land will reduce peak flood flows and average stream flows, but may cause problems in some catchments for downstream water uses and for maintaining water levels in surviving wetlands.

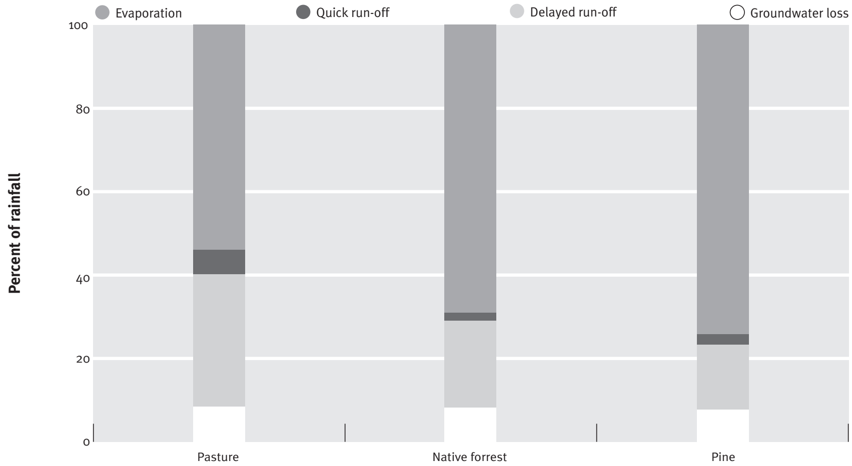
However, it should be noted, that the effects of vegetation change on river flows do not apply uniformly to all catchments. Pine forest was planted over 21 percent of the 26,000 hectare Esk catchment in Hawke's Bay but had no affect on flow rates (Black, 1991). The Esk river is in one of New Zealand's drier areas, so there was little rain for the newly established forest to intercept. It appears that most of the Esk's water enters as run-off and seepage from limestone rocks high up in the catchment headwaters, where rainfall is also highest. This has far more effect on flow rates than the comparatively small amount of rainfall that runs off pasture and forest lower down in the catchment. The obvious conclusion to be drawn from this is that the distribution of rainfall within a catchment is as important as the distribution of vegetation cover. In dry areas, therefore, afforestation of the lower part of a catchment is unlikely to have any great impact on downstream water uses.

*Irrigation pressures*

Every year, pastoral farmers, orchardists and market gardeners remove (or abstract) approximately 1,500 million cubic metres of water from surface waters and groundwater (Table 7.4). This is an estimate, as no national statistics exist on water abstraction. Much of the removed water returns to rivers and groundwater, but a large amount is absorbed by plants, soil and animals. Such a large draw-off can potentially reduce the water flows available for urban water supplies, recreational activities (e.g. swimming, fishing, boating), habitat (e.g. for fish and insects), and ecological processes (such as dilution and the prevention of eutrophication).

**Figure 7.7**

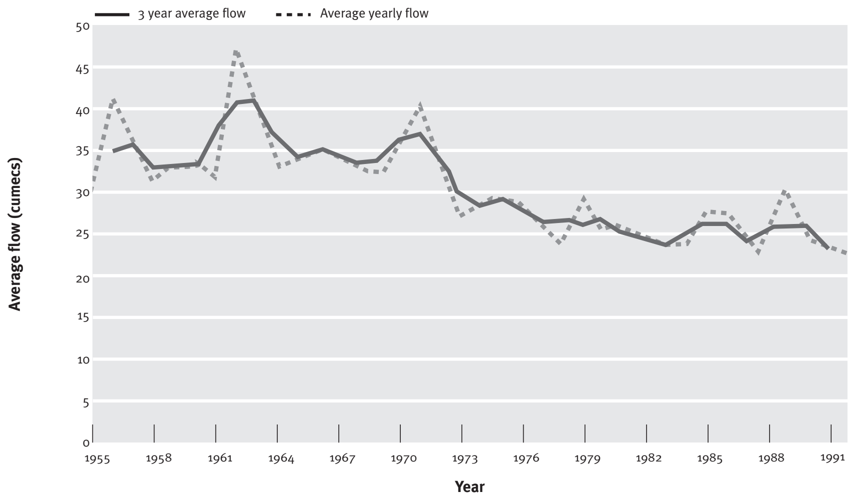
**Patterns of water run-off from pasture, native forest and pine forest catchments at Purukohukohu,central North Island**




*Source: Dons (1987)*

**Figure 7.8**

**Tarawera river flows before and after catchment afforestation in the 1960s**




*Source: Pang (1993)*

The bulk of the abstracted water is used to irrigate pasture, or is consumed directly by farm animals. Although horticulture is a heavy user of irrigation water, its overall share is relatively small because of the smaller land area involved. Horticulture covers 95,000 hectares, not all of which is irrigated, while the total irrigated land area is more than 300,000 hectares. About 50 large schemes, with a potential coverage of about 160,000 hectares, were established with government assistance between 1910 and 1987. The government share of these schemes was sold in 1989 and 1990, and all the irrigation schemes are now privately owned. Most of the irrigated land is pasture land in the South Island, particularly Central Otago and Canterbury. The much smaller area irrigated for horticulture, is mostly in drier parts of the North Island.

Agriculture's demand for water is highest during summer months when river flows and groundwater levels are at their lowest. This has led to intensive competition for water in some rivers and aquifers, particularly in cropping, market gardening, and horticultural areas such as Canterbury, South Auckland, the Waimea Plains, and Hawke's Bay (Armstrong, 1993). Large-scale irrigation can reduce river flows to the point where fish, wetlands, and recreational activities are affected. In Canterbury, for example, where up to 30 cumecs ($m^3/s$) of water are drawn from the Rangitata River, the flow halves during the irrigation season from a yearly average of 98 cumecs to about 50 cumecs (Mosley, 1993).

The effects of irrigation were even greater under the old system of notified water rights. During the 1985 drought, when the combined flow of all streams and rivers in South Canterbury fell from an average of 180 cumecs to just 80, irrigators were entitled to draw off 51 cumecs, leaving a downstream flow of barely 30 cumecs (Scarf, 1988). That same year, Canterbury's Rakaia River became one of the first to be protected under a Water Conservation Order, partly because of the potential impacts of irrigation (see Table 7.13). Under the new system of water management plans, irrigation draw-offs from these rivers have been reduced.

Quite apart from its impact on river flows, irrigation also has the potential to affect groundwater quality in some areas through the leaching of nutrients and contaminants. The effect is only detectable in areas where shallow aquifers underlie thin soils and where rainfall is low enough to allow irrigation to play a dominant role, such as the Levels Plain and Temuka area in South Canterbury (Smith, 1994).

After decades of continual expansion, large-scale irrigation development halted when Government assistance came to an end in the mid-1980s. The prolonged spate of El Niño-associated dry seasons between 1989 and 1995 led to revived interest among some farming groups in developing new irrigation schemes, particularly in Canterbury. To date, the only recent schemes have been small ones, mostly on dairy farms. The small schemes draw off less water than the large formerly subsidised schemes, but, in some areas, their combined impact may have the potential to be significant.

### *Land drainage pressures*

Beginning last century, land drainage has had a marked effect on New Zealand's wetlands, and also on some rivers, shallow lakes and groundwater. The main reason for draining large areas of low-lying land has been to increase the area of pasture, but flood control schemes and urban development have also played significant roles. Most of the changes occurred between 1920 and 1980, but in some areas, the drainage work is continuing, and even increasing, partly in association with the increase in dairying farming.

The drainage schemes have removed most of the nation's wetlands and have altered the natural character of some rivers and shallow lakes. Rivers were straightened and stopbanked, lake levels fell, and, some groundwater levels were lowered. Today, New Zealand is criss-crossed by several thousand kilometres of channels and ditches which quickly divert unwanted water into straightened rivers and eutrophying lakes. The drainage schemes have also caused greater scouring of rivers and riverbeds because of the increased volume of water flowing through them. The result in many rivers is a gradual rising (or aggradation) of the riverbed, causing peak flood flows to also rise. If the drainage schemes had caused the wholesale disappearance of lakes they would have been questioned much sooner, but communities have allowed their wetlands to disappear quietly with scarcely a question raised, despite a National Wetlands Policy approved by Cabinet in 1986. Some regional councils (e.g. Bay of Plenty) now restrict drainage in vulnerable catchments. While the rate of drainage of wetlands for conversion to pasture has declined, new land development methods such as 'humping and hollowing' are still having impacts on adjoining wetlands.

### *Agricultural pressures on water quality*

Because it extends over half New Zealand's land area, agriculture dominates the middle and lower catchments of most streams and rivers. In the course of each year, significant parts of these catchments are defecated on by millions of farm animals, sprayed with fertilisers and pesticides, and rained on. As a result, tonnes of faecal matter, nutrients (i.e. nitrogen and phosphorus), and sediment are washed into surface waters, while nutrients and other contaminants leach into groundwaters. Additional organic waste is discharged into surface waters from facilities that process agricultural products and animal carcasses.

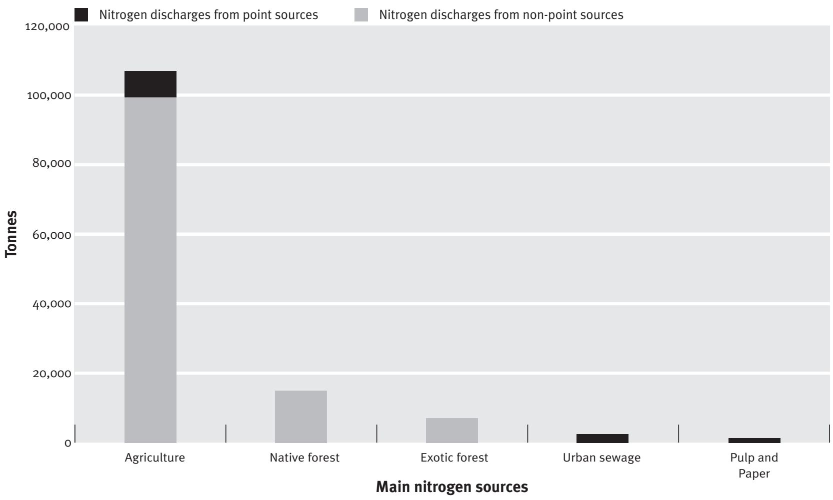
Where these pollutants are discharged from specific sites (e.g. meatworks, dairysheds, piggeries), they are referred to as **point source** pollutants. Where they wash into streams as run-off from land surfaces (e.g. paddocks, roads, forests) they are referred to as **non-point source** pollutants. Surveys in the 1970s showed that agricultural run-off accounted for 58 percent of the biochemical oxygen demand ($BOD_5$) in freshwater, 45 percent of total phosphorus (TP), and 88 percent of total nitrogen (TN) (McColl and Hughes, 1981; McColl, 1982). A decade later, agricultural non-point sources were still the main cause of water pollution, accounting for 75 percent of the total nitrogen loading to surface waters (see Table 7.6 and Figure 7.9).

**Table 7.6**
**Estimated yearly nitrogen loadings to New Zealand surface waters.**

| | |
|---|---|
| **Non-point sources** | **122,000 tonnes** |
| *Agriculture* | *100,000 tonnes* |
| *Native forest* | *15,000 tonnes* |
| *Exotic forest* | *7,000 tonnes* |
| **Point sources** | **10,200 tonnes** |
| *Agriculture* | *7,000 tonnes* |
| *Sewage/urban* | *2,400 tonnes* |
| *Pulp and paper* | *800 tonnes* |

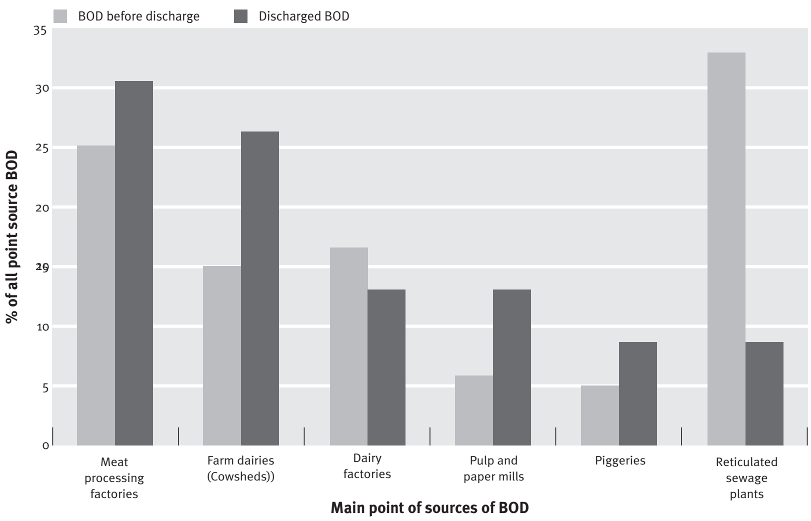
*Source: Cooper, 1992*

**Figure 7.9**
**Estimated yearly nitrogen loadings to New Zealand surface waters**




*Source: Cooper, 1992*

**Figure 7.10**
**The major point sources of organic pollution ($BOD_5$) in surface water**




*Source: Hickey and Rutherford (1986)*

### *Point source discharges into surface water*

Ten years ago, meatworks and dairysheds were particularly important point sources of organic waste pollution (see Figure 7.10). Today, meatworks have declined in number, but dairysheds have increased, with milk production rising by 23 percent through the decade 1986-1996. Production from dairy factories and from pulp and paper mills has also increased. It is difficult to estimate the significance of these changes because the treatment and disposal of waste from all the major point sources has improved since 1986 (see Box 7.5).

Other point sources associated with agriculture include stockyards, holding pens, rendering plants, wool scourers, tanneries, canneries, and fertiliser plants. On some farms they also include rubbish dumps, sheep dips, and storage sites for pesticides, fertilisers and fuels.

### *Non-point source run-off into surface water*

Most non-point source pollution is caused by rainwater washing organic matter, sediment and nutrients from land surfaces into streams, rivers and lakes. Non-point source pollution also occurs when nutrients or other contaminants are leached through the soil into groundwater. Apart from urban stormwater run-off, most of the significant non-point sources are associated with agriculture simply because agriculture dominates the land surrounding most streams. A decade ago, about 30 percent of New Zealand's pastoral land (more than 4 million hectares) was estimated to be adversely affecting water quality through run-off (Wilcock, 1986).

**Box 7.5**

### *Tackling the point sources*

In most New Zealand rivers, pollution from point sources has declined noticeably. This is partly because the total number of point sources has fallen, and partly because waste treatment processes have improved. For example, 200 or so dairy factories operated in 1970. Today they have been replaced by just 30 very large dairy plants whose waste disposal systems are more sophisticated (Barnett *et al.*, 1994). One river that illustrates these trends is the 161-kilometre Waimakariri River which traverses Canterbury from the mountains to the sea. For more than a century the lower reaches and tributaries of the river have been used for point source waste disposal. Thirty years ago one tributary, the Otukaikino Creek, received wastes from two freezing works, a wool scour, and a soap factory. Another tributary, the Kaiapoi River, received point source discharges from two fellmongeries, a flour mill, a woollen mill, a freezing works, a milk powder factory and many septic tanks from Rangiora and Kaiapoi townships. Many small milking sheds also discharged waste into the river's tributaries. Since that time, most of the large discharges have ceased and the few that continue have greatly improved the quality of their effluent. From 1956 to 1994, the amount of organic matter in the river ($BOD_5$ ) fell by an estimated 80 percent (Canterbury Regional Council, 1995) Many other regions can report similar trends, though the gains are sometimes masked by increasing pollution from non-point sources (e.g. dairy pastures).

The difficulties in controlling river pollution are highlighted by the Bay of Plenty's Tarawera River, sometimes nicknamed 'the black drain'. Despite a large improvement in point source discharges of toxic substances, the river's organic matter pollution has worsened–and not just because of farm run-off. The Tarawera is not a typical example of New Zealand's rivers. Besides receiving discharges from surrounding dairy farms, and stormwater and sewage from the town of Edgecumbe, the lower part of the river also receives effluent from the pulp and paper industry. The effluent comes from the Tasman and Caxton mills, their nearby geothermal power plant, and the mill town of Kawerau. The mills discharge more than 160 million litres of industrial waste every day, including organic matter, tannins, lignins, resin acids and organochlorines (e.g. dioxins). The geothermal plant adds sulphates and heavy metals to the mix. The water below the discharge points is significantly discoloured and gives off an odour typical of chemical pulp and paper mill discharges. Compared to its upper reaches, the lower part of the river has low concentrations of dissolved oxygen (often falling below the minimum guideline for aquatic life of 5 $mg/m^3$), elevated temperature, more chemical and microbial contaminants, little or no submerged vegetation, a restricted range of fish and invertebrates, and a highly mobile pumice river bed seething with oxygen-sapping micro-organisms (Bay of Plenty Regional Council, 1995).

For four decades, the Tasman mill was subject to special legislation, the Tasman Pulp and Paper Enabling Act 1954, which gave it immunity from water and soil legislation, the Health Act, and any other laws prohibiting water pollution or nuisance effects from industrial waste. Prior to 1971, all the mill's discharges were untreated. Trout vanished from the lower Tarawera within months of the mill's opening. Through the next two decades other fish kills occurred from time to time. Tannins in the sewage discoloured the river, giving it the appearance of strong tea. Discharge limits were imposed in the 1960s, but were frequently exceeded. During the 1970s, the mill began to improve its discharge practices, principally by installing oxidation ponds. Between 1974 and 1981, the number of days on which excessive $BOD_5$ levels were recorded fell from 44 percent to 13 percent. However, the river quality was still below its permitted "D" classification and was unsuitable for livestock, irrigation, horticulture, domestic consumption and recreation.

In the past decade, millions of dollars have been spent at the Tasman mill to reduce the discolouration and organochlorine discharges (Ogilvie, 1995b). The organochlorines come from the mill's pulp bleaching process which, unlike many other mills, is still chlorine-based rather than oxygen-based. The geothermal plant has also reduced its toxic discharges. As a result, water clarity has improved, and laboratory analyses of water samples can find no evidence of toxicity (Bay of Plenty Regional Council, 1995). However, set against these improvements is the fact that organic matter discharges from both the Caxton and Tasman mills have increased, particularly since Caxton opened a new treatment plant in 1992. Dissolved oxygen is now lower than it was in 1985. As a result, the river's ability to support balanced invertebrate populations has fallen in recent years, with the sensitive and important mayfly and caddisfly species declining both downstream and upstream of the discharges (Bay of Plenty Regional Council, 1995).

It will be some time before the Tarawera loses its 'black drain' tag, but progress has been made and more is expected now that the Tasman mill's special legislation has expired and all discharges into the river are under the jurisdiction of the Bay of Plenty Regional Council. The council has developed a management plan for the whole catchment which targets not only point source discharges but also dairy farm run-off and land drainage. These non-point sources have reduced dissolved oxygen in some of the region's streams and rivers to concentrations as much as five times lower than those in the lower Tarawera. So, even in the Tarawera catchment, where the battle against point source discharges is far from over, attention is shifting to the far larger problem of controlling non-point pollution sources.

The **organic matter** in non-point source pollution comes mostly from farm animals. Faecal contamination of surface waters is most severe in areas of high cattle density (e.g. dairy farms). In 1995, the faeces from New Zealand's 9.3 million cattle, 49.1 million sheep and farm goats, and 1.2 million deer produced a waste load equivalent to a human population of 153 million people, up from 142 million just two years earlier. The vast majority of this came from cattle whose total $BOD_5$ loading was about 9,000 tonnes per day in 1995, compared to about 1,600 tonnes from the more numerous sheep and goat population. Much of this waste entered the soil and was re-absorbed by plants, some was leached into groundwater, and a significant amount was washed into streams, rivers and lakes.

The **sediment** in non-point source pollution comes mostly from deforested slopes that have been converted to pasture. Rivers which drain pastoral catchments tend to have sediment loads 2 to 5 times greater than those flowing from forested catchments. Where the bedrock is particularly erodible, the sediment loads may be even greater. The impacts of deforestation are particularly great during the removal of vegetation, when sediment loads in streams and rivers may increase 100-fold. Sediment loads generally decline as vegetation is re-established, but this may take 5–10 years.

The quality of the pasture growth also affects sedimentation rates. Dense pasture growth has relatively low sedimentation rates (but may have high concentrations of unabsorbed fertilisers and animal waste), while sparser grass cover has high sedimentation rates (but lower concentrations of fertiliser and animal waste). Urban land development and forest harvesting operations can also cause significant sedimentation of surface waters, but affected areas are small compared to the area of eroding farmland.

The **nutrients** in non-point source run-off come from animal waste, the soil itself (which contains nitrate from the nitrogen-fixing clover) and fertilisers which have been applied to the soil. On land of a given slope and soil type, the rate of nutrient run-off is affected by the density of vegetation cover and the density of animal populations. In the experimental catchments at Purukohukohu, where no nitrogenous fertiliser had been applied, pasture lost about 15 times more phosphorus (P) and about 3 and 10 times more nitrogen (N) than the native and pine forest catchments respectively (see Table 7.7). In general, nitrogen and phosphorus losses were similar from the two forested catchments.

#### *Groundwater contamination*

Although groundwater is vulnerable to contamination from many sources, including chemicals leaching from urban and industrial sites (e.g. landfills), most groundwater runs beneath agricultural land where it is at risk of contamination from nitrate-nitrogen, faecal matter, and pesticides. Nitrate-nitrogen is the most widespread of these contaminants. It enters soil from animal wastes (predominantly urine), nitrogen-fixing legumes (e.g. clover), and fertilisers, and seeps into groundwater more easily than other nutrients. Each year an estimated 30–70 kg per hectare can enter groundwater from dairy pastures (Burden, 1982). In some situations this may reach 100 kilograms of nitrate-N per hectare per year (Selvarajah, 1994). Most of this groundwater ends up in rivers, lakes, or estuaries.

### *Changes in Agricultural Pressures on our Water Environment*

Relatively depressed economic conditions during the 1980s and early 1990s may have temporarily reduced some of the agricultural pressures on water while increasing others. Several studies have reported that farmers responded to the combined effects of economic restructuring, removal of subsidies, rising interest rates and declining sheep and beef export returns by cutting their expenditure on farm maintenance and development (Wilkinson, 1994; Wilson, 1994; Smith and Saunders, 1996).

Reduced maintenance meant less fertiliser to run off pasture and leach into water, but also a deterioration in hill pasture cover and a reduction in erosion control works. Between 1985 and 1988, phosphate fertiliser use fell by about 45 percent, but has since picked up. Of greater significance is the increased use of nitrogen fertiliser (see Figure 7.11). In recent years, this has soared to record levels as dairy farming has expanded into new areas, particularly in the South Island, and intensified in established areas, mostly in the North Island.

The growing cattle numbers themselves also increase the pressures on waterways from animal waste and stream bank damage. Because a cow's excreta has a $BOD_5$ loading about 30 times greater than that of a sheep, the nation's total livestock $BOD_5$ has actually risen in recent years, despite the fall in sheep numbers. The expansion of dairying is part of a broader change in the composition of our livestock populations. This change is reducing pressure in steep catchments but increasing it in lower lying areas.

As sheep numbers decline in steeper pasture lands native vegetation is regenerating in some areas and pine forests are being planted in others. This will have the long-term effect of reducing erosion rates, run-off, sedimentation, and flood flows. About 70,000 hectares of exotic forest are now being planted each year, 80 percent of it on marginally productive pasture land (e.g. hill country). If planting continues at this rate into the next century, the area of unforested agricultural land will decrease by almost 4 percent, from around 14 million hectares to about 13.5 million. At present, we have no estimate of the area of regenerating native vegetation.

In contrast to non-point source pollution, point source discharges from farms appear to have improved considerably in the past two decades, as have point source discharges from most industries. A big improvement occurred in the 1970s, as farmers began using either two-pond treatment systems or land irrigation to dispose of their waste water. Irrigation returns waste nutrients, such as nitrogen, phosphorus and potassium, to land rather than water. However, too much irrigation can cause nutrients to wash off into streams or leach into shallow groundwater so some local authorities have imposed limits on waste water irrigation.

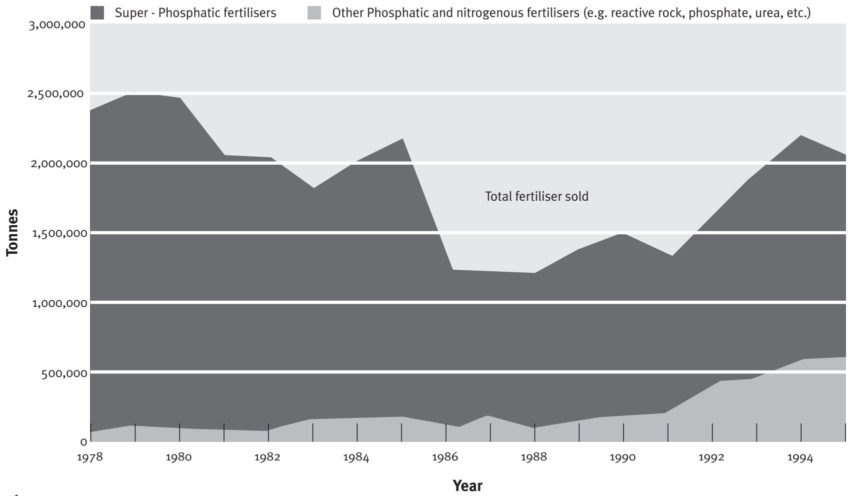
In a two-pond system, the effluent is discharged into streams or rivers after passing through an anaerobic pond and then an aerobic, or facultative, pond. The system is designed to remove organic matter ($BOD_5$) from waste water but it does not remove nutrients or reduce their impact on aquatic life (Hickey *et al.*, 1989; Rutherford *et al.*, 1992; Bolan, 1996).

**Table 7.7**
**Nutrient losses in run-off to streams in the Purukohukohu experimental catchments.**

| | Nutrient losses in run-off from: (kilograms/hectare/year) | | |
|---|---|---|---|
| **Nutrient indicators** | **Pasture** | **Pine forest** | **Native forest** |
| *Total (Kjeldahl) nitrogen*[1] | 10.76 | 0.76 | 0.83 |
| *Nitrate nitrogen ($NO_3$-N)* | 1.19 | 0.55 | 2.84 |
| *Total nitrogen*[2] | 11.95 | 1.31 | 3.67 |
| *Dissolved reactive phosphorus* | 0.37 | 0.04 | 0.02 |
| *Total phosphorus* | 1.67 | 0.1 | 0.12 |

*Source: Cooper and Thomsen (1988)*
[1] *Total Kjeldahl nitrogen (TKN): organic nitrogen and ammonia*
[2] *Total nitrogen (TN): Total Kjeldahl nitrogen + nitrate nitrogen + nitrite nitrogen*

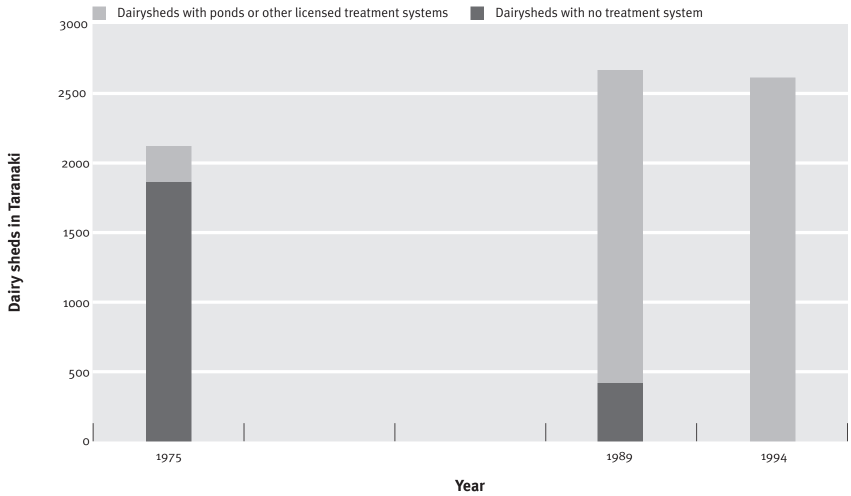
**Figure 7.11**
**Phosphate and nitrogen fertilisers sold by major fertiliser works**




*Source: Ministry of Agriculture (1996)*

**Figure 7.12**

**Improving dairyshed discharges in Taranaki**




*Source: Taranaki Regional Council (1996)*

Furthermore, even though it removes 95 percent of the $BOD_5$ in dairy waste, the sheer volume of waste means that pond discharges of $BOD_5$ often still exceed a stream's assimilative capacity (Barnett *et al.*, 1994).

From 1972 to 1982 the percentage of farmers disposing untreated dairyshed waste into open drains declined from 50 percent to under 30 percent and the percentage using pond treatment or spray irrigation rose from 13 percent to 36 percent (McColl, 1982). More recent national figures are unavailable, but data from some regional councils show that the improvements continued into the mid-1990s.

In Taranaki, for example, only 250 (12 percent) of the 2,100 or so dairysheds had pond treatment systems in 1975, and only 39 of these were licensed (see Figure 7.12). However, since the early 1980s, the council has required on-farm treatment of dairyshed wastes and has issued licenses for those which meet the required discharge standards. By 1996, all of Taranaki's 2,593 dairysheds were licensed, with 60 percent disposing their waste to treatment ponds and 40 percent disposing it to land through irrigation (Taranaki Regional Council, 1996). About half the 6,000 or so dairy farms in the neighbouring Waikato region use treatment ponds, with most of the remainder using irrigation systems.

## Urban Pressures

Although agriculture is New Zealand's dominant land use, most of us are town and city dwellers. In fact, 85 percent live in urban areas of 1,000 or more people. This concentration of about 3 million people and their pets, vehicles, homes, gardens, workplaces, schools, swimming pools, sports fields, and shopping centres into some 730,000 hectares, places heavy pressures on local waterways and aquifers. The populations tend to be concentrated in areas which are prone to water shortage (e.g. Auckland, Nelson, Hawke's Bay, Canterbury) and they also tend to be located on estuaries, harbours and river mouths most of which have been heavily modified by development, recreation and waste disposal. All of our large coastal cities, for example, are situated on estuaries (i.e. Invercargill, Dunedin, Christchurch, Nelson, Wellington, Lower Hutt, Napier, Tauranga, Auckland and Whangarei).

The main pressures which urban populations exert on water are: **consumption** for household, garden, and industrial use; pollution from **sewage** and **stormwater** (and also, in some cases, from leachate and run-off draining from landfills and other contaminated sites); and **degradation** of aquatic ecosystems through drainage, channelling, land reclamation, infilling, construction, roads, causeways, and shoreline developments around harbours, estuaries, wetlands and river mouths.

### *Consumption pressures*

All urban centres have public water supplies. In areas prone to low rainfall, consumption pressures on those supplies can sometimes be very intense (e.g. Auckland, Napier, Hastings, Christchurch). Total urban and industrial water consumption is estimated at 470 $Mm^3$ (or 470 billion litres) each year (see Table 7.4). Surface water provides 60 percent of this, and groundwater supplies 40 percent. Daily water use in most main urban areas in the late 1980s ranged from around 180 litres per person to over 900 litres per person (see Table 7.8).

Water use peaks in summer and is mostly for domestic purposes, though commercial and industrial uses are also significant, as are reticulation losses from taps, pipes, tanks and reservoirs (see Figure 7.13). In drier areas, such as Renwick (Marlborough), maximum daily demand can reach 2,000 litres per person during the summer. The increased seasonal demand for water puts pressure on surface water resources, which are usually at their lowest levels in summer. It may also stretch the ability of the supply system itself to meet demand. In many places, restrictions have to be placed on the use of water in gardens during the summer.

Until recently, demand for water was increasing steadily throughout New Zealand. From 1970 to 1990 the amount used by Wellingtonians and Aucklanders increased by 25 percent and 32 percent respectively (see Figure 7.14). However, since the Auckland water crisis of 1993, and the adoption of water conservation strategies, Auckland's water use has reverted to early 1980s levels. The average Aucklander now uses around 300 litres per day, 21 percent down on the 1988 figure of 380 litres per day.

### *Urban pressures on water quality*

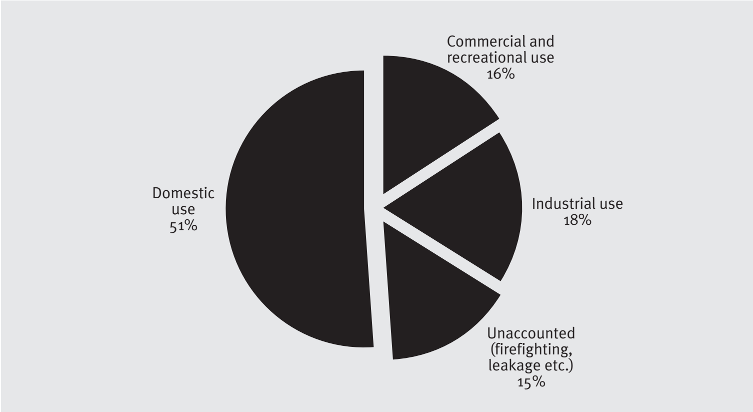
The most severe urban pressures on water quality in streams, rivers and coastal waters are from the point source discharge of **sewage** and the non-point source discharge of **stormwater** run-off. According to the water quality experts surveyed by Sinner (1992), the impacts on surface water from these pressures rank second and third in severity after agriculture. Most sewage is now piped through treatment installations to remove or reduce pollutants before discharge. Treatment systems vary, however, and some are also vulnerable to flooding and stormwater infiltration. Stormwater quality is determined by the road debris and other contaminants it picks up when flowing from land to water. Pollution from motor vehicles through oil leakage and dust contamination has a significant impact on urban stormwater quality, particularly in Auckland which has large volumes of road traffic passing by estuarine waters (Auckland Regional Council, 1995).

**Table 7.8**
**Daily water use in some cities and districts.**

| Locality | | Average daily water use (litres per person) |
|---|---|---|
| *North Island* | *Auckland* | *380* |
| | *Taupo* | *610* |
| | *Gisborne* | *180* |
| | *Opotiki* | *500* |
| | *Kapiti Coast* | *670* |
| | *Wellington* | *550* |
| *South Island* | *Nelson* | *190* |
| | *Renwick* | *760* |
| | *Greymouth (metered)* | *400* |
| | *Greymouth (unmetered)* | *600* |
| | *Christchurch* | *450* |
| | *Dunedin* | *500* |
| | *Invercargill* | *360* |

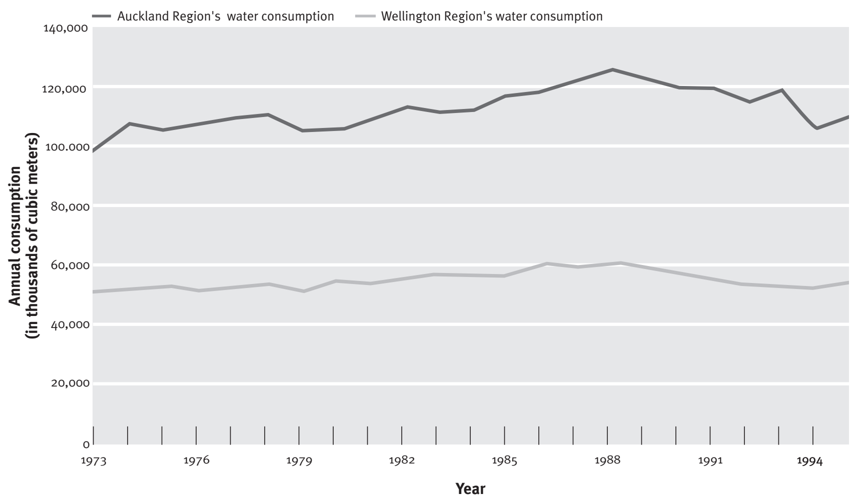
*Mosley (1993); Watercare Services (Auckland); Wellington City Council*

**Figure 7.13**
**Main uses of public water supplies in the Auckland urban area**




*Source: Watercare Services (Auckland) (1994)*

**Figure 7.14**
**Water use in the Auckland and Wellington regions, 1973 to 1995**




*Source: Watercare Services (Auckland); Wellington Regional Council*

The quality of urban drinking water is a special case. Where possible, public water supplies are drawn from rivers, lakes, built reservoirs or deep aquifers that are not exposed to agricultural and urban waste. To further reduce the possibility of contamination, supplies are hygienically treated to remove micro-organisms, potentially harmful chemicals and sediment. Variations in drinking water quality are more often caused by variations in treatment method than by pressures from the surrounding environment.

*Sewage point source pressures*

Households and workplaces discharge a vast amount of human excreta, detergents and other substances into the nation's sewers. All towns with populations of 5,000 or more have a reticulated sewerage system which pipes everybody's waste water to a common discharge point. The vast majority of this sewage ends up in rivers or the sea, with only a small percentage being disposed of on land.

Human waste has a $BOD_5$ loading of about 74 grams per person per day (Vanderholme, 1984; Hauber, 1995). This means that in 1950, when the New Zealand population numbered 1.9 million people, the bacteria working to decompose their waste would have removed 140 tonnes of dissolved oxygen from the water each day. By 1996, with a population of 3.6 million, this daily $BOD_5$ loading from human wastes has nearly doubled to about 266 tonnes. Fortunately, these days most of this decomposition occurs at sewage treatment plants rather than in natural waterways. In 1950, New Zealand had only about five sewage treatment plants. Today we have more than 220, and about 80 percent of our households are connected to them. This means the total $BOD_5$ loading to waterways from human waste has probably declined in 45 years to less than 50 tonnes per day, though precise figures are not available.

The sewage pollutants of greatest concern are rotting organic matter (measured as $BOD_5$), disease-causing micro-organisms (measured by counting faecal coliform bacteria), excess nutrients (particularly nitrogen and phosphorus) and suspended solids. These can be harmful to aquatic ecosystems and to humans who accidentally eat contaminated shellfish, or, in badly polluted areas, swallow the water. Sometimes, too, ammonia from urine may reach concentrations that are toxic to fish (Hoare and Rowe, 1992).

Sewage treatment systems can be classified as primary, secondary or tertiary according to their ability to remove progressively smaller pollutants. **Primary** treatment removes suspended solids by filtering or milliscreening them or allowing them to precipitate to the bottom of settling ponds. **Secondary** treatment reduces the organic matter and nutrients in primary-treated effluent by allowing micro-organisms to consume and decompose them in oxidation ponds or wetlands. **Tertiary** treatment uses various methods, including chemical treatment and fine filtering, to reduce the nutrients and micro-organisms in secondary treated effluent.

In general, New Zealand's sewage treatment systems appear to be very good at reducing the organic matter, suspended solids and faecal coliform bacteria in sewage, but are less successful at removing the nutrients. A 1992 survey of 17 sewage plants revealed that $BOD_5$ was reduced by a factor of 91 percent on average (though the actual decreases ranged from 30 percent to 99 percent, depending on the system), suspended solids by 86 percent (ranging from 53 percent to 99 percent), and faecal coliforms by 98 percent (ranging from 89 percent to 100 percent) (Hauber, 1995). However, the average reduction in nitrogen was only 31 percent (ranging from an actual increase of 12 percent to a maximum decrease of 77 percent), and that of phosphorus was just 24 percent (ranging from a 9 percent increase to a 57 percent decrease). As a result, sewage is a significant source of nutrient inputs to many harbours. In Whangarei, for example, which has relatively few dairy farms in the harbour catchment, sewage is the main nitrogen source (see Figure 7.15).

Some of the older sewerage systems are prone to developing cracks in pipes and joins, often caused by tree roots or earth tremors. This can lead to sewage escaping or to stormwater infiltrating the sewerage system, causing it to flood. Local authorities are steadily repairing and upgrading these older systems, but the cost of doing so makes the process a gradual one.

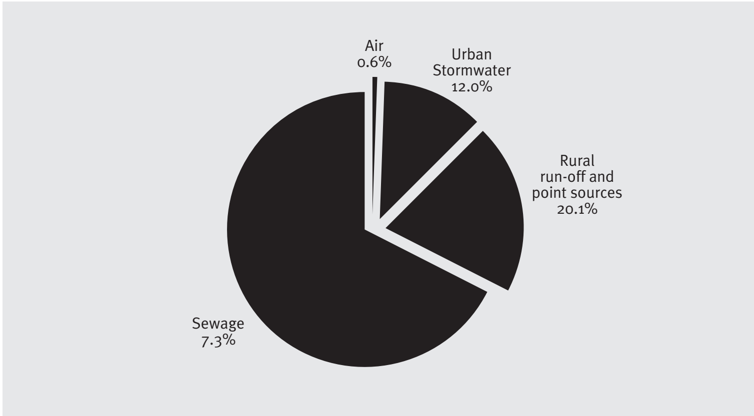
National data on our sewerage systems are only now beginning to be compiled after a gap of over a decade (Woodward-Clyde, 1996). The last national survey was 15 years ago (Ministry of Works and Development, 1981). Up until then local authorities had been surveyed every five years for information on their sewerage systems. The surveys came to end when the Ministry of Works and Development was dissolved in the government restructuring of the mid-1980s.

The 1976 and 1981 surveys showed that just over 60 percent of the population were connected to sewerage treatment plants. Around 17 percent of the population had their sewage discharged untreated, mostly into the sea, and around 20 percent were not connected to a sewerage system at all, but relied on septic tanks (Ferrier and Marks, 1982). In the intervening decade, the percentage connected to treatment plants is believed to have risen to about 80 percent, while those discharging untreated sewage are just a few percent. Some 15–20 percent of people probably still use septic tanks.

Septic tanks are used in small towns, rural communities and beach settlements. They are an efficient form of sewage treatment but when they malfunction contaminants can leach into nearby waterways (Higgins, 1991). This can cause problems in enclosed groundwaters and shallow ponds and lakes, but is not a problem in aquifers with a large throughput of groundwater. For example, it has been estimated that septic tank discharge into the gravels west of Christchurch would be rapidly diluted one million-fold by the time it had flowed 5 metres below the water table and 20 metres down-gradient (Sinton, 1982).

To get some information on the changes that were occurring in sewage treatment, the magazine *Terra Nova* in 1991 commissioned a survey of local authorities serving populations greater than 20,000 (Shields, 1991). Of the 46 councils approached, 42 (90 percent) replied. In total, they gave information on 74 sewerage systems which process the wastes of more than 2.5 million people (three quarters of the total population). The systems varied from 'state-of-the-art' facilities (e.g. Whangarei and Rotorua) to very basic disposal of raw sewage through ocean outfalls (e.g. Wellington and Napier).

**Figure 7.15**
**Sources of nitrogen inputs into the Whangarei Harbour**



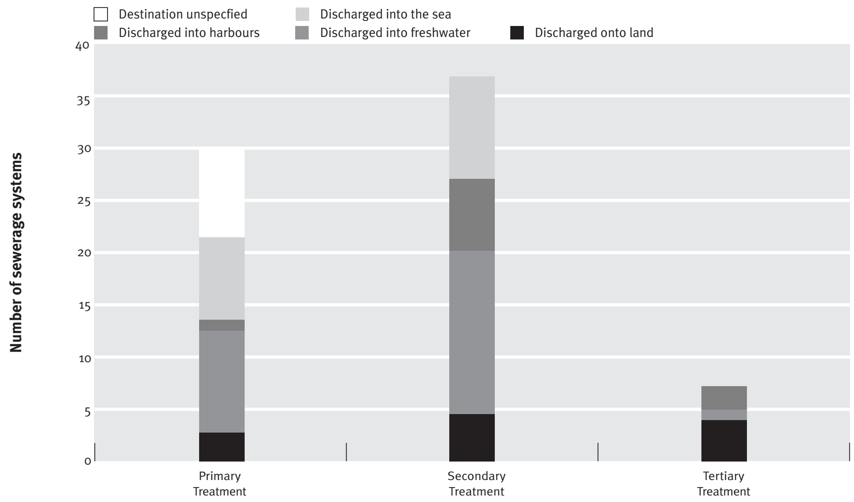

*Source: Williamson (1991)*

Seven (9 percent) of the sewerage systems provided tertiary treatment. Half provided secondary treatment and 30 (41 percent) provided primary treatment. A number of authorities indicated that they were upgrading their systems. The authorities were also asked about the final destination of the treated effluent. Of the 65 sewerage systems for which this information was given, 18 discharged into the sea, 27 discharged into rivers or, in one case, a lake, 18 discharged into estuaries or harbours, and 10 discharged to land (see Figure 7.16). Land disposal was used by four of the seven tertiary treatment systems but by very few of the primary and secondary treatment systems (Shields, 1991).

Although this survey covered sewerage systems that serve three quarters of the population, it missed the majority of the nation's sewerage systems. Two thirds of our treatment plants serve communities with populations of less than 20,000. Two recent surveys have attempted to get a more comprehensive view of sewage treatment. Greenpeace New Zealand (1996) received 40 replies to its survey of 75 local authorities (a 53 percent response rate). A total of 69 treatment plants were described but, because the response rate was low and the survey was not restricted to communities above a certain size, interpretation of the results is difficult.

**Figure 7.16**

**Sewage treatment and disposal in communities of more than 20,000**




A much more successful result was obtained from a survey of 74 local authorities which was commissioned by the New Zealand Wastewater Association with funding from the Ministry for the Environment's Sustainable Management Fund (Woodward-Clyde, 1996). Responses were obtained from 57 of these (77 percent), half of whom also replied to a second, more detailed, questionnaire, providing information on 242 of the nation's 258 sewerage systems. The database is still being developed and, at the time this report was being prepared, only limited analyses had been conducted on it. The unpublished results showed that many small communities discharge their sewage to rivers and lakes (64 percent compared to only 37 percent of the larger communities in the *Terra Nova* sample) and to land (28 percent compared to 14 percent), while very few discharge to sea (5 percent compared 25 percent) and harbours and estuaries (3 percent compared to 25 percent). This appears to reflect the New Zealand settlement pattern in which most of the larger communities are located near the coast and most of the smaller ones are located near rivers or lakes.

Apart from household and community sewage, a considerable amount of wastewater is discharged by factories and power plants. Some of these discharge into the community sewerage system while others discharge independently into rivers or coastal waters.

Industrial discharges into the sewerage system account for an estimated 9 percent of sewage wastewater, though it can be as high as 25 percent in some cities and nil in others (Hauber, 1995). Most large companies discharge their wastes separately under a permit from the local council.

Among the largest industrial dischargers are the Tasman Pulp and Paper Mill, which sends 160 million litres of treated wastewater into the Tarawera River each day (see Box 7.5), and the Kinleith Pulp and Paper Mill which discharges over 110 million litres per day into a tributary of the Waikato River. By comparison, the combined daily discharges from Wellington and Lower Hutt come to around 100 million litres, those from Christchurch total 140 million litres, and those from the Mangere sewerage plant, which processes the wastes of 70 percent of the Auckland population, come to nearly 230 million litres.

Most community and industrial discharges end up in the sea. In 1976 and 1981 60 percent of the population had their sewage discharged into estuaries, harbours or the ocean. The more recent surveys do not give population estimates, but it is likely that the figure has not changed markedly. A 1982 survey identified at least 52 coastal discharges, a third of them industrial (Abbott and Leggat, 1982), while a review three years later listed 32 'major' outfalls (i.e. discharging more than 1,000 litres per second) of which only seven were industrial (Williams, 1985).

No recent statistics on coastal outfalls have been compiled. Outfall pipes are a visible, and often controversial, means of disposing of wastewater, particularly where they discharge on the shoreline, near swimming or shellfish gathering areas, or in semi-enclosed estuarine waters (Abbott and Leggat, 1982; Smith *et al.*, 1985). In estuaries and harbours with restricted water circulation, outfalls have caused pollution or deoxygenation problems (e.g. Avon-Heathcote, Manukau, Waimea Inlet and Nelson Haven, upper Whangarei Harbour and the Otamatea River estuary). The Moa Point and Pencarrow outfalls at Wellington Harbour have also caused problems and rendered the harbour's shellfish inedible.

Most of these problems are now being addressed through better effluent treatment or new disposal systems. For carefully-sited, long, deep, outfalls, however, most research indicates that the sea's dispersal powers quickly dilute any contaminants (Smith *et al.*, 1985). The impacts are greatest in the immediate vicinity of the outfall and become undetectable within half a kilometre.

Incidents of severe river or coastal pollution from sewage have declined markedly in recent decades as treatment systems in most areas have improved, and more stringent environmental requirements have caused local authorities to look towards land disposal systems. An informal survey of regional councils in 1992 found that most water management officials considered sewerage systems and other point source discharges within their regions to be under adequate control (Hoare and Rowe, 1992). Although point source pollution of the lower reaches of some rivers was considered a problem, this was more often attributable to accidents or uncontrolled discharges rather than inadequate treatment systems.

Most regional water managers considered non-point source pollution from grazing animals as the number one cause of water quality problems, though urban stormwater was considered a main cause in some urban locations (Hoare and Rowe, 1992). Malfunctioning septic tanks can also cause non-point source pollution in some areas near enclosed waters, such as lakes (Higgins, 1991).

*Urban stormwater*

Because urban areas are largely paved, rainwater cannot be absorbed by soil and vegetation. To reduce the risk of flooding during storms, most towns and cities have stormwater systems which channel the rainwater into gutters and drainage pipes, eventually discharging it through outfall pipes into streams, lakes and coastal waters. This can be a significant source of pollution. In fact, urban stormwater is often similar in quality to secondary treated sewage (Jessen and Hawley, 1981; Melville, 1991; Williamson, 1991; Hoare and Rowe, 1992; Auckland Regional Council, 1995).

Pollution comes from the substances that are washed off the street and adjacent surfaces, and also from the accidental mixing of stormwater and sewage. Many sewerage systems are prone to stormwater invasion either through faulty pipework, illegal connections, or undetected past connections. Stormwater in a sewer can quadruple the volume of effluent, placing a heavy burden on treatment and disposal facilities, and reducing the effectiveness of treatment. If sewerage systems are flooded, untreated effluent can escape. In Auckland, stormwater can amount to 75 percent of the total quantity of sewage effluent and is a major environmental engineering problem for local authorities.

Contaminants that are washed off streets, construction and industrial sites, and other surfaces, include sediment, organic matter, nutrients, disease-causing organisms, and toxic substances ranging from oil products and contaminated dust from vehicle exhausts, to industrial chemicals (Williamson, 1991; Auckland Regional Council, 1995). Any of these may threaten water quality and aquatic life, or endanger the health of swimmers, other recreational water users and seafood gatherers and eaters. Stormwater is also a major source of marine debris, such as floating plastic, which is both unsightly and hazardous to marine mammals and birds (Island Care New Zealand Trust, 1995).

Stormwater that runs off construction sites can carry very high levels of sediment, particularly where the vegetation and topsoil are stripped beforehand. Sediment yields from small catchments that are undergoing construction throughout 100 percent of their area may be as high as in the most intensely eroding country of the East Cape (Williamson, 1991). A study of the Pauatahanui inlet near Wellington, for example, found that almost a tonne of sediment per hectare per month ran into the estuary from a catchment undergoing urban development (Curry, 1982). This was fifteen times greater than the sediment loss from a neighbouring non-urbanised catchment. When a flood struck, the sediment loss was seventy times greater in the urbanised catchment.

### Pressures from dams

Dams alter the flows of rivers and streams, and create barriers to fish movement. Large dams have flooded valleys, raised lake levels, and reduced the flows of some major rivers to residual trickles. Even small dams can be insurmountable obstacles to our native fish, many of which need to migrate to estuaries or the ocean in order to breed. New Zealand has thousands of dams, most of which are small water-supply dams on farms. However, more than 400 dams have storage capacities greater than 18,500 $m^3$ (18.5 million litres). They range in height from 1.8 metres to the imposing 118 metres of Benmore dam in the Waitaki headwaters. Some of these large dams were built to store water for irrigation, others for power generation, and others for domestic and industrial supply or floodwater control (Freestone, 1992).

The largest dams are for power generation. In fact, 98 percent percent of the water which is harnessed for human use in New Zealand is used to generate electricity (see Table 7.4). The controlled release of large torrents of water from dams provides the raw energy to spin the electricity-generating turbines at some 80 power stations around the country. These stations have power generating capacities ranging from 1,000 Megawatts (MW) at Clyde, to less than 1 MW at small stations operated by local electricity supply authorities.

The impact of a dam on river flows varies with the size of both the dam and the river. Most hydroelectric dams in New Zealand are 'run of the river' schemes, with enough storage for only a few hours or days of generation. This means they do not modify the seasonal flow patterns but may cause large day-night fluctuations in response to varying power demands. For example, daily flows in the Clutha River vary from 200 to 600 cumecs as the Roxburgh power station responds to changing demand for power. Such disturbance of the flow regime can affect river channel stability and reduce fish habitat and spawning areas.

Large dams have dramatically altered the flows of some of New Zealand's rivers and lakes. They include Otago's Clutha, Waitaki and Waipori rivers, and the North Island's Waikato River. Other rivers have been affected by diversions of water, such as Southland's Waiau River whose flow was halved when water was diverted to the Manapouri power station, and the Whanganui River in the central North Island. In the South Island's Waitaki River catchment, the diversion of flows into a system of canals and power stations reduced the flows in the Tekapo, Pukaki and Ohau rivers to 'residual' levels (see Figure 7.17).

Some natural lakes have had their levels artificially altered for electricity generation. They include Lakes Tekapo, Pukaki and Ohau in the Waitaki headwaters, Lake Hawea in the Clutha headwaters (which does not generate power directly but feeds into Lake Dunstan) and Lake Manapouri. The level of Lake Taupo is also controlled to help manage generation from the Waikato River. In some cases, natural features have been lost or degraded by flooding from the construction of artificial lakes (e.g. the Aratiatia Rapids and Orakeikorako Geothermal Field on the Waikato River, and the Cromwell Gorge on the Clutha River).

### Pressures from forestry

Forestry can exert pressure on water flows and water quality, though the area affected is relatively small and the negative effects are generally short-term. Tree felling and road or track construction can degrade stream and river quality by increasing the amount of sediment and nitrate-nitrogen ($NO_3$-N) that washes into water (O'Loughlin, 1994). Other nutrient concentrations in the water may also increase, such as potassium (K), magnesium (Mg), calcium (Ca), ammoniacal nitrogen ($NH_4$-N) and total phosphorus (TP) (Rowe and Fahey, 1991). These concentrations are reduced if narrow riparian (riverbank) strips of forest are retained, and they decline rapidly in the second year after replanting.

Although the scale of the hydrological impact depends on the area harvested, logging in moderate-to-high rainfall areas can cause a 60–80 percent increase in water run-off for three to five years after clearfelling and can raise flood peaks by 50 percent (Fahey, 1994). At present, the overall impact of forestry on water is likely to be positive. While about 20,000 hectares are harvested and replanted each year, a further 70,000 hectares of unforested land, much of it pasture, are converted to plantation forests. As discussed earlier, stream flows and sedimentation generally return to pre-harvesting levels within six to eight years of replanting, and pasture run-off generally falls by 30 percent to 50 percent within five to ten years of afforestation.

A more indirect impact of forestry is the effect of roading and vehicles on sedimentation and run-off into streams, and the impact of timber treatment chemicals at some contaminated sites where toxic substances have leached into streams or groundwater (see Chapter 8 for discussion of contaminated sites).

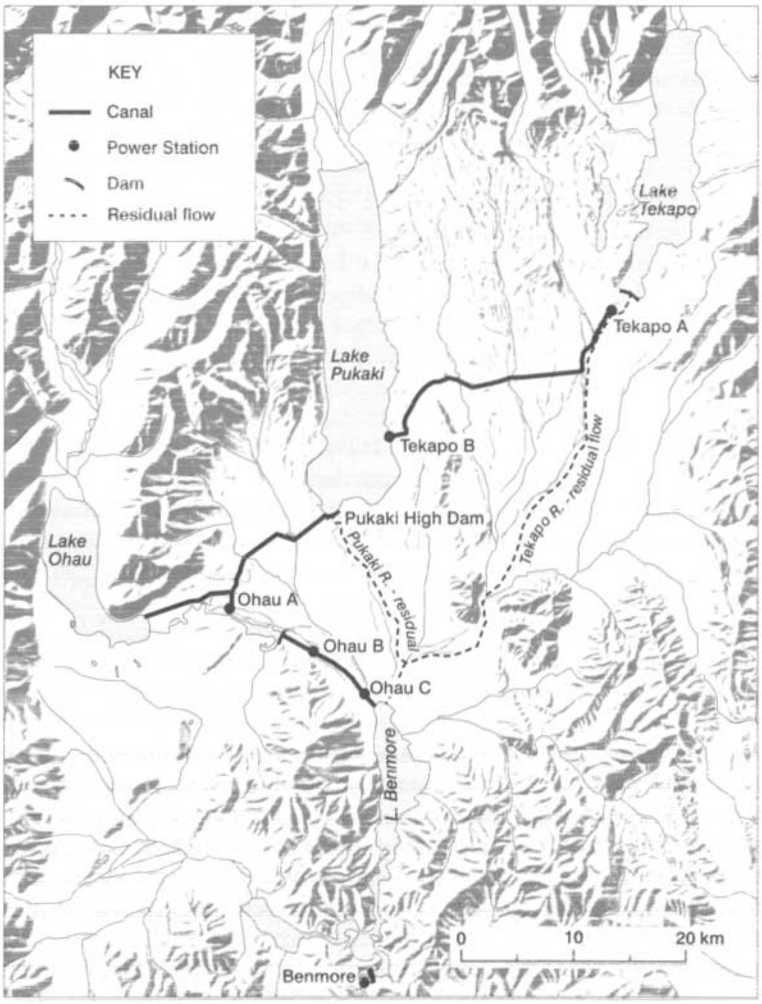
**Pressures from mining**

Mining can affect water in several ways. It can alter the flow pattern or volume of a stream by diverting or abstracting water, it can reduce the water table because of the need to remove groundwater from the mine shafts, it can change the amount of water, silt and sediment entering streams, and it can also increase their concentrations of processing chemicals (e.g. cyanide) and of heavy metals from ground rock. However, compared to the large impacts of gold and coal mining last century, the impacts of modern mining are better controlled and are confined to fewer locations (Glasby, 1991; Barker and Hurley, 1993).

For example, in the 1970s, the open-cast coal mines at Huntly discharged huge but unmeasured loads of silt to Lake Waahi and the Waikato River. These days each mine has a properly designed and maintained treatment system and the treated waste water is used for things such as spray irrigation of rehabilitated areas (Hoare and Rowe, 1992; Barker and Hurley, 1993). Every day, more than 6,000 cubic metres of waste water are discharged from the Huntly East underground mine into a nearby stream and wetland. Before being discharged, the water is held in settling ponds to allow silt and clay to settle out so that the water quality is within acceptable limits.

Gold mining, by its nature, tends to occur in areas where the rocks have a naturally high metal content (e.g. the Coromandel peninsula). When the rocks are exposed by other natural processes or land disturbance to oxygen and water, the metals within them can react chemically. The dissolved metals can then enter nearby streams and groundwater, causing them to become more acidic and to have elevated concentrations of metals. Mineral processing can speed up this process by exposing large mounds of finely ground

**Figure 7.17**
**Effects of the Upper Waitaki power scheme on river flows in the Mackenzie Basin.**




*Source: Cooper and Thomsen (1988)*

waste rock to air and water. The mining industry is well aware of this risk and has developed methods of dealing with it.

The standard process is to pump the finely ground rock (or tailings) as a slurry to a tailings dam where it settles and compacts. Contaminated water from the slurry collects in the tailings dam and in the drainage system beneath it and is then pumped to an on-site treatment plant where most of the heavy metals and other contaminants are removed. The clean water is recycled through the mine and any excess is discharged to nearby rivers. The stream water quality is virtually unchanged by the mining discharges.

However, failures are not impossible. The large tailings dam at the Golden Cross mine in the Coromandel area is built on land which, while stable on the surface, is moving beneath the surface. The dam's location was approved before the passing of the Resource Management Act. Investigations into the possible relocation of the dam are currently being undertaken. Although attempts are being made to stabilise the dam, it is not known how successful these will be in the long term. For example, there is a possibility that the drains beneath it could be breached by the earth movements and allow contaminated water to escape. Fortunately, the location problems at the Golden Cross mine appear to be the exception rather than the rule.

Wastewater discharged from the nearby open-cast Martha mine is actually cleaner than required and the mine's tailings piles are being restored to pasture (Barker and Hurley, 1993; Morrell *et al.*, 1995). The mine will be exhausted in a few more years and the whole site rehabilitated. Measures have been taken to minimise any long-term risks of leachate escaping from the tailings beneath the restored pasture (Mathias, 1991; Morrell *et al.*, 1995).

Arguably, the worst case of ongoing environmental damage caused by past mining is at another Coromandel site, the former Tui mine near Te Aroha where lead, copper and zinc ores were exploited and processed on site (Carter, 1982; Morrell *et al.*, 1995). Four years after the mine closed, water feeding from the Tui stream into the town's water supply was found to be contaminated with heavy metals leaching from the tailings heap. The stream was disconnected from the water supply and attempts were made to stabilise the tailings pile. Today, the site's 4-hectare barren dam contains over 100,000 cubic metres of very acidic, sulphide-rich, tailings whose drainage has severely contaminated local streams. No natural plant recolonisation has occurred at the site for more than 20 years and methods for revegetating it are being investigated.

Another mining impact on water is caused by the extraction of aggregate (e.g. sand and gravel) from rivers, beaches and the sea bed. Aggregate provides the raw material for constructing roads and buildings. Aggregate mining can change the natural character of beaches. Although this is not yet a cause for concern, it has the potential to cause problems in areas where there is a high demand for aggregate and no large river beds to supply it (e.g. Auckland's east coast).

**Pressures from Pests and Weeds**

Alien plants, animals and micro-organisms are an increasing source of pressure on water ecosystems. Among the better established freshwater invaders are the so-called oxygen weeds, *Egeria*, *Elodea* and *Lagarosiphon*, which can almost completely fill a pond, lake or stream, growing up to 6 metres, and crowding out native aquatic plants (Vant, 1987). In some cases, the extent of their growth has been extreme by world standards (Taylor, 1971). A fourth oxygen weed, *Hydrilla verticillata*, which may be the worst yet, has recently become established in four Hawke's Bay lakes (Champion and Clayton, 1995). Some introduced aquatic plants, such as water hyacinth *(Eichhornia crassipes)* and *Salvinia molesta*, are so invasive that they are now regarded as noxious aquatic weeds. Introduced weeds have established themselves in our largest lakes, including Lake Taupo, and our smallest wetlands, such as Pukepuke Lagoon in the Manawatu (see Box 7.8). In many cases, the aquatic plant invasions have been made easier by the clearance of riverbank forests (Howard-Williams *et al.*, 1987).

Boats and water fowl frequently spread weeds from one water body to another. The recent algal invader, water net (*Hydrodictyon reticulatum*), was first reported in an ornamental pond in Tauranga in 1986, having apparently arrived here with fish or aquatic plants imported by a local hatchery (Hall, 1994). It spread throughout the eastern Bay of Plenty and Rotorua Lakes and became widespread in the

Waikato River system. The floating mats formed by this lattice-like green algae spoiled swimming, boating and fishing, and smothered the habitat of desirable aquatic plants, invertebrates, fish, and water fowl. Its decay caused odour problems and oxygen depletion, and the mats clogged pump filters, stock ponds and drainage ditches (Hall, 1994). Fortunately, this particular invader did not come to stay. In 1995, after four years of grappling with the weed, Bay of Plenty Regional Council officials were reported to be baffled by its mysterious decline throughout the region (Ogilvie, 1995a). Spraying and suction dredge trials were cancelled and, a year later, the invader was deemed 'extinct'.

Several introduced fish are also listed as noxious species in the Third Schedule to the Freshwater Fisheries Regulations 1983, including rudd (*Scardinius erythrophthalmus*) and European or koi carp (*Cyprinus carpio*) (McDowall, 1990). Catfish (*Amerinus nebulosus*) is not designated as a noxious fish, but is regarded as a nuisance. The most widespread fish invaders, however, are probably brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*), which were introduced, with salmon (*Salmo* spp., *Oncorhynchus* spp.), as sports fish and are still protected as such because they provide a significant recreational resource. Trout have displaced or become predators of some of our native galaxiid fishes (see Chapter 9, Box 9.9). Another significant problem is the illegal distribution of fish by fishers.

Not all water pests are invaders. Some disease-causing micro-organisms, such as *Giardia*, *Cryptosporidium*, *Campylobacteria* and *Entamoeba* have probably always been part of the freshwater ecosystem and are only pests to people who swallow them in untreated water. Public water supplies are treated to remove these organisms. Although the quality of treatment varies, few cases of water-borne disease have been traced to public supplies.

Coastal waters may be more susceptible than land-based waterways to unnoticed invasions. One that has been noticed is *Colpomenia durvillaei*, a brown sac-like seaweed that was first seen in 1980 at Leigh and has since been found in Hawke Bay and in Wellington Harbour where it appears to be a very successful coloniser of space, potentially competing with native seaweeds (Nelson, 1994). A widespread animal import is the Asian date mussel, *Musculita senhousia*, which was first recognised here around 1980 and is apparently still spreading, forming mats on the sea floor over hundreds of square metres which smother other species.

The impacts of invaders cannot always be predicted. A seaweed called *Codium fragile tomentosoides* is known as the 'oyster thief' because of the damage it inflicted on North American oyster fisheries. It was first noticed here in 1975 but, 20 years on, has not become a serious weed problem. A widespread animal invader, the Pacific oyster (*Crassostrea gigas*), arrived in the Auckland area in the early 1970s and reached Cook Strait by 1980. It is now the basis of New Zealand's oyster farming industry (Nelson, 1994).

Most of the successful invaders come from cool water environments in the northern hemisphere. Warm-water invaders sometimes arrive here but are less successful in establishing themselves. In warm La Niña years (i.e. 1970-71, 1973-75, 1988-89) the East Australian Current, which bathes the northern part of the North Island, brings warm-water algae, protozoans and animals to north-eastern New Zealand, depositing them in rocky habitats where they usually die out when temperature and other conditions return to normal (Nelson, 1994).

In contrast to these natural invaders, the cool-water species often arrive from the Northern Hemisphere in human-made structures, particularly the ballast water of foreign ships. This phenomenon is not as well monitored in New Zealand as in Australia where scientists have identified with reasonable certainty at least 14 exotic species of fish, crustaceans, molluscs, worms, seaweeds and toxic algae that have arrived recently in ballast water (Jones, 1991). Ballast prevents ships becoming top-heavy when their cargo holds are light. Ships began using sea water for ballast, in place of sand and boulders, around 1880. Sea water ballast is known to contain many marine organisms, spores and eggs (Nelson, 1994).

Whaling ship ballast water last century is believed to have brought the red tidal seaweed, *Chondria harveyana*, from Tasmania to Porirua, and the brown algae, *Chnoospora minima*, from tropical waters to Port Underwood (Nelson, 1994). These species have not spread, but a more recent ballast water invader is spreading fast–the prolific Japanese seaweed, *Undaria pinnatifida*. This very large brown kelp which grows up to 3 metres in length was first discovered in Wellington Harbour in 1987 and has reached Timaru, Oamaru, Port Chalmers, Lyttelton and Picton. It is an important food species in Asia where it is grown in vast marine farms. Its impact in New Zealand is not known at this point, though its aggressive competition for space may crowd out some native seaweeds and the organisms that depend on them for food and shelter (Nelson, 1994). Ballast water was also a suspected, though unconfirmed, source of at least some of the toxic algae involved in recent shellfish poisoning episodes (see Box 7.12).

Marine invaders are known to 'hitch-hike' on natural rafts, such as large floating seaweeds, and on human-made rafts, such as cut logs, glass floats, fishing gear, plastic objects (e.g. bottles), ship hulls, oil rigs and other large structures such as the Maui gas platforms which were towed from Japan in 1975 and the clip-on pieces of the Auckland Harbour Bridge (Nelson, 1994). One of the tiniest invaders, a *Herpes* virus which kills pilchard fish by damaging their gills, swept through our coastal waters in 1995. It appears to have arrived in dead pilchards which were imported as longline fishbait from Australia. The same virus had already killed large numbers of Australian pilchards and may have reached Australia in fishbait imported from the Americas. The epidemic appears to have been short-lived.

**Pressures from Climate Change**

The water cycle is driven by temperature. Temperature determines the rate at which water evaporates from land and sea, the moisture carrying capacity of the air, the melt rate of polar ice and alpine snow, and the air pressure differences that give rise to the world's winds. Climate scientists therefore expect significant changes in climate patterns if greenhouse gas pollution continues to force up global temperatures (see Chapter 5).

Such temperature-induced climate changes could alter New Zealand's rainfall patterns and wind currents, speed up snow and glacial melt rates and water evaporation rates, and affect river flows, water temperatures and sea levels. Although Mosley (1988) found no apparent impact of rising temperatures on New Zealand river flows, possible future impacts include decreasing winter rainfall, and increasing summer rainfall in western and northern parts of the country (Ministry for the Environment, 1994). Increased coastal erosion may also result from rising sea levels (Hicks, 1990).

Despite the uncertainty over the likely impacts of global climate change on New Zealand's water, there is no doubt that the intermittent climate changes associated with the El Niño phenomenon do affect water supplies in different parts of the country (see Box 7.2). Because it is a recurrent natural phenomenon, El Niño-related climate change is generally considered as something quite separate from long-term global climate change. However, some scientists are now suggesting that the recent increase in El Niño events may itself be a symptom of global warming (Kerr, 1994; Wuethrich, 1995).

## THE STATE OF OUR WATER ENVIRONMENT

With all the pressures that people impose on New Zealand's surface waters and groundwaters, it is no surprise to find that water flows and quality have been widely affected. The natural character of many waterways has also been lost, something which is listed as a matter of national importance in the Resource Management Act.

Assessing the extent of these effects is difficult because most water data are collected by regional councils for local purposes and cannot be readily combined into national statistics. Some regional data have been used in preparing this chapter but other data have come from national surveys of rivers (Close and Davies-Colley, 1990; Smith and Maasdam, 1993; Maasdam and Smith, 1994), lakes (Livingston *et al.*, 1986; Burns, 1994) and drinking water (Mattingley, 1992; Nokes, 1993; Walker, 1994; Ministry of Health, 1997) as well as published scientific papers. Two particularly useful sources have been NIWA's review of agricultural impacts on water quality (Smith *et al.*, 1993) and the Hydrological Society's collection of papers on New Zealand's water resources (Mosley, 1992).

### The State of Our Rivers and Streams

New Zealand rivers have very high quality water by international standards. They contain lower concentrations of dissolved material, and are low in nutrients when compared with rivers overseas. The Pupu Springs which feed the Waikoropupu River near Takaka in the South Island have been described as possibly the clearest freshwater in the world (D.G. Smith, 1993). The cold, turbulent, springs with their blue-violet water are very popular with divers. NIWA scientists discovered why when they measured the water's clarity. Visibility was so good that mirrors had to be used to increase the viewing range in the 30 metres wide by 7 metres deep main basin. The results showed that the water is optically almost indistinguishable from distilled water, with a horizontal clarity of 62 metres and a vertical clarity, as measured by a Secchi disk, estimated at 70-75 metres—a measurement surpassed only at a few sites in Antarctic sea waters.

Water quality varies with the geology of the catchment, the volume of stream flow, and, most significantly, the pattern of land use and associated human activities. In contrast to many overseas rivers, for example, New Zealand rivers are very short and steep. This gives them less time and distance in which to gather contaminants but also gives them high levels of sediment from erosion. As a result most New Zealand rivers are nowhere near as clear as Pupu Springs. In fact, in most of them, the black disk used for measuring clarity becomes invisible well before the 2 metre mark (see Table 7.9).

River water quality is generally best in sparsely developed areas, including many South Island rivers and the headwaters of major North Island rivers, but it deteriorates in the lower reaches of most rivers, particularly those in the North Island. The national river surveys do not test water quality in the many small streams around the country, but a national review of other studies has found that many streams and creeks in lowland areas tend to have poor water quality (Smith *et al.*, 1993).

Particular water quality problems include faecal contamination from agricultural and urban run-off, excessive concentrations of nutrients, profuse aquatic plant growth, and high sediment concentrations. River survey results from the National Water Quality Network (NWQN) are summarised in Table 7.9 which shows the median or mid-point measurements from various water quality tests, as well as the range between the top 10 percent of water samples and the bottom 10 percent. Also included in the table are 'suitability thresholds' beyond which river water may be unsuitable for a specified use.

#### *Suspended solids*

Sediment from eroding land is the main source of suspended solids. It gives the water a turbid, or muddy, appearance, especially after heavy or prolonged rainfall on steep and deforested land. As a result, black disc visibility in half the rivers monitored by the NWQN is 1.3 metres or less, compared to the water clarity guideline requiring visibility of 1.6 metres or more for swimming and aesthetic quality (Ministry for the Environment, 1994). In the

**Table 7.9**
**Water quality in 77 rivers monitored by the National Water Quality Network, showing medians, ranges and suitability thresholds.**

| Parameter | Median[1] | Range 10%–90% | Suitability thresholds for particular uses | |
|---|---|---|---|---|
| *Suspended solids* | | | | |
| *Turbidity* | *2.15 NTU* | *0.45–31.3 NTU* | *No more than 2 NTU* | *Contact recreation (e.g. swimming)* |
| *Black Disc visibility* | *1.3 metres* | *0.17 - 5.10 metres* | *No less than 1.6 metres* | *Aesthetics* |
| *Biochemical oxygen demand ($BOD_5$)—grams of consumed oxygen per cubic metre of water* | *0.45 g/m³* | *0.15–1.2 g/m³* | *No more than 1–2 g/m³ (filtered water sample) No more than 3–5 g/m³ (unfiltered, total $BOD_5$)* | *Contact recreation Aesthetics* |
| *Dissolved reactive phosphorus (DRP)* | *4 mg/m³* | *2–20 mg/m³* | *No more than 15–30 mg/m³* | *Contact recreation Aesthetics Preventing algal growth* |
| *Dissolved inorganic nitrogen[2] (DIN)* | *Not known but likely to exceed threshold* | *Not known* | *No more than 40–100 mg/m³* | *Contact recreation Aesthetics Preventing algal growth* |
| *Nitrate - nitrogen ($NO_3$-N)* | *105 mg/m³* | *10–620 mg/m³* | *No more than 30,000 mg/m³ for 10,000 mg/m³ for* | *Stock water supply Human consumption* |
| *Ammoniacal nitrogen[3] ($NH_4$-N)* | *9 mg/m³* | *3–15.0 mg/m³* | *Suitability varies with temperature and pH* | *Aquatic ecosystems* |
| *Dissolved oxygen (DO)* | *100.3%* | *93–108.2%* | *No less than 80%* | *Aquatic ecosystems* |
| *pH (acidity/alkalinity)* | *7.68 (mildly alkaline)* | *7.23–8.19* | *Acceptable within the range 6 - 9 (i.e. slightly acidic to moderately alkaline)* | *Aquatic ecosystems Water supply* |

*Sources: Ministry for the Environment (1992; 1994), Smith et al. (1993), Smith and Maasdam (1994)*

1 *The median is a statistic which presents the middle score or measurement from all the samples. It is used in this instance to describe typical water quality. Unlike an average, the median is insensitive to changes in extreme values, making it a better indicator of normal water quality.*

2 *DIN is the sum of nitrate-nitrogen and ammoniacal nitrogen, but needs to be summed separately for each sample before the overall median can be calculated. Based on the nitrate-nitrogen component, however, DIN in more than half our rivers is likely to exceed the suitability threshold for contact recreation, aesthetic appreciation, and prevention of nuisance algal growth.*

3 *The toxicity of ammonia to aquatic life varies with pH and temperature. The threshold for long-term toxicity is a 4-day average concentration of 1,150 mg/m³ of ammonia at 20°C and pH 7.75.*

worst 10 percent of the sampled rivers, visibility was 17 centimetres or less, while in the top 10 percent it was 5.1 metres or greater (see Table 7.9).

### *Dissolved oxygen*

Dissolved oxygen decreases at night and increases during the day in response to the respiration and photosynthesis of aquatic plants. When the concentration of oxygen falls below 80 percent, aquatic life can become stressed. None of the NWQN rivers fell below the 80 percent level *at the time of measurement* and more than half the NWQN rivers were fully saturated, with dissolved oxygen levels of 100 percent or greater. Because monitoring occurred during the day, when dissolved oxygen levels are at their highest, it is not known how many rivers fall below the 80 percent level after dark.

### *Biochemical Oxygen Demand ($BOD_5$)*

Biochemical oxygen demand ($BOD_5$) in uncontaminated waters is generally less than 1 g/m³. Most of the NWQN river sites have $BOD_5$ concentrations well below this, indicating that these rivers are not polluted with organic material (Table 7.9). A guideline value of 2 g/m³ (for filtered water samples) is proposed by the Ministry for the Environment (1992) to prevent undesirable bacterial or slime growths in surface water.

Only four sites in the NWQN have $BOD_5$ levels which exceed 2 g/m³ frequently, and they are all downstream of known organic waste discharges (e.g. processing works, pulp mill) (Smith and Maasdam, 1994). Excessive $BOD_5$ levels are more common in small streams surrounded by cattle pasture (Smith *et al.*, 1993).

***Nutrient concentrations (nitrogen and phosphorus)***

Half the NWQN rivers have a nitrate-nitrogen concentration of 105 mg/m$^3$ or more (Table 7.9). This poses no threat to human or animal health but may make those rivers susceptible to nuisance algal growths. Nitrate concentrations appear to reflect the level of pastoral run-off, being higher in wet seasons and in rivers surrounded by pasture, such as the Mataura, Oreti (Southland), Waipa (Waikato - King Country), Tukituki (Hawke's Bay), Waingongoro (Taranaki), and Waihou (Hauraki Lowlands) (Smith and Maasdam, 1994). When low summer flows were monitored by the '100 Rivers' survey, the median nitrate-nitrogen concentration was only 40 mg/m$^3$ (Close and Davies-Colley, 1990).

Nitrogen also enters water as ammonia. High concentrations can occur in swamps and other naturally low oxygen environments (such as geothermal areas) and downstream of point source discharges. Sustained high concentrations can be lethal to fish, though toxicity varies with pH and water temperature. The median ammonia concentrations in the '100 Rivers' and NWQN surveys were 13 and 9 mg/m$^3$ respectively. Even with variations in pH and temperature, these levels pose little risk to fish life in most New Zealand rivers (Smith and Maasdam, 1994).

The combined nitrogen load from nitrates and ammonia is referred to as dissolved inorganic nitrogen (DIN). To prevent nuisance algal growths, the Ministry for the Environment (1992) has proposed that DIN concentrations be kept below 40-100 mg/m$^3$.

Although direct measurements of DIN are not available, it is obvious from nitrate-nitrogen concentrations alone that many of our rivers probably exceed the guideline and are at risk of developing nuisance algae (see Table 7.9). However, although nitrogen levels are high enough to promote algal growth in over half the NWQN rivers, phosphorus levels are comparatively lower. In half the samples, concentrations of dissolved reactive phosphorus (DRP) were only 4 mg/m$^3$ or less (see Table 7.9). This is well below the 15–30 mg/m$^3$ level which facilitates algal growth (Ministry for the Environment, 1992). In total, some 50 percent to 60 percent of river sites in the NWQN have sufficiently high nutrient levels to create a risk of nuisance algal growth. However, actual proliferations of algae in these rivers appear to be inhibited in many cases by the rivers' silty or mobile sandy beds and variable flows.

**Box 7.6**

***Changing water quality in the Waikato River***

The Waikato River, which originates in Lake Taupo, is the longest and most used river in New Zealand. It is 425 kilometres long with a catchment area of 1,114,000 hectares. The catchment includes agricultural land, electric power stations, planted exotic forests, mining and manufacturing industries, townships, and a major city (Hamilton). Until recently, the river was also New Zealand's representative waterway in UNEP's Global Environmental Monitoring Survey (GEMS).

A survey of the catchment's status between 1972 and 1978 showed that the river was under stress (Ministry of Works and Development, 1979). Large amounts of fertiliser and around 30 billion litres of animal wastes, were deposited annually in the catchment. The river also received wastes from 12 dairy factories, two abattoirs, one wool scour, one pulp and paper mill, several open cast coal mines, one sulphur mine, one ironsand mine and 13 urban sewage treatment plants. Further pressures came from 13 power stations, nine of which were hydro powered, two thermally powered and two geothermally powered. The stations drew off substantial amounts of cooling water and also discharged effluent into the river. Discharges from a geothermal station were high in toxic elements such as arsenic, fluoride and borate (Glasby, 1991).

In the years since the original survey, the Waikato Catchment Board and its successor, the Waikato Regional Council (or Environment Waikato), have systematically monitored the river. By 1988, the river was considered to be of very high quality along most of its length (Zuur, 1989). Improvements in waste treatment had significantly reduced bacteria numbers and $BOD_5$ levels. Dissolved oxygen levels had increased, and nutrient levels, though still higher than in many other New Zealand rivers, were declining as a result of cutbacks in fertiliser use and stock numbers. Six years on, the improvements were still being sustained, with a slight increase in dissolved oxygen, a continuing decline in nutrient concentrations, and no significant changes in bacterial numbers, $BOD_5$ levels or water clarity (Environment Waikato, 1995).

However, the improvements have not been evenly spread along the river. The lower reaches drain intensively used farmland, as well as swamps and peatlands, and are in far worse condition than the upper reaches of the river. Turbidity and faecal bacteria in the lower river commonly exceed the recommended guidelines for recreational waters. The black disc, which is used to measure water clarity, is visible for less than half a metre in the lower river compared to a visibility depth of 10 metres in Lake Taupo. Concern has also been expressed that the boom in dairy farming may reverse the Waikato River's declining trend in nutrient levels as more nitrogen fertiliser is used on pasture (Environment Waikato, 1995).

***Bacterial concentrations***

When disease-causing bacteria and protozoans get into water through animal waste and human sewage, they pose a risk to swimmers and shellfish eaters (see Box 7.7). The risk is greater for shellfish eaters because the shellfish are filter feeders which accumulate large amounts of bacteria from the water and become heavily infected themselves.

Two recent studies have investigated the risk to swimmers at coastal bathing beaches (Bandaranayake *et al.*, 1996) and river swimming spots (McBride, *et al.*, 1996). The river study is still in progress, but the coastal study has been completed. It compared the symptoms of 3,887 people at three different types of beach which we could label as: 'rural' (i.e. beaches exposed to some pastoral run-off), 'town' (beaches exposed to some sewage from oxidation ponds), and 'ideal' (beaches exposed to neither of these).

All beaches had relatively low bacterial levels, and the overall rate of pollution and illness was low by international standards. Nevertheless, small but statistically significant differences were found. Those who spent more than half an hour in the water at either the rural or town beaches had a slightly higher rate of stomach bugs and chest infections. Paddlers at the town and rural beaches had a slightly higher rate of chest infections but not of stomach bugs. Those at the ideal beaches, and those who stayed out of the water at all beaches, had no increase in rates of illness (Bandaranyake, *et al.*, 1995).

Although the national river surveys do not monitor bacteria, many regional authorities do. The Bay of Plenty Regional Council, for example, surveys bathing water quality in its region every two years. In its 1995 survey, it found a significant improvement over the previous survey with all marine beaches and 96 percent of lake shores meeting the Ministry of Health guidelines. However, only 38 percent of the river sampling holes came up to standard, reflecting land use patterns (Ogilivie, 1995c).

A selection of unpublished regional council microbiological data was mapped in 1994 by the Ministry for the Environment to show average bacterial concentrations at swimming sites around the country (see Figures 7.18a and 7.18b). Smith et al. (1993) also consulted regional microbiological data in assessing the effects of agriculture on stream and river quality. From these data it seems that the upper reaches of many streams and rivers are suitable for contact recreation (e.g. swimming and other activities where there is a risk of swallowing water or transferring it from hands to food) but that, further downstream, some rivers become quite unsuitable. In some areas sewage and industrial discharges contaminate waterways, and streams surrounded by dairy pasture are particularly prone to faecal and nutrient contamination. Sometimes, they may even be unsuitable for sheep and cattle to drink (Smith et al., 1993).

***Overall river and stream quality***

In general, the upper reaches of most rivers have high water quality. The middle and lower reaches of South Island rivers also have high water quality, but the middle and lower reaches of North Island rivers tend to have elevated turbidity and nutrient levels (Maasdam and Smith, 1994; Smith *et al.*, 1993). In most cases contamination is from pasture run-off, but contamination also occurs downstream of towns and industrial sites with significant sewage and stormwater discharges (see Box 7.6).

**Box 7.7**

### *Microbiological contamination of surface waters*

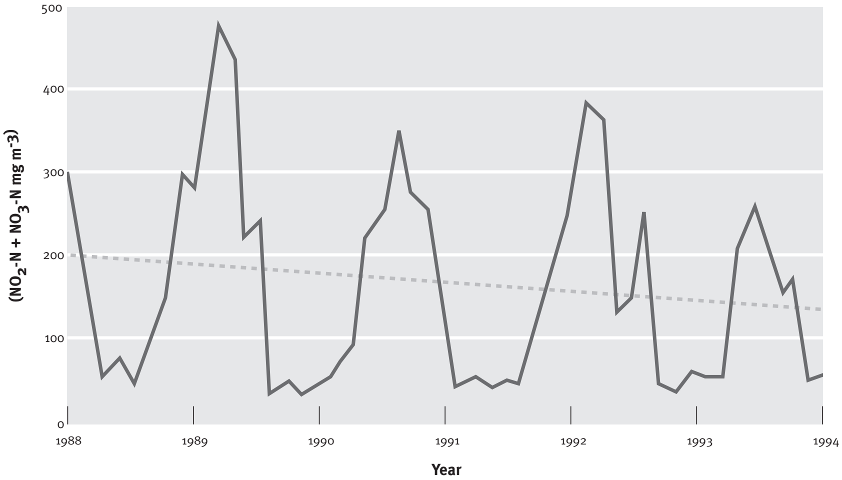
Micro-organisms are single-celled creatures that are invisible to the naked eye. The smallest are bacteria and the larger ones, algae and protozoans, are collectively called protists. While most are harmless to humans, some micro-organisms can cause serious health problems. The *Campylobacter* bacterium, for example, is the most common source of food and waterborne illness in New Zealand, causing stomach ailments in people and abortions in sheep and cattle (Public Health Commission, 1994). Other harmful bacteria which can occur in water are *Salmonella* and *Shigella* (which cause severe stomach upsets and dysentery), *Meningococcus* (which causes a type of meningitis) and *Rickettsia* (which causes typhus). Harmful protists include *Giardia* (see Box 7.11), *Cryptosporidium* (which causes diarrhoea), *Naegleri fowleri* (an amoeba which causes meningitis and which can be caught in geothermal pools) and several types of toxic algae (e.g. *Gymnodinium*) which may cause nausea, diarrhoea, disorientation or even paralysis (see Box 7.13).

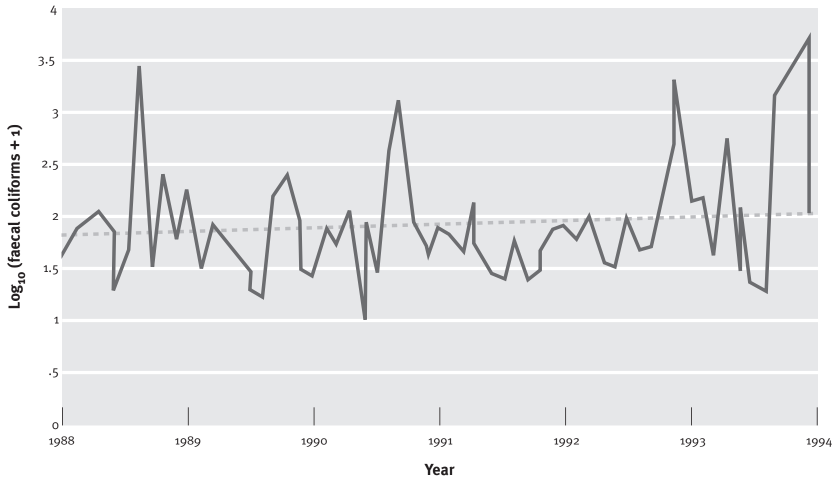
It is not practical to monitor water for all potentially harmful micro-organisms. Instead, most authorities monitor for a few common micro-organisms on the assumption that, where these are rare, harmful ones are also likely to be rare. The most commonly monitored micro-organisms are ordinary bacteria which live inside humans and other mammals and usually exit with their faeces. These are the **enterococci** bacteria, which normally live in the intestine, and the **faecal coliform** bacteria, which normally live in the colon or bowel. Faecal coliforms were used to define the water quality classes in the Water and Soil Conservation Act 1967, and enterococci were used in the Department of Health 1992 guidelines for bathing and shellfish gathering. If these bacteria are present at all, water is classified as unfit for human consumption. As bacterial density increases, water is progressively classed as unfit for shellfish harvesting, contact recreation and sheep and cattle consumption.

For this report, a number of regional councils and health authorities provided bacterial data from a selection of swimming areas, including rivers, lakes and beaches. Where possible, data were from sites which had been monitored at least five times at regular intervals, though in some cases sites had only been monitored once. Averages were calculated for the sites that had been monitored more than once. The averaged figures were graded into four water quality classes using published standards and recommendations. These are presented in Figures 4.18a and 4.18b (Department of Health, 1992; Water and Soil Conservation Act, 1967; ANZECC, 1992).

Coastal sites had fewer bacteria than river sites, and the upper reaches of rivers were less contaminated than the lower reaches. However, these averages mask significant variations. Pastoral run-off yields higher bacterial counts at times of high rainfall, usually winter, while point sources, such as sewage outfalls, yield higher counts in summer. Also, these data come from swimming sites, rather than sites exposed to run-off and outfalls. In estuaries and harbours, for example, water quality varies markedly. Advice from health authorities should be sought before shellfish are taken from harbours which are near ports or urban areas.

**Figure 7.19**
**Trends in Waikato River water quality 1988-94 (Narrows Bridge site, Hamlton)**




## The State of our Lakes

Both the number and size of our lakes have been affected by human activities. Hydroelectric development has increased the size of some of the deep lakes, and has created 16,000 hectares of new lakes. On the other hand, land drainage has reduced the size of many shallow lakes. Total lake area has probably undergone little net change, though local changes have been quite substantial. The creation of Lake Dunstan, for example, flooded the gorge and half the old town of Cromwell, while the development of farmland around Lake Ellesmere reduced the lake from a pre-European area of some 30,000 hectares to around 18,000 hectares (Stephenson, 1986).

Water quality in our lakes ranges from the apparent high quality of the large deep lakes to the very poor quality of some small shallow lakes. Because of the difficulty and expense of monitoring the deep lakes, details of their water quality are relatively unknown, but visible water quality problems seem rare. Most of the hundreds of shallow lakes are also unmonitored. In those for which data exist, however, eutrophication is a frequent problem.

Eutrophication occurs when too many nutrients enter a lake or stream and cause excessive growth of weeds and photosynthesising algae (phytoplankton). These can suffocate the oxygen-breathing organisms in the lake. Eutrophic lakes have low levels of dissolved oxygen, poor water clarity, nuisance algal blooms and fewer fish. Many small lakes, particularly in the North Island, exhibit some or all of these problems. Nutrient-enriched run-off from surrounding pastoral catchments is the main cause (White, 1982). Although small urban lakes are usually eutrophic too, as a result of drainage, groundwater seepage, large duck populations and intensive recreational use, urban sewage has not been a contributing factor except in two lakes–Lake Rotorua and Levin's Lake Horowhenua (White, 1982).

Smith *et al.* (1993) reviewed data on the trophic (or nutrient) state of 177 lakes (see Table 7.10). Seventy-one of the lakes were eutrophic or hypertrophic (extremely eutrophic). This represents 40 percent of their sample and 10 percent of all New Zealand's shallow lakes. Because the sample was not selected on a random basis, but on the basis of data availability, it would be wrong to conclude that 40 percent of all New Zealand shallow lakes are eutrophic. What can be concluded is that at least 10 percent are, and that the true figure is probably considerably higher.

More than 90 percent of the eutrophic lakes are in the North Island, while a similar proportion (86 percent) of the high quality oligotrophic (low nutrient) lakes are in the South Island. The largest of the eutrophic lakes are Wairarapa in the North Island and Ellesmere in the South Island. Both of these lakes have predominantly agricultural catchments, although Lake Ellesmere also receives wastes from several town sewerage systems.

Evidence that run-off from pastoral land is the main cause of eutrophication comes from the strong relationship between catchment type and trophic state (see Table 7.10). Only 6 percent of the oligotrophic lakes in the sample are in pasture-dominated catchments (i.e. catchments with half or more of the land in pasture as opposed to forest or tussock), but pasture-dominant catchments surround 36 percent of the mesotrophic lakes, 66 percent of the eutrophic lakes and 92 percent of the hypertrophic lakes.

We cannot say whether our lakes are getting better or worse. A 1976 review of 72 lakes, reported that 11 (15 percent) were eutrophic, 30 (42 percent) were mesotrophic, and 31 (43 percent) oligotrophic (White, 1976). Comparisons cannot be made, however, as the study was not based on a random selection of lakes and its main purpose was classification. However, the author subsequently reported that: "Eutrophication is here, it will worsen insidiously, it will require control in places, but rapid and widespread environmental degradation will not occur" (White, 1982).

**Table 7.10**
**Trophic (nutrient) state, catchment status and water quality of 177 New Zealand lakes.**

| | **Oligotrophic lakes (low nutrient levels)** | **Mesotrophic lakes (moderate nutrient levels)** | **Eutrophic lakes (high nutrientlevels)** | **Hypertrophic lakes (very high nutrients)** |
|---|---|---|---|---|
| *Number in sample* | *63* | *43* | *39* | *32* |
| *Percent of sample* | *36%* | *24%* | *22%* | *18%* |
| *% in North Island* | *14%* | *72%* | *90%* | *94%* |
| *% in South Island* | *86%* | *28%* | *10%* | *6%* |
| *% of lakes in pasture-dominant catchments* | *6%* | *35%* | *66%* | *92%* |
| *Phytoplankton biomass as chlorophyll a (mg/m$^3$)* | *less than 2* | *2–5* | *5–30* | *more than 30* |
| *Water clarity (metres)* | *more than 10* | *5–10* | *1.5–5* | *less than 1.5* |
| *Oxygen status of bottom waters in summer* | *Well oxygenated* | *Moderately depleted* | *Depleted* | *Severely depleted* |
| *Total phosphorus (mg/m$^3$)* | *less than 10* | *10–20* | *20–50* | *more than 50* |
| *Total nitrogen (mg/m$^3$)* | *less than 200* | *200–300* | *300–500* | *more than 500* |

*Adapted from Smith et al. (1993)*

**Figure 7.18a**

**Microbiological quality of some North Island swimming areas**

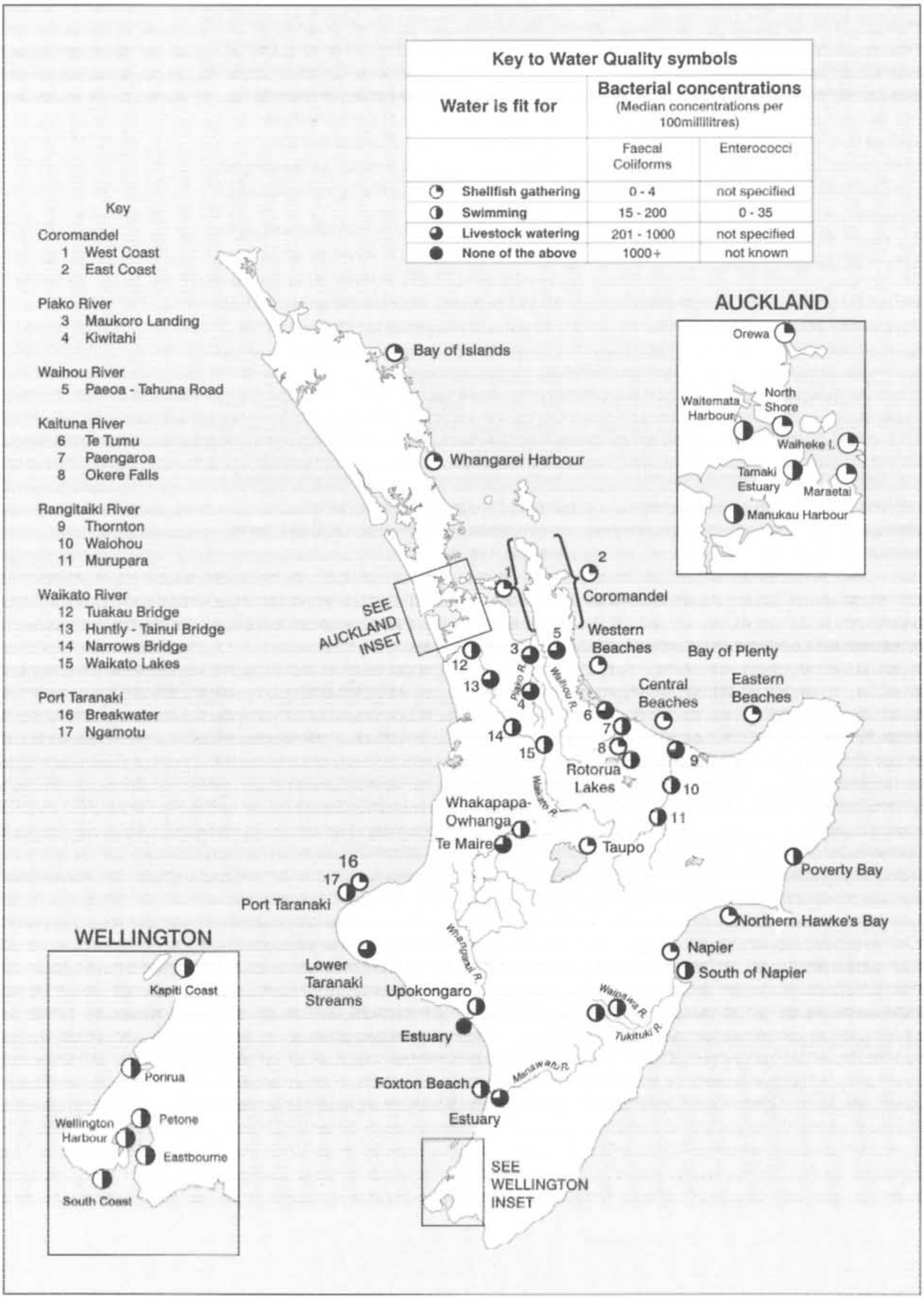


**Figure 7.18b**

**Microbiological quality of some South Island swimming areas**

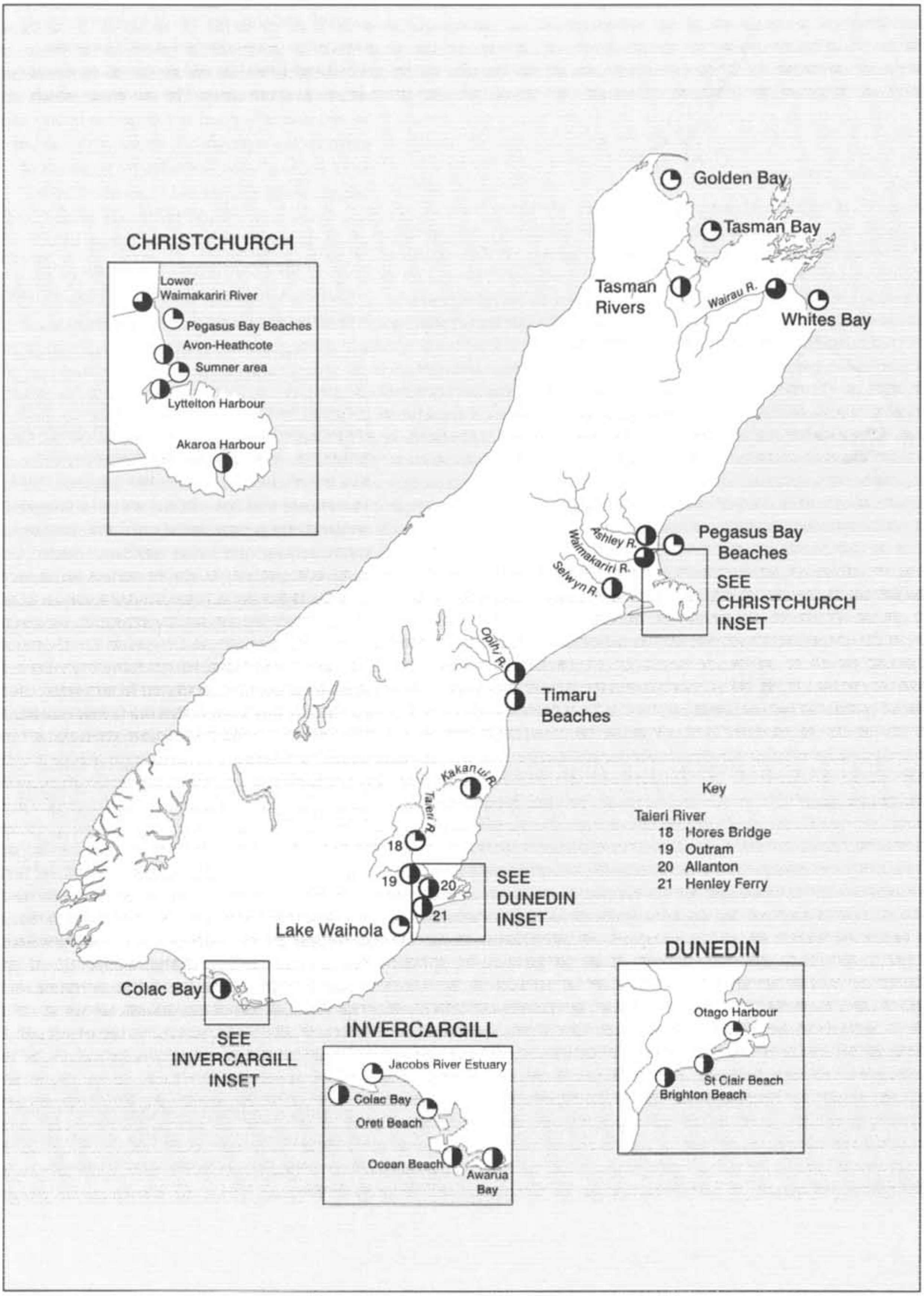
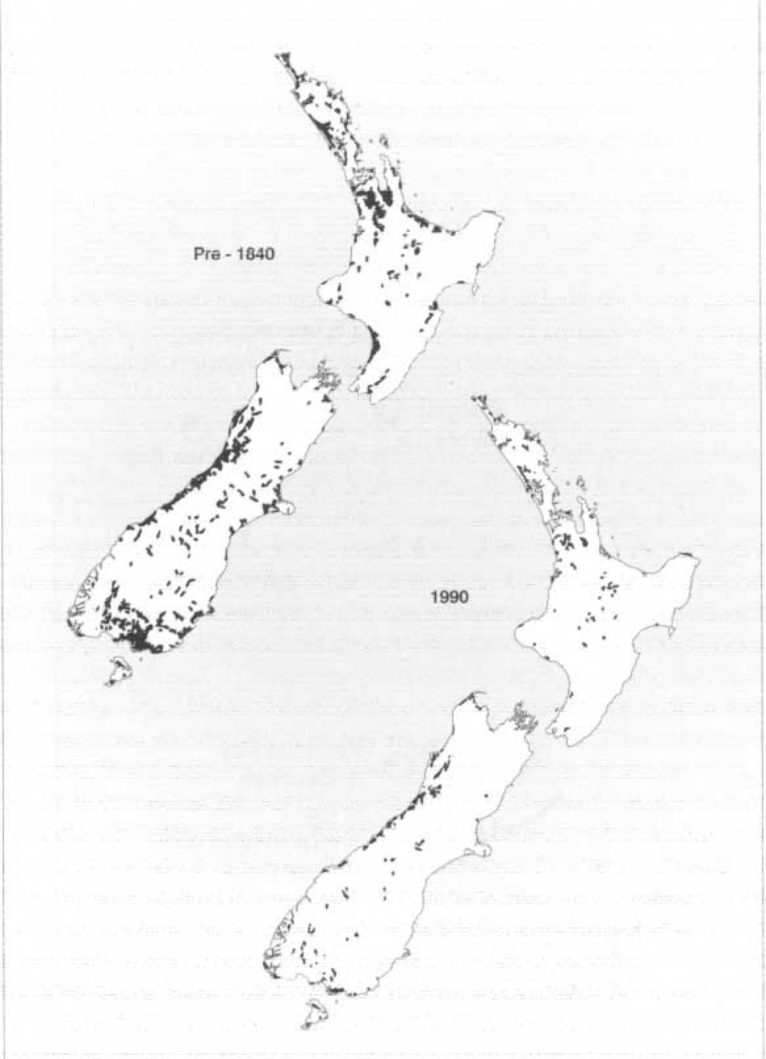


**Figure 7.20**
**The decline of New Zealand's freshwater wetlands, inferred from soil types.**




*Source: Landcare Research*

## The State of our Wetlands

The vast majority of New Zealand's wetlands have been drained or irretrievably modified for coastal land reclamation, farmland, flood control, and the creation of hydro-electricity reservoirs. This occurred mostly between 1920 and 1980 but still continues to a limited degree in some areas. The rainwater which would normally pond and seep slowly into the surrounding waterways is now swiftly carried to rivers, reservoirs and lakes by hundreds of kilometres of ditches and channels. Cattle now graze where water birds once waded, and weeds, eutrophication and pollution have reduced the biodiversity of many surviving wetlands. Only the South Island high altitude wetlands have escaped this process.

Several attempts have been made to estimate the extent of the wetlands' decline. Soil type is a useful guide to the original wetland area because many vanished wetlands left distinctive soil types. In an analysis commissioned for this report, Landcare scientists used soil maps to estimate that the original area of freshwater wetland was approximately 672,000 hectares (see Figure 7.20). An earlier estimate, which included saltwater wetlands, such as estuaries and salt marshes, put the original wetland area at over one million hectares (Stephenson, 1983).

The area of wetland which remains today cannot be simply calculated from maps because it has been shrinking yearly (see Box 7.8). Between 1954 and 1976, surveys by the former Wildlife Service found that 263,000 hectares were lost–a rate of nearly 12,000 hectares per year. Resurveys of sample areas in Northland indicated that between 1978 and 1983 approximately 15 percent (3,175 hectares) of the remaining wetland had been drained. These surveys ceased in the mid-1980s when the Wildlife Service became part of the newly established Department of Conservation. The Department subsequently set up a wetland inventory (known as WERI), which lists about 3,000 wetlands. However, the inventory's focus is on ecologically and regionally significant wetlands rather than general trends in wetland loss or restoration and, in any case, it is not systematically updated.

**Box 7.8**

### *Wetlands - what remains*

Thousands of wetlands remain, but their total area is small (Stephenson, 1983, 1986; Cromarty and Scott, 1996). Although some span thousands of hectares, most are only a few hectares. The WERI database held by the Department of Conservation contains data on about 3,000 wetlands. It is not comprehensive, but includes all the important wetlands. The Taranaki Regional Council has identified five times more small wetlands in its region than are recorded on the WERI database, but this figure also includes artificial ponds.

Among the known survivors are more than 900 mountain tarns and small lakes (e.g. Lewis Pass Tarn, Lakes Heron and Alexandrina), a number of coastal lagoons (e.g. Ellesmere, Wairarapa, Okarito in Westland, Waituna near Invercargill), many small dune lakes (e.g. along the Northland and Manawatu coasts), several peat wetlands (e.g. Kopuatai and Whangamarino in the Waikato), numerous swampy valleys (e.g. Taupo Swamp near Wellington), saltmarshes (e.g. Pauatahanui inlet near Wellington), mangrove estuaries (e.g. Waitangi in the Bay of Islands), and braided rivers (e.g. the large Canterbury rivers). To these should be added a small number of constructed wetlands specially created on farms and the margins of hydro lakes for duck shooting, bird watching or waste water disposal. Different ends of the range can be illustrated by two examples: the large peat wetlands of the Waikato, and the tiny Pukepuke lagoon in the Manawatu dunelands.

#### *Example 1: The Waikato peat wetlands (Kopuatai and Whangamarino)*

By the 1970s, Waikato's low-lying wetlands had been reduced to less than 15 percent of their original area, and are probably even smaller today (Ogle and Cheyne, 1981). However, two of the surviving wetlands, Kopuatai and Whangamarino, still retain enough of their grandeur and natural character to have been designated as wetlands of international importance for wildfowl under the Ramsar Convention (Cromarty and Scott, 1996). Although they are the two largest wetlands in the North Island, they were once much larger. Kopuatai originally covered the Hauraki Plain from the Firth of Thames as far inland as Matamata, and just ten kilometres to the west, on the other side of the Hapuakohe Range, Whangamarino was almost as vast.

Kopuatai Peat Dome is a remnant of the raised peat bogs which were once a feature of this area. Several rare or threatened plants dwell here, including the endemic greater jointed rush (*Sporadanthus traversii),* several threatened birds, and the black mudfish (*Neochanna diversus)*. The wetland is also important for what lies beneath its surface. The peat layers represent various stages in the formation of coal from ancient forests. They also contain pollen, plant macro-fossils, and evidence of past seismic activity, sea level fluctuations and climate change. Like most peatlands, Kopuatai is extremely vulnerable to fire, and is also threatened by such invaders as crack willow *(Salix fragilis)* on the more fertile margins.

Whangamarino, which has a road through its centre, is an accessible and well-known wetland, lying within 100km of Auckland and Hamilton. It has four peat domes and provides habitat for 56 bird species, including such threatened species as the weweia or dabchick (*Poliocephalus rufopectus)* and brown teal *(Anas aucklandica chlorotis)* and perhaps 30 percent of the known New Zealand population of bitterns *(Botaurus poiciloptilus)*. The Reao arm of the swamp is a vital habitat for fernbirds (*Bowdleria punctata)* and spotless crakes *(Porzana tabuensis*) though marsh crakes (*P. pusilla)* have not been seen here for the past 15 years or more. The wetland's 18 fish species include the threatened black mudfish, while the invertebrates include New Zealand's only species of moth with aquatic larva (*Nymphyla niteris*).

Although only a small range of plant species live in the peat bog itself (e.g. wire rush and manuka) they include the threatened orchid, *Corybus carsei*, for which the Reao arm is its last remaining site. Away from the peat, the surrounding swampland contains nearly 240 wetland plant species, 60 percent of which are indigenous. Several of these are threatened, including the large water milfoil or yarrow, *Myriophyllum robustum*. The Department of Conservation's management plan for Whangamarino seeks to control the threats currently posed by low water levels, fires, stock grazing and invasions of willows and the exotic grass, *Glyceria maxima*, around the margins.

#### *Example 2: Pukepuke Lagoon in the Manawatu dunelands*

Located north of Levin in the Manawatu sand dune country, Pukepuke is not a wetland of international importance, having been greatly modified by drainage and introduced plants and animals. Its fate is more representative of the many small wetlands around our coasts affected by livestock, rabbits, and weeds, and by lowered water tables from surrounding land uses such as pine plantings and drainage. In 1870 the Pukepuke wetland was around 480 hectares, consisting of a lagoon of 160 hectares and swampland of 320 hectares (Ogden and Caithness, 1982). A hundred years later, the total area is barely 100 hectares (one square kilometre), and the lagoon itself, 15 ha (see Figure 7.21). Even so, it is probably the largest and least modified dune lake in the Manawatu coastal region - a region whose wetlands once spanned thousands of hectares–and one of the few formally protected such areas.

Before agricultural development, the area was stable, with the surrounding dunes held in place by the native plants, raumoa (spinifex) and pingao. For the local Maori tribe, Ngati Apa, the area was once the site of a pa (fortified settlement) and a significant source of eels, harakeke (flax), and wildfowl. The Ngati Apa owners sold the land to the Crown in 1958 but retained fishing rights. Cattle, sambar deer and rabbits were introduced before the turn of the century. By 1906 cattle had destroyed the raumoa on the foredune causing extensive mobile dunes to drift inland, covering much of the lagoon and swampland. The drifting dunes also blocked off the outlet drain, causing flooding of the surrounding farmland. This led to efforts to drain the lake and to stabilise the dunes by planting introduced marram grass, tree lupins, pine trees and even the native reed, raupo. The dunes continued to drift, however, splitting the lagoon in two and reducing its area to about 50 hectares. Dairy farming commenced in the 1920s and, with it, the first applications of phosphate fertilisers which contributed to eutrophication, and caused raupo to spread at the expense of other plants. More drainage during the 1930s and 1960s helped further reduce the area until, by 1970, the swamp had shrunk to 90 hectares and the lagoon was less than 15 hectares. The lagoon dried up in 1956, 1961, and again in 1970. The Wildlife Service dug six artificial ponds between 1970 and 1974 and maintained the wetland as a wildlife reserve.

Scientists found that, by the late 1970s, two-thirds (120) of the 176 vascular plants at Pukepuke were introduced species. One native species, raupo, had proliferated into a virtual weed because of pollution from cattle and fertilisers (Ogden and Caithness, 1982). The scientists also found dramatic changes in the native duck populations. Scaup (*Aytha novaeseelandiae*) and brown teals (*Anas aucklandica chlorotis*), once abundant, had disappeared, and grey ducks (*Anas s. superciliosa*) had been replaced by the introduced mallard (*Anas p. platyrhynchos*). Banded rails *(Rallus philippensis)* had also not been seen for many decades. Since the late 1970s attempts have been made to re-establish the indigenous duck populations, including New Zealand shovelers (*Anas rhyncotis variegata*), and today the lagoon provides habitat for them as well as small numbers of other rare or declining bird species, such as fernbirds, dabchicks, bitterns, and marsh crakes. The extent to which the coastal wetlands have been lost is revealed in the fact that Pukepuke, despite its drastic changes, is now considered one of the best of those remaining.

Estimates of the amount of freshwater wetland that still remained in the mid-1970s range from 89,000 hectares (Newsome, 1987) to 265,000 hectares (Stephenson, 1983). The higher estimate includes 'developed' wetlands (partially drained pasture). The Landcare Research estimate for this report put the figure at around 100,000 hectares, suggesting that the original freshwater wetlands have declined by about 85 percent since European settlement. The working party convened by Stephenson (1983) put the decline at 90 percent. Both estimates exclude the 45,000 hectares of pakihi heathland mostly in the western South Island and Stewart Island. The pakihi area, with its low fern, scrub, rush and moss plants on poor-draining podzol soils, does not appear to have changed since pre-European times.

The national estimates of wetland loss disguise wide regional variations. While the trend has been downward in all regions, it has been more marked in some than in others, depending on both the extent of the original wetland cover and the degree of agricultural and urban development. For example, unmodified wetlands have been reduced to about 37 percent of their original area in Southland, about 15 percent in the Waikato, 2 percent on the Rangitikei Plains, and less than 1 percent in the Bay of Plenty (Cromarty and Scott, 1996). The national estimates of loss also disguise wide variation between different types of wetlands. For example, ephemeral wetland systems (eg, in dunelands) have been impacted more than lacustrine (standing, open water) wetlands.

Taranaki region has a particularly good inventory of its remaining wetlands. As in other areas, most of Taranaki's wetlands were drained or filled for pasture development, but many small ones still remain in valleys and hollows. In fact, the regional council has recently identified 717 surviving wetlands, five times more than the 139 identified in the region by the Department of Conservation's Protected Natural Areas Programme and recorded on the WERI database, although the council's tally also includes artificial ponds (Taranaki Regional Council, 1996).

The council considers that 61 percent of the WERI wetlands are threatened by pollution from agricultural run-off, 58 percent are threatened by grazing animals, and a quarter (27 percent) are still threatened by ongoing drainage. Virtually half of the wetlands (48 percent) appear to have suffered some degree of modification since they were first recorded by the Department of Conservation 10 years ago, many having significantly decreased in size and one having disappeared completely since being included in the WERI database (Taranaki Regional Council, 1996).

### The State of our Groundwaters

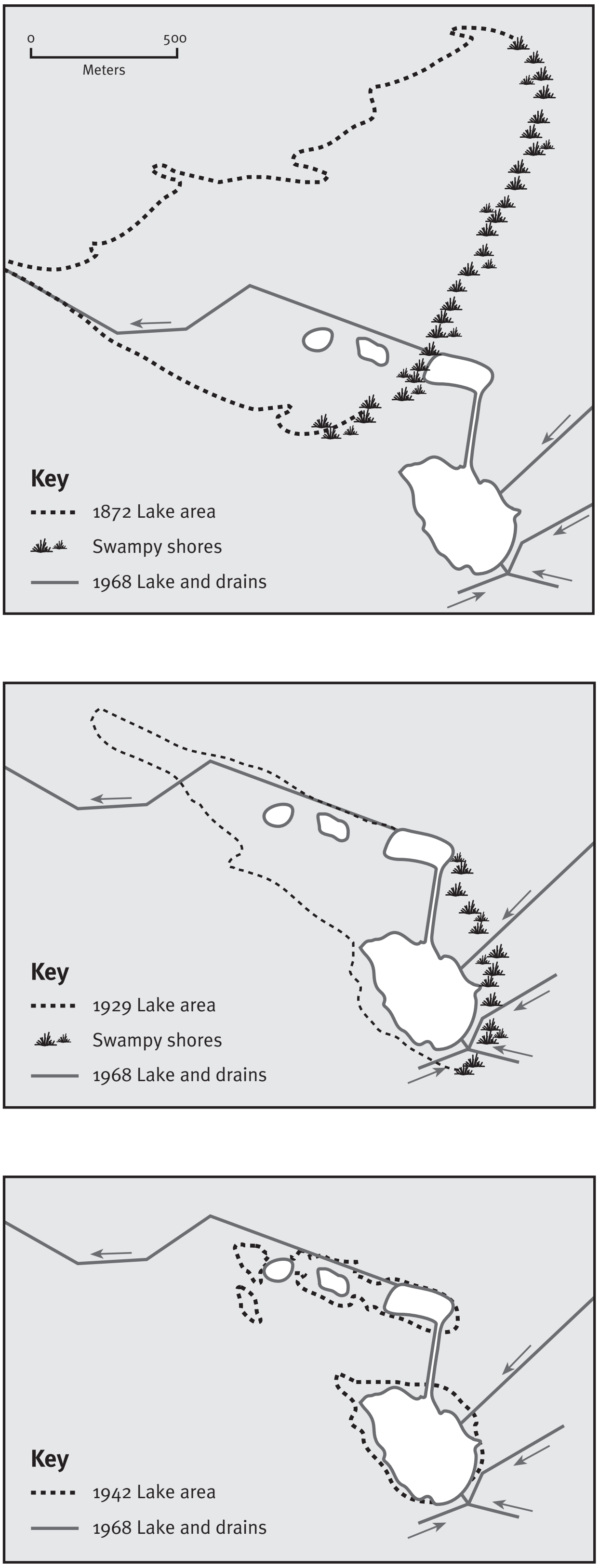
Both the quantity and quality of groundwater may be affected by human activities. Excessive draw-off or land drainage may reduce the supply available for irrigation or urban use. Near the coast, excessive use can actually reduce groundwater levels below sea level so that sea water intrudes into the aquifer, making the groundwater salty and unusable. Groundwater is also affected by the activities on the land above it. Nutrients, faecal bacteria and toxic chemicals can all leach down from the land surface degrading the quality of the groundwater. On the evidence to date, such effects have been relatively minor, though sea water intrusion has occurred in some coastal areas, and a number of aquifers, particularly in dairying areas, show elevated levels of nitrate-nitrogen. Careful management of groundwater supplies has prevented serious depletion in most parts of the country. However, depletion of geothermal fields is a more serious issue (see Box 7.9).

#### *Quantity of Groundwater*

Groundwater levels have fallen in most of New Zealand's flood plains through a prolonged programme of unchecked land drainage. Farmers themselves consider some areas to be 'over-drained'. For example, the groundwater below Christchurch declined progressively from the 1890s to the 1950s. Since then it has stabilised, with levels dropping in summer, then returning to normal in winter. However, dry seasons can sometimes disrupt the process of winter replenishment, causing longer term declines in groundwater. For example, a series of dry winters in Hawke's Bay from 1981 to 1984, led to a decline in the groundwater beneath the Heretaunga Plain. The amount of water entering the aquifer fell below the 320,000 m$^3$ being removed for agricultural, industrial and domestic purposes. To counteract this, trenches were constructed on the river flood plain to artificially recharge the aquifer by 54,000 m$^3$ per day (Mosley, 1993).

**Figure 7.21**

**The changing shape of Pukepuke Lagoon and wetland**




*Source: Ogden and Caithness (1982)*

Lowered aquifer levels have led to sea water intrusion in a number of places, including quite extensive aquifers on the Heretaunga and Waimea Plains, and small aquifers situated beneath rural seaside communities such as those on the Coromandel Peninsula. In 1990, for example, seawater intruded 600 metres into a shallow gravel aquifer at Lower Moutere near Nelson after irrigation caused groundwater levels to drop. In this case, water use restrictions and improved rainfall allowed the aquifer to recover, but in some areas contamination can last for many years. To prevent such occurrences in the Christchurch area, yearly draw-off limits, or 'safe yields', have been set for the artesian aquifers (Mosley, 1993).

**Box 7.9**

### *The state of our geothermal aquifers*

Although only a fraction of our useable geothermal energy is currently exploited, the effects of extraction have been dramatic in the geothermal systems that have been developed. Of the 24 high-temperature geothermal fields in New Zealand, many, including Wairakei and Ohaaki, Tauhara, Tokaanu-Waihi, Rotoiti, Kawerau and Rotorua are exploited for industrial, commercial and domestic purposes, and for electricity generation.

For centuries, Maori communities in the central North Island had used geothermal waters for cooking, washing, warmth and healing. In the 1930s drilling began for domestic heating supplies in Rotorua and continued on a large scale in the 1940s. In 1956, the Tasman Pulp and Paper Mill began piping steam from the Kawerau geothermal field for timber drying and to generate electricity for the plant. In 1958 a geothermal power station was commissioned at Wairakei. It reached full production in 1963. Glover (1977) monitored the Geyser Valley around Wairakei and found that the development of the field caused the geothermal activity to change from mainly geysers and flowing springs to steam-heated pools, fumaroles and steaming ground. Some changes were also noticed as far away as Taupo (10 km from Wairakei), with some springs recording an increase in temperature, as a result of fluid withdrawal at Wairakei (Environment Waikato, 1993).

The number of active geysers in New Zealand diminished from 130 in 1950, to only 11 by 1990. Of these, 50 were lost when the geyser field at Orakeikorako was drowned for hydroelectric development. The rest were destroyed by excessive draw-off for power generation, industrial and domestic uses. Many natural features have been destroyed or altered by the development of land in and around geothermal fields. Houghton *et al.* (1980 and 1989) reviewed the country's geothermal systems and recommended five areas for complete preservation: White Island, Waimangu and Waiotapu (south of Rotorua), Ketetahi ( near the Tongariro National Park), and the Rotorua field. Most of the surface features are protected within reserves, but the Resource Management Act does allow regional councils to grant consent to draw from contributing fields. Any person may apply for a Water Conservation Order over a geothermal field. To date, none are protected.

At present, some 520 megawatts (MW) of energy are extracted from geothermal aquifers, half as electricity, half as direct heat. The total resource is estimated at 2,100 to 4,700 MW of energy, or 21,000 to 43,000 petajoules (PJ) of useable heat. This compares to a total coal resource of some 37,000 PJ and gas/oil/condensate resources of 5,000 PJ, making it a vast energy resource (Hunt and Bibby, 1992; Ministry of Commerce, 1992; Cave *et al.*, 1993).

***Quality of Groundwater***

Groundwater quality varies markedly, depending on the sources of the incoming water (e.g. rainfall, rivers, run-off and leachate), as well as the geology, soils and land use of the surrounding catchment, and the chemical characteristics of the aquifer itself. The potential for groundwater pollution is greatest where the aquifers are closest to the surface, where the overlying land is permeable, where human activity is significant, and where there is a high recharge (refill) rate from rainfall, irrigation or liquid waste disposal. In contrast to surface waters, groundwater movement, and the chemical processes that go on in groundwater, are very slow. Once aquifers are contaminated they may take several to hundreds of years to cleanse themselves of pollution.

In the opinion of the water management experts surveyed by Hoare and Rowe (1992), Sinner (1992) and C.M. Smith (1993) the greatest contamination threats to groundwater are from the leaching of nitrates, and to a lesser extent, pesticides, from agricultural soils. Other threats to groundwater quality include leachate from landfills and dumps, contaminated sites, and waste disposal facilities, including the disposal of wastewater onto land.

*Nitrate in groundwater*

Nitrate contamination of groundwater is of concern because, at quite low concentrations, nitrate can be toxic to humans. The Ministry of Health has set a maximum allowable nitrate limit in drinking water of 50 g/m$^3$, which is equivalent to 11.3 g/m$^3$ of nitrate-*nitrogen*. (The nitrogen makes up only a small part of the total nitrate molecule, $NO_3$).

**Table 7.11**
**Nitrate nitrogen concentrations in some New Zealand groundwaters.**

| Location | Type of aquifer | Concentration (g/m$^3$ nitrate-N) | Exceeds MAV[1] | Land use above aquifer | Data sources |
|---|---|---|---|---|---|
| **South Island** | | | | | |
| *Waimea Plain, Tasman* | *Confined<br>Unconfined* | - | ✓<br>✓ | *Crops,<br>Effluent disposal* | *Thomas (1995)* |
| *Christchurch* | *Unconfined<br>Confined* | *4–8 g/m$^3$<br>< 1 g/m$^3$* | - | *Pasture, Crops,<br>Point sources* | *Bowden (1986)* |
| *Lincoln* | *Unconfined* | - | ✓ | *Pasture, Crops* | *Adams et al. (1979)* |
| *Ashley Catchment* | *Unconfined* | - | ✓ | *Pasture, Crops* | *Bowden et al. (1982)* |
| *Ashburton* | *Unconfined* | *4–8 g/m$^3$* | - | *Pasture, Crops* | *Burden (1984)* |
| *Clutha Valley (1988)* | - | *0.2–5.3 g/m$^3$* | - | *Pasture* | *Close and McCallion* |
| **North Island** | | | | | |
| *Northland* | - | *<0.01–3.5 g/m$^3$* | - | *Pasture* | *Smith et al.(1993)* |
| *Bay of Plenty (48 wells sampled)* | - | *<4.3 g/m$^3$* | - | *Pasture* | *O'Shaughnessy and Hodges (1992)* |
| *Pukekohe, Onewhero (129 wells sampled)* | *Confined & unconfined* | *<0.1–23.5* | ✓<br>*(7 wells)* | *Pasture, Market gardening* | *Ringham et al., (1990)* |
| *Hamilton Lowlands* | *Unconfined* | - | ✓ | *Pasture, Dairy* | *Hoare (1986)* |
| *Hauraki Lowlands* | - | - | ✓<br>*(5 wells)* | *Pasture* | *Environment Waikato (1993)* |
| *Takapau Plains* | - | *about 10 g/m$^3$* | ✓ | *Pasture, Effluent disposal* | *Willoughby and Dravid (1992)* |
| *Heretaunga Plains* | *Unconfined* | *10–20* | ✓ | *Pasture* | *Burden (1980)* |
| *Tokoroa* | *Confined<br>Unconfined* | - | ✓ | *Pasture, Effluent disposal* | *Bird (1987)* |
| *Taranaki* | - | *<10 g/m$^3$* | - | *Pasture, Effluent disposal* | *Smith et al. (1993)* |
| *Manawatu* | *<30 m<br>>30 m* | *3–13 g/m$^3$<br>< 2 g/m$^3$* | ✓ | *Pasture* | *Brougham et al. (1985)* |
| *Wairarapa* | *Confined* | *< 7.5 g/m$^3$* | - | *Pasture* | *O'Dea (1980)* |

*Adapted from Roberts et al. (1995)*

[1] *A tick in this column means that at least one of the wells in each sample exceeded the Maximum Acceptable Value (MAV) for nitrate-nitrogen stipulated by the New Zealand Drinking Water Standards (Ministry of Health, 1995c). The MAV is much lower for groundwaters discharging into nitrogen-limited lakes in the central North Island.*

Generally, significant nitrate concentrations are only found in shallow unconfined aquifers. Deeper confined aquifers, fine-grained aquifers and aquifers containing high concentrations of dissolved iron, rarely have elevated nitrate concentrations. The most widespread sources of the nitrates which leach into groundwater are animal urine, clover-based dairy pastures, and nitrogen fertilisers used on dairy farms, orchards, and market gardens. Point sources of nitrate from waste disposal or waste irrigation systems may also be significant in some areas.

Table 7.11 shows groundwater nitrate concentrations from a variety of aquifers around New Zealand. Confined aquifers rarely have nitrate-nitrogen concentrations exceeding 1 $g/m^3$, except where their water comes from contaminated unconfined aquifers, or other contaminated sources. This is the case with the two major confined aquifers of the Waimea Plains which regularly exceed the maximum allowable values for nitrate in drinking water (Thomas, 1995).

Most of the major unconfined aquifers in New Zealand also have elevated nitrate levels and some exceed the maximum allowable limit for drinking water. For example, groundwater beneath the Oreti Plain in Southland has recently been found to have excessive nitrate levels which may take years to recover. Groundwater sampling of five sites in 1982, had found only one with excessive nitrate levels (Robertson, 1992). Southern Taranaki is another area where nitrate levels have risen (Taranaki Regional Council, 1996).

Particularly high nitrate concentrations occur around meat and dairy effluent disposal systems. For example, Hoare (1986) reported nitrate-nitrogen concentrations of up to 67 $g/m^3$ around a dairy factory effluent disposal area at Cambridge in the Waikato region. Large increases in nitrate concentrations have also been observed in some unconfined aquifers below irrigated pastures. Nitrate-nitrogen concentrations beneath the Ashburton-Lyndhurst irrigation scheme in Canterbury increased from 1.6 $g/m^3$ to 7.5 $g/m^3$ from 1961 to 1976 (Mosley 1993).

*Leachate in groundwater*

Substances leaching from landfills, rubbish dumps, effluent disposal areas and contaminated sites are a potentially serious threat to groundwater. New Zealand has an estimated 7,800 potentially contaminated urban and industrial sites (see Chapter 8). The groundwaters beneath some of these are currently being investigated by local authorities, but results from a representative number of sites are not yet available.

*Pesticides in groundwater*

Some 3,000-4,000 tonnes of pesticide ingredients were applied to New Zealand farms, orchards, market gardens, commercial forests and household gardens in 1989 in the midst of a farming downturn (McIntyre *et al.*, 1989; Wilcock, 1989; Wilcock and Close, 1990). Most of this (75 percent) was in the North Island. Similar, or greater, quantities are probably being applied now. Given public concern about the potential impact of pesticides on the environment, a number of groundwater investigations have been undertaken during the past decade (Close, 1994).

The results of these investigations show that the vast majority of groundwater, including all surveyed public drinking water supplies, are free from pesticide contamination (Close, 1994; Nokes, 1992). Even among high risk sites (i.e. those with shallow groundwater, leachable soils, and high rates of pesticide use) less than 20 percent have detectable pesticide levels and nearly all of these are well within acceptable limits (Close, 1994 and 1995). In a small number of cases where excessive levels have been found, they have generally been in association with a landfill or other point source discharge. The main pesticide studies to date are summarised below, and results of some of these are outlined in Table 7.12.

The Ministry of Health's monitoring of public drinking water supplies found no pesticides in either the 60 groundwater-based supplies sampled between 1987 and 1991 (Nokes, 1992) or the 290 sampled during 1993 and 1994 (Close, 1994). Districts covered in these surveys included Whangarei, Gisborne, Hamilton, Napier, Palmerston North, New Plymouth, Lower Hutt, Greymouth, Christchurch, Timaru and Dunedin.

**Table 7.12**
**Concentrations of pesticides in groundwater where detectable.**

| Region | Pesticide | Concentration ($mg/m^3$) | MAV[1] ($mg/m^3$) | Class of pesticide |
|---|---|---|---|---|
| *Poverty Bay*[2] | *Atrazine* | *37* | *2* | *Triazine* |
| | *Diazinon* | *0.03* | *10* | *Organophosphate* |
| | *Chlorpyriphos* | *0.03* | *70* | *Organophosphate* |
| *Te Puke*[2] | *2,4-D* | *0.05–0.1* | *30* | *Phenoxy* |
| *Pukekohe*[2] | *Procymidone* | *1.7* | *700* | *Dicarboximide* |
| | *Unidentified* | *Trace* | | *Organochlorine* |
| *Motueka*[2] | *Unidentified* | *Trace* | | *Organophosphate* |
| | *Pirimiphos methyl* | *0.06* | *100* | *Organophosphate* |
| *Oamaru*[2] | *Unidentified* | *Trace* | | *Organophosphate* |
| *Canterbury*[3] | *Simazine* | *0.01–0.78* | *2* | *Triazine* |
| | *Atrazine* | *0.01–0.31* | *2* | *Triazine* |
| | *Terbuthylazine* | *0.07* | *20* | |
| *Marlborough*[4] | *Simazine* | *1.3–1.6* | *2* | *Triazine* |
| | *Mecoprop* | *2.4–3.2* | *10* | |
| | *Phenylphenol* | *0.1–2.3* | | |
| | *Clorophene* | *2.1* | | |
| *Taranaki*[5] | *Metalaxyl* | *2.4* | *200* | |
| | *Simazine* | *0.1–0.3* | *2* | *Triazine* |

[1] *Maximum Acceptable Values (MAV) stipulated by the Ministry of Health (1995c)*
[2] *Wells sampled by Close (1991)*
[3] *Wells sampled by Canterbury Regional Council (1995)*
[4] *Wells sampled by Marlborough District Council (Close, 1994)*
[5] *Wells sampled by Taranaki Regional Council (Evans, 1995)*

The first National Assessment of Pesticides in Groundwater was carried out in 1990 and 1991. It focused on 17 areas where the risk of contamination seemed highest because of high pesticide usage, permeable soils and shallow groundwater (Close, 1993a and 1993b). A total of 82 wells were sampled of which only nine (11 percent) had detectable pesticide levels and only one (1 percent) exceeded the maximum acceptable value (MAV) for drinking water (Ministry of Health, 1995c). The contaminated well, which had nearly 20 times the allowable concentration of atrazine, was shallow and adjacent to a maize field. Three of the other wells where pesticides were detected had such low concentrations that the pesticide could not be identified and two had a pesticide which was identifiable (2,4-D), but at levels that were too low to measure accurately. The districts surveyed were: Pukekohe, Te Puke, Poverty Bay, Motueka, Ashburton, and Oamaru.

The second National Survey of Pesticides in Groundwater was carried in 1994. Again the shallower, more vulnerable, aquifers were targeted, and the results were very similar to the first survey. This time, out of a total of 79 wells, 13 (17 percent) had detectable pesticide levels, most of which were well within acceptable limits (Close, 1995). Because these were the high risk groundwaters, it is likely that the percentage of other groundwaters with detectable pesticides is very low indeed. This conclusion has been borne out in several regional studies.

Canterbury Regional Council has carried out the most extensive monitoring for pesticides, beginning in 1988. However, pesticides have only been detected in one part of the region—the Levels Plain and Temuka area which cover about 10,000 hectares (Smith, 1993a and 1993b). Virtually all samples were well within acceptable limits, and the only high reading was attributed to point source contamination (Smith, 1994). Unlike other parts of Canterbury, the district has a unique combination of features which predispose it to pesticide leaching. These include: thin soils; a thin unconfined aquifer close to the surface; numerous pits and irrigation channels; the application of pesticides just before the irrigation season; and irrigation water forming the dominant water source for the aquifer.

Marlborough District Council surveyed groundwater quality in the Wairau Plains in May 1994 and again in June 1994 and found that only 2 wells (6 percent) of the 33 wells sampled had detectable pesticide levels on both occasions. Both were within the acceptable levels. One was beneath a vineyard and the other was near a landfill. Two other wells had detectable pesticide levels in one of the two surveys, and these were well below the acceptable levels (Close, 1994).

Taranaki Regional Council surveyed 30 sites in 1995 and found only one (3 percent) with detectable pesticide residues (Evans, 1995). Two other Taranaki sites were included in the national survey of high risk groundwaters and one of these had detectable pesticide residues. The low result is not too surprising, as Taranaki has the lowest pesticide use of any region in New Zealand (Wilcock, 1989).

**The State of our Drinking Water**

Probably the most immediate water quality concern for New Zealanders is the quality of their drinking water. Since 1960 when the former Board of Health began grading New Zealand drinking-water supplies, the safety of many supplies was found to be suspect. In 1991, a quarter of the supplies surveyed failed to meet the Department of Health's microbiological standards (Walker, 1993). In 1992 and 1993, several small communities were advised to boil water because of microbiological contamination of their supplies (Public Health Commission, 1994). In 1994, at least 8 percent of the population were served by unsafe water supply systems while a further 35 percent had supply systems of unknown status because they were inadequately monitored (Ministry of Health, 1995a and 1995b).

The Ministry of Health grades water supplies by assessing the quality of the original water source and the ability of the treatment system and water pipes to prevent contamination. The results are published four times a year in the *Register of Community Drinking Water Supplies in New Zealand* which is available at public libraries. The latest survey shows that New Zealand has 1,638 community drinking water supplies, serving 85 percent of the population (Ministry of Health, 1997). Of these supplies, 7 percent (serving 54 percent of the population) are considered safe and are graded A or B. A further 2 percent (serving 5 percent of the population) are of borderline safety and are graded C.

However, 19 percent of supplies (serving 18 percent of the population) provide an unsatisfactory level of protection against contamination and are graded D or E. The D and E gradings do not mean the supplies are actually contaminated, merely that the risk is high. Most of these high risk water supplies serve small communities, though four serve cities of over 20,000 people (Dunedin, Timaru, Nelson and Wanganui). The remaining 71 percent of community water supplies (serving 8 percent of the population) have not been graded because they are in communities of less than 500 people. Approximately 15 percent of the population are not connected to community supplies.

The Ministry of Health gradings focus on the adequacy of the supply system rather than the actual quality of drinking water as it comes out the tap. However, some data on drinking water quality does exist. Reviews of data gathered in the 1980s show that concentrations of some common chemicals exceeded the standard guidelines in a significant percentage of water supplies. One review found that 82% of samples failed to comply with at least one guideline value (Mattingley, 1992; Nokes, 1992; Public Health Commission, 1994). Common failings were excessive levels of: aluminium (in 20% of supplies), copper (in 31%), turbidity (25%), and potentially carcinogenic trihalomethanes (26% of chlorinated supplies) and all were a result of poor water treatment. Two thirds were outside the recommended pH range of 7.4 to 8.5 (Public Health Commission, 1994).

One chemical that is excessively low in many water supplies is fluoride. Nutritionists recommend a daily fluoride intake of 0.9 to 1.1 parts per million (ppm) to minimise tooth decay. Because New Zealand waters have unusually low fluoride concentrations (ranging between 0.1 and 0.3 ppm), many local authorities add fluoride to water supplies to improve dental health. In the early 1990s, some 84 water supplies, serving around 50% of the population, were fluoridated but nearly half these (44%) were below the recommended level (Public Health Commission, 1994).

**Box 7.10**

***Giardia in New Zealand waters***

*Giardia lamblia* is a single-celled protistan parasite that lives in the intestines of warm-blooded animals, including humans, and is passed on through water, hands or food that have been contaminated by faeces. Once expelled from the body, it survives by enclosing itself in a protective cyst until swallowed by another host (Ryan, 1991). *Giardia* is of interest to scientists for two reasons. First, it is the most primitive living organism after the bacteria and may be the common ancestor of all higher organisms (Day, 1994). Second, in our particular species of higher organism, it can cause a nasty illness (giardiasis) which may last for months. Although up to 80 percent of infected people show no symptoms, a minority experience severe diarrhoea, stomach cramps, bloating, dehydration, nausea and weight loss. The illness is most common in children under five years and those in close contact with them.

*Giardia* received a great deal of attention during the early 1990s, when the first test results showed it to be widespread in New Zealand waters (Ampofo *et al.*, 1991). Monitoring in 1990, found cysts in 33 percent of water samples (135 of 412). Concentrations ranged from 1 cyst per 10 litres in some streams to 450 cysts per 10 litres in the worst infected water. However, it takes about 10 cysts to infect a person, so the risk in most New Zealand waters appears to be quite low. Although the parasite has been identified in some high-use parts of national and forest parks, and several trampers have contracted giardiasis, the highest infection rates seem to be in urban regions where, ironically, water supplies are most thoroughly protected against *Giardia* (e.g. Auckland). This suggests that infection is spread more through person to person, and animal pet to person contact, than through water.

Giardiasis was first detected among returning servicemen in the 1940s. Like other food and waterborne diseases, it now seems to be on the increase. By 1993, the number of laboratory-identified cases had risen to 2,882, or 85 per 100,000 people, which is high compared to the reported rates for other western countries (van Duivenboden and Walker, 1993). Because it is not a notifiable disease, many cases probably go unreported. The most common notifiable food and waterborne diseases are campylobacteriosis (8,101 cases in 1993) and salmonellosis (1,340 cases in 1993) which are both caused by bacteria.

*Cryptosporidium* is another disease-causing micro-organism. It is a slightly more advanced protist than *Giardia*, and may turn out to be a more significant health risk. The extent of its distribution in New Zealand waters and water supplies is unknown because the cysts are small and difficult to detect. The infective dose of *Cryptosporidium* is not known, but may be as low as one cyst. Public water supplies are not permitted to contain even low concentrations of bacteria and infectious protists (Ministry of Health, 1995c). As a result, most (but not all) urban water supplies have treatment systems which remove organisms such as *Giardia* and *Cryptosporidium*. Most supplies with substandard treatment are currently being upgraded.

Local authorities and other public water suppliers, are required under the Health Act to monitor the state of their water to ensure that it is safe to drink. Several of the largest authorities carried out monitoring programmes which met or exceeded the requirements of the former Health Department's 1984 Drinking Water Standards, but monitoring by many of the smaller authorities was quite inadequate. To supplement the authorities' monitoring, the Ministry of Health carried out a surveillance programme which drew on microbiological data from Crown Health Enterprises but also contracted the Institute of Environmental Science and Research (ESR) to monitor the chemical and physical quality of drinking water.

Since 1992 the Ministry of Health has undertaken a programme to improve water quality management. This has involved the review of management procedures and of legislation relating to the public health aspects of drinking water. It has also involved the revision of public health grading procedures for community drinking water supplies, the development of an accessible national drinking water database and the publication of *Guidelines for Drinking-Water Quality Management*, *Drinking Water Standards for New Zealand 1995* and the *Register of Community Drinking-Water Supplies in New Zealand*.

The 1995 Drinking Water Standards include a number of features that were not in the previous standards. Under these new procedures, community water supplies are graded according to the degree to which they can show that both their drinking water and their treatment systems are safe from a public health point of view and will continue to remain so. Because the previous grading criteria were based principally on the quality of the source water and the nature of treatment and management, the grading given did not always reflect the actual quality of the tap water. The programme has significantly improved the quality of information on New Zealand's drinking-water supplies and stimulated many water supply authorities to upgrade their monitoring and their treatment systems.

**The State of our Coastal and Marine Waters**

The harbours, estuaries and coastal waters around New Zealand receive the outflow of hundreds of rivers, the stormwater run-off from many towns and cities, and sewage from both rivers and coastal outfalls. They also receive spillage and effluent from vessels. Coastal water monitoring by regional councils is generally confined to bathing and shellfish gathering areas and, in general, the results show that our coastal water quality is high. Harmful micro-organisms are relatively uncommon and shellfish from most locations can be safely eaten.

Coastal swimming areas have better water quality than many river sites (see Box 7.7). However, coastal water near river mouths, in some harbours and estuaries, and near outfall pipes is unsuitable for shellfish gathering (e.g. Wellington's Moa Point), and in rare cases (e.g. the Whanganui River estuary) may be unsuitable for bathing. Nutrient enrichment of coastal areas from land-based sources is likely to be significant. The impacts of this are largely unknown in coastal water, but recent blooms of sea lettuce (a native seaweed) in Tauranga Harbour, have been attributed to increased nutrient inputs in combination with other factors such as favourable substrate, and temperature (Hawes, 1994). The outbreak of toxic algal blooms may also be partly nutrient-related. In recent years, these blooms have become a recurrent problem in some coastal areas (see Box 7.11).

The coastal waters that have probably been most affected by pollution and human activities are the estuaries. Most estuaries have people living on or near them and six have cities in excess of 80,000 people (Burns *et al.*, 1990). Estuaries have also been affected by the management of surrounding land and tributary rivers. For example, a small number have been converted from freshwater to saline coastal estuaries (e.g. Maketu in the Bay of Plenty) or brackish lagoons (e.g. Matata and Whakaki) by the removal of their rivers of origin for flood control purposes. Most of these are now the subject of expensive rehabilitative works. Many other estuaries have had water quality problems arising from the surrounding land uses.

No recent assessment of the nation's estuaries has been undertaken, but an impressionistic survey of estuarine pollution status was undertaken by the New Zealand Ecological Society 20 years ago through a questionnaire sent to local authorities (McLay, 1976). Of the 162 estuaries for which replies were received: 62 (38 percent) were described as 'clean'; 67 (41 percent) as 'slightly polluted'; 26 (16 percent) as 'moderately polluted'; and 7 (4 percent) as 'grossly polluted'.

The problem estuaries included Waitemata Harbour, Manukau Harbour, Kaipara Harbour, Tauranga Harbour, Porirua Harbour, Wanganui River mouth, Ahuriri Estuary, Pauatahanui Inlet, Wellington Harbour, Waimea Inlet (Nelson), Brooklands Lagoon and the Waimakiriri River mouth, Avon-Heathcote estuary, Lyttelton Harbour and the New River Estuary (Invercargill).

In the decade following the Ecological Society survey, contamination levels in a number of estuaries were scientifically measured (Smith, 1986). Heavy metals and toxic organic chemicals were found near several large urban areas, though levels were generally well below those found overseas (e.g. Manukau, Waitemata and Tamaki near Auckland, the Waiwhetu Stream near Petone, Christchurch's Avon-Heathcote estuary and also Whangarei). Since then, point source discharges have been considerably improved in many areas and measures have been taken to restore water quality in many harbours, such as Whangarei (see Box 7.13). However, no national assessment has been made of estuarine water quality.

**Box 7.11**

### *The toxic algae menace*

New Zealand's first outbreak of shellfish poisoning occurred in the summer of 1992 and lasted through the early months of 1993 (Jasperse, 1993). It began when two cats in Whangarei showed symptoms of poisoning after eating shellfish. Their owners, who had also eaten shellfish, showed similar symptoms. More cases came to light. By the end of January more than 130 cases had been diagnosed, most of them in the top half of the North Island, and the nation's entire coastline was closed to shellfish gathering. The shellfish industry suffered no long-term economic effects, but was brought to a temporary halt with around 1,000 workers laid off for some months. By May the final tally of human poisonings had risen to 187, none of them fatal.

Although most concern focused on the impacts on human health and commercial shellfish, other environmental effects were also reported, though not all could be definitely attributed to toxic algae. In Northland, thousands of dead shellfish were washed up along five kilometres of coast north of Mangawhai Heads. Dead paua, kina, octopus, whelk, sea slug and chiton were found at Bream Bay. In Hawke Bay, paua, cat's-eye and paddle crab were found dead at Kairakau Beach. Dead pipi were reported from New Plymouth, and dead cockles, tuatua, and turret shells from Te Horo, near Wellington. Paua and pipi were found dead at Gore Bay and Robinson's Bay near Kaikoura. In Southland dead toheroa were washed up at Oreti beach. Little blue penguin deaths were reported from various coastal locations, mostly from East Cape to Northland. Poisoned gulls and shags were found in both the North and South Islands. In May, 300 sooty shearwaters were found dead near Christchurch.

The shellfish poisoning had been triggered by a spate of 'algal blooms' in our coastal waters. The blooms contained billions of marine algae—microscopic organisms which are normally invisible to the naked eye—whose populations had exploded to densities of more than 100,000 per litre, to form red, brown and green patches in the sea. The prime offender was identified as a species of dinoflagellate called *Gymnodinium breve*. This algae produces a substance called brevetoxin which causes Neurotoxic Shellfish Poisoning (NSP). Symptoms include respiratory problems, diarrhoea, muscular weakness and changes in skin sensitivity which sometimes cause a reversal of temperature sensations so that hot water seems freezing and cold water seems hot.

The toxin had entered the food chain when algae were ingested by filter-feeding shellfish such as mussels, oysters, scallops and clams and by algal grazers such as paua. Humans became infected by eating the shellfish or simply by inhaling sea spray which contained broken cells of *Gymnodinium breve*. *Gymnodinium breve* was not found south of New Plymouth or the Bay of Plenty. Other illnesses reported south of there may have been caused by some other type of shellfish toxicity, or may have been unrelated to the consumption of shellfish. Extensive blooms of other toxic algae, including species from another dinoflagellate genus, *Alexandrium*, were found around the lower North Island and off the north, south and east coast of the South Island at this time, but it is not known whether they caused the reported illnesses.

The outbreak caught the country by surprise. The only monitoring being done was a small industry-funded programme set up just six months earlier in the four main commercial shellfish areas. The need for more extensive monitoring had not been recognised because, although there had been occasional reports of fish kills and slime outbreaks going back to 1860 (including a serious outbreak in 1982 and 1983 from Northland to the Bay of Plenty), shellfish poisoning of humans was unknown or unrecognised in New Zealand. During and after the crisis, many theories were put forward to explain the sudden surge of toxic blooms. Some blamed nutrient pollution. Others blamed ballast water discharged from foreign ships (Baldwin, 1993). Shortly before the crisis in 1992, for example, in a report on the threats posed by ballast waters, the Ministry of Agriculture and Fisheries noted that toxic dinoflagellate algae were currently unknown in our waters, but that *Gymnodinium* and *Alexandrium* had recently been found in Australian waters (Ministry of Agriculture and Fisheries, 1992). The implication that these species may have arrived in foreign ships cannot be proven. Some scientists argue that the algae may have lain here unnoticed all the time and that their sudden blooming was caused by the unusual weather conditions associated with El Niño (Chang, 1993).

Whatever the explanation, the crisis was not an isolated event. Less extensive blooms occurred in subsequent summers and throughout the year in parts of Northland (Mackenzie, 1994; Mackenzie *et al.*, 1995). The blooms will continue to occur whenever temperature and currents are favourable. Worldwide, in fact, blooms appear to be increasing (Anderson, 1994). Although less than two dozen of the world's 27,000 formally identified species of marine algae are known to be toxic to humans, they pose a constant threat to coastal marine life and to people who gather and eat shellfish. To reduce the risk, shellfish and phytoplankton are now monitored regularly around our coastline.

**Box 7.12**

***Cleaning up Whangarei Harbour***

Like many other harbours in New Zealand, Whangarei Harbour used to receive raw and partially treated wastewater, uncontrolled stormwater, and industrial wastes. Also, like many other harbours, there has been a prolonged and concerted effort by the Northland Catchment Commission and then the Northland Regional Council, to improve the quality of discharges to the harbour, or to divert them wherever possible. Between Whangarei City and the Whangarei Heads there are many beachfront settlements, such as Parua Bay and McLeod Bay. Other than parts of Parua Bay, these settlements are unsewered and the on-site wastewater treatment and disposal systems they contain sometimes contribute to the faecal contamination of the harbour waters. In 1994, the District Council commissioned a study which identified options for wastewater disposal over the next 25 years for 13 communities or sets of communities in the district. As a result, it is expected that this source of contamination will be significantly reduced.

In the late 1980s, the Whangarei Main Wastewater Treatment Plant was upgraded by the construction of additional secondary treatment stages, ultraviolet (UV) disinfection, and the country's largest wetland treatment system. As a consequence, water quality in the vicinity of the discharge from the plant has been significantly improved. For example, there has been a 10-fold reduction in median faecal coliform concentration of the waters in this area of the harbour. The closure of the Onerahi Wastewater Treatment Plant, the upgrading of he Okara Park pumping station to reduce overflows, and a sewer rehabilitation programme, have also had a beneficial effect on harbour water quality. The Marsden Point Oil Refinery wastewater collection and treatment system is quite sophisticated and is monitored closely. The cement works at Portland used what was called 'the wet manufacturing process'. In 1983, this was changed to 'the dry process', which ceased the discharge of 106,000 tonnes per annum of limestone washings into the Portland area of the harbour. This discharge had reduced water clarity over a large area of the harbour. Smothering of some of the shellfish beds and the disappearance of extensive areas of eelgrass were also attributed to the effects of the discharge. Since the conversion to the dry process, water clarity in the Portland area of the harbour has markedly improved and growths of eelgrass have re-established.

Recently, the Regional Council's attention has turned to controlling other discharges into the harbour, including those from slipways and boat maintenance areas, and the discharge from the main storage area at Port Whangarei. The Regional Council's farm wastes programme has reduced the impacts of dairy farm wastes on receiving water quality throughout the region, although there are only a few dairy units in the harbour catchment. It is expected that the result of all these activities has improved the harbour's water quality. A few years ago the clarity of the water was quite poor; boaties often could see only 1 metre into the water, but today it is possible to see the bottom through 10 metres. (Dall and Ogilvie, 1996).

The most comprehensive recent studies of estuarine contamination are probably those in the Auckland region which have found that, although there has been a steady fall in contamination from pesticide residues, such as DDT and chlordane, there has been a steady increase in concentrations of heavy metals (specifically lead, zinc and copper) and hydrocarbons (specifically polycyclic aromatic hydrocarbons, or PAHs). Heavy metal levels in the sediment of some estuaries and harbours exceed North American criteria for the protection of aquatic life. In fact, about half of Auckland's 3,500 hectares of coastal sediment have excessive concentrations of lead, zinc and copper, with circumstantial evidence of reduced animal diversity, elevated contaminant levels in shellfish and crustaceans, and changes in their growth or behaviour. The worst affected areas are estuaries or upper harbours that are sheltered from ocean currents (Auckland Regional Council, 1995).

The main source of these increasing contaminants is the motor vehicle. The heavy metals come from leaded petrol, tyres (zinc), and vehicle wiring (copper). PAHs come from vehicle exhausts. Like lead, they bind to particles of dust and sediment which are then washed into the stormwater system. At present, PAHs are not at levels which threaten aquatic life, but they are increasing (Wilcock, 1994). The banning of leaded petrol will probably lead to a slow decline in lead pollution, but if the other contaminants continue to be generated at present day rates, the proportion of contaminated estuarine sediment will expand from 50 percent to 70 percent by the year 2021 (Auckland Regional Council, 1994).

Waste disposal from boats is a problem in some areas. In 1994, for instance, the Tasman Bay oyster fishery had to be closed because of raw sewage discharges from Russian trawlers which were not covered by New Zealand regulations. Fishing industry sources estimate that approximately 45 percent of the total fish catch is waste material, much of which is thrown overboard. For example, some 50,000 tonnes of hoki offal are dumped into the sea each year by vessels fishing on the continental slope off the South Island West Coast. This has raised concerns that the decomposing waste could locally deplete oxygen levels (Livingston and Rutherford, 1988). A preliminary assessment confirmed that enough waste reaches the sea floor to alter the species composition (Grange, 1993).

Oil spills are also a frequent problem. In 1996 the Maritime Safety Authority received 84 reports of marine oil spills, most of them small. Of these, 18 (21 percent) were false alarms and only 12 involved spills of more then 100 kilograms. Only two of the reported spills released more than a tonne of oil, with the largest being 6.5 tonnes of marine diesel and lube oil. Despite the false alarms, these numbers probably under-represent the true frequency of oil spills, particularly small ones. The rate of spill reporting varied considerably between the first half of the year when only 15 spills were reported nationwide and the second half when 69 were reported at a rate of about 11 per month.

The dramatic change in spill reporting followed the completion of the Maritime Safety Authority's Marine Oil Spill Response Strategy, which formalised a national reporting procedure. The improved reporting rate was also associated with the development of regional and national oil spill contingency plans. Adjusting for under-reporting in the first half of the year, and false alarms in the latter, a truer minimum estimate of the number of spills in 1996 is probably around 104. However, even this figure is likely to be an under-estimate as many small spills still go unreported.

Non-biodegradable litter (e.g. plastic bags, wrappers, strapping and containers, aluminium cans, glass bottles, wire, synthetic ropes and nets), is a widespread problem, particularly near large urban areas (Gregory, 1991). Plastic items are by far the most common. The steady build up of plastic litter on the sea floor can inhibit gas exchange between sediments and overlying waters, thereby reducing oxygen levels and killing organisms that normally dwell there (Goldberg, 1995). Plastic items can also entangle or be swallowed by marine mammals, seabirds and turtles. In fact, they may be a greater cause of death among the world's marine mammals than oil spills, heavy metals, or other toxic materials. Plastic bags were found in the guts of three rare whales which stranded on the New Zealand coast in 1994, and Department of Conservation staff at Kaikoura get 20 to 30 callouts each year to seals caught with plastic strapping around their necks (Island Care New Zealand Trust, 1995).

Although boats are an important source of marine debris, a recent year-long study of Auckland's stormwater discharges found that 28,000 pieces of litter per day, or over 10 million items per year, mostly plastic, pour from Auckland's stormwater drains into Waitemata Harbour. This does not include small plastic granules which escaped the survey nets. Beach surveys in Auckland and Canterbury have found that marine litter increases near cities, confirming that stormwater is a major source. Compared with many other countries, New Zealand's marine debris contains less plastic and more cardboard and paper, fewer bottles but more food containers and wrappers, less boating waste and sewage waste but more plastic sheeting and strapping. It is predicted that, as coastal populations increase, marine debris is likely to worsen (Island Care New Zealand Trust, 1995).

Sediment washed down from eroding hillsides and riverbanks is believed to be having an impact on the water and marine life of harbours and estuaries. In the South Island, the loss of reef sponges, kelp forests, weed beds, and the disappearance of fish nursery grounds has been linked to increased coastal sedimentation (Royal Society of New Zealand, 1993). The disappearance of seagrasses in harbours and estuaries has also been attributed to declining water clarity, which is caused by sedimentation (Turner, 1995).

Deforestation by early Maori communities appears to have led to a three- or four-fold increase in estuarine sedimentation in some areas (Hume and McGlone, 1986). Modern patterns of land use have continued the process. In the past hundred years, intertidal sediments have been accumulating at a rate of 3–6 millimetres per year in sandy estuaries (e.g. Nelson Haven, Pauatahanui Inlet, and Tairua Harbour) and 2–5 mm per year in muddy ones (e.g. Waitemata and Manukau Harbours) (Burns *et al.*, 1990). This amounts to a sediment layer 20-60 cm deep deposited in our estuaries.

Another source of sediment is coastal erosion, which is also a problem in populated coastal areas because it creates a hazard for houses and roads that have been built too close to the shoreline. Although most of the coastline is static, an estimated 20 percent is eroding, while about 15 percent is extending, or accreting, into the sea (Gibb, 1984; Hicks, 1990) (Figure 7.22). The accreting areas are near river mouths where large sediment flows accumulate. The eroding areas tend to be on exposed beaches of sand and gravel with no sources of new sediment. Though largely a natural hazard, coastal erosion has been assisted in some areas by such human activities as aggregate mining of seabed, beaches and rivers, and by the removal or destabilisation of coastal foredunes. Threatened homeowners and beach communities often contribute to the problem by erecting sea walls and barriers of concrete and boulders whose reflected waves can intensify the scouring action.

On a global scale, the human-influenced 'greenhouse effect' may be influencing marine water quality in several ways. In the past century, average temperatures have risen by half a degree and New Zealand's sea level has risen by 15 centimetres, or an average of 1.5 millimetres per year (Hamilton, 1992). This may be contributing to the spread of invasive seaweeds and toxic algae, altering the distribution and composition of marine life around the coasts, and exacerbating coastal erosion by causing sea levels to rise (Hicks, 1990).

In summary, although a variety of human-induced pressures are known to have localised impacts on our coastal waters, pervasive widespread impacts have not been documented to date, though some are suspected. In general, our coastal waters are of high quality by international standards but are under stress in some areas, particularly near the larger estuarine towns and cities. Beyond the coastal zone, very little is known about the status of the sea water environment.

## SOCIETY'S RESPONSES TO PRESSURES ON OUR WATER ENVIRONMENT

The first rules for water use were developed by Maori communities to prevent spiritual and physical pollution of food-gathering areas. The rules were often elaborate and varied from place to place. Concern about both forms of pollution is still important to Maori and was highlighted in the 1970s and early 1980s in a number of successful actions to stop sewage being discharged near traditional fishing and food-collecting areas.

In the first century of European settlement, miners, farmers and townspeople alike were more concerned with controlling the quantities of water than with worrying about its quality. Early water legislation included the Gold Fields Act 1862, which dealt with water use for alluvial gold mining, the Canterbury Rivers Act 1868, which was the first of many dealing with flood control, and the Drainage Act 1906, which concerned wetland drainage for agricultural purposes. Other concerns were ensuring adequate supplies of drinking water, obtaining irrigation water and identifying sites for hydro-electric development.

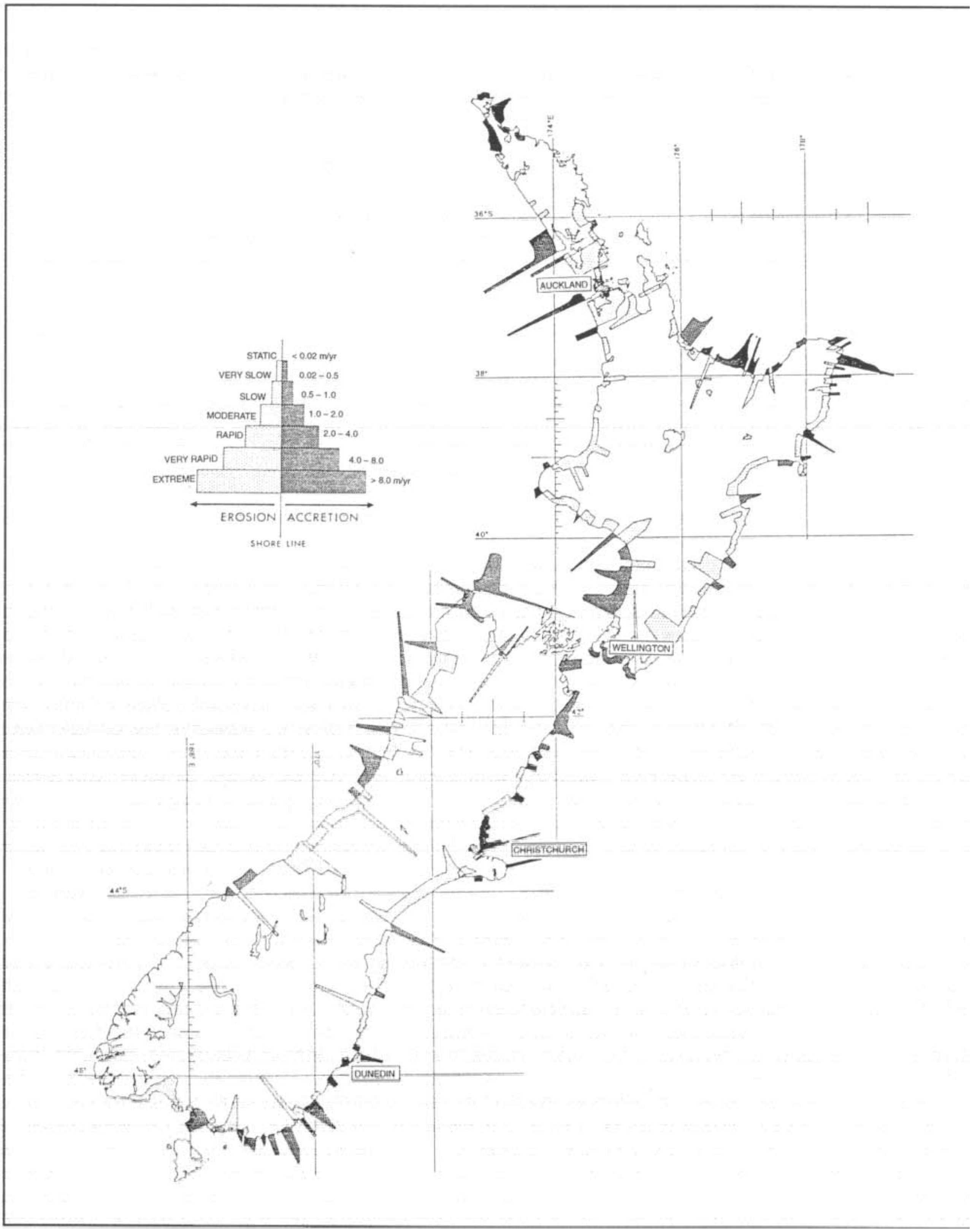
By the 1950s, however, the effects of sewage, industrial discharges and agricultural runoff were becoming all too visible in many rivers and streams. In the following decades of growing environmental awareness, concern about water quality became widespread. Today, it is an important element of our environmental legislation.

### Water management responsibilities

Over the past fifty years, New Zealand has developed more and more coherent responses to water management. The Soil Conservation and Rivers Control Act 1941 established a national system of 21 regional catchment authorities with responsibilities for controlling flooding, soil and riverbank erosion (Poole 1983; Roche 1994). These authorities worked

**Figure 7.22**

**Historical rates of erosion and accretion around the New Zealand coast.**




*Source: Ministry for the Environment (1990) after Gibb (1984)* with local landowners and communities to provide protection measures. Initially the measures dealt with localised problem sites, but eventually they began to extend to whole catchments. The catchment authorities received assistance in the form of technical support and funding subsidies from central government with oversight from a national board.

The Water and Soil Conservation Act 1967 extended the management role of catchment authorities to cover both the quantity and quality of water. For this role they were referred to as regional water boards. Scientific and technical support came from central government, including the establishment of specialist water and soil science research units. Water was managed on a multiple use basis and anyone wanting to take water from a natural body of water or discharge pollutants into it had to apply for a water right. Rights were generally granted by the regional water boards but large rights sought by the Crown were decided by the national body, the National Water and Soil Conservation Authority. The 1967 Act contributed to the dramatic decline in $BOD_5$ pollution from point source discharges but did little to assist with the problem of non point source pollution because it did not provide for statutory plans or the ability to constrain land uses to protect water quality or quantity.

In 1991, many of the existing water management laws were superseded by the Resource Management Act which made regional councils responsible for the sustainable management of natural and physical resources within their catchment boundaries, including surface water, groundwater, geothermal water, coastal water, and also land and air. The councils are required to maintain water quality and supply, both for human purposes and to sustain fish habitat, ecosystems and other intrinsically or culturally valuable features.

The Act requires regional councils to set out their overarching water management policies in Regional Policy Statements - statutory documents that aim to achieve integrated management of a region's natural and physical resources. The Council may also devise statutory plans for water with more detailed policies and rules where this is considered to be an effective way to deal with recurrent or significant issues.

Under the Act most activities on the beds of lakes and rivers, and the seabed, as well as most draw-offs of water and all discharges of wastes into water must have a resource consent from the relevant regional council or unitary authority, or be authorised (with certain conditions) by a rule in a regional plan. The only exceptions are: consumption of water by livestock; draw-offs for household use and for fire fighting; and the customary Maori use of geothermal water. The authorities also have some power to prescribe land use rules to limit pasture run-off and non-point source pollution, though most prefer to achieve these goals through informal advice and services.

Along with the decentralisation of water management has come the removal of government financial assistance for many activities which affect water supply and use. Agricultural subsidies were abolished (leading to a decline in sheep numbers and the reafforestation of some erodible hill areas) and grants, tax exemptions and subsidies were also ended for stock water supply, irrigation and drainage projects, and flood control and soil conservation programmes.

While the key management responsibilities are now vested in regional authorities, central government still plays a variety of roles in water management. For instance, the main priorities in coastal water management are established through the national Coastal Policy Statement which is issued by the Minister of Conservation (1994). This Statement guides regional authorities in the development of their coastal plans. These plans determine which activities in coastal waters are permitted and which need a coastal permit (see Box 7.13).

**Box 7.13**

***Water and the Resource Management Act 1991***

Although the Crown does not own water, it has the sole right to use water throughout New Zealand and up to 12 nautical miles offshore under section 354 of the Resource Management Act. Section 14 of the Act provides that anyone seeking to use water must be authorised by a resource consent from the regional authority or by a rule in a regional plan. Not all uses are restricted. Consents are not required for:

- individuals' domestic needs;
- livestock watering;
- firefighting; and
- geothermal water for uses consistent with Maori custom.

Section 15 of the Act requires that discharges of contaminants must be authorised by a resource consent, a rule or regulations. Minimum water quality standards outlined in section 107 prohibit, after reasonable mixing:

- conspicuous oil or grease scums, foams;
- conspicuous floatable or suspended material;
- conspicuous change in colour or visual clarity;
- objectionable odours;
- fresh water unsuitable for stock; and
- significant adverse effects on aquatic life.

The Resource Management Act has a special focus on coastal management. The Act requires regional councils to prepare regional coastal plans and requires the Minister of Conservation to produce a New Zealand Coastal Policy Statement (NZCPS). Regional plans must not be inconsistent with the NZCPS. The latter was gazetted in May 1994 and sets out specific policies on:

- preservation of natural character from subdivision, use and development;
- protection of characteristics of special value to Maori;
- provision for appropriate activities;
- recognition of natural hazards;
- public access to and along the coast;
- the Crown's interests in Crown owned coastal land;
- water quality management;
- sewage discharges (the policy statement discourages coastal discharges in favour of land disposal options);
- waste disposal from and maintenance of vessels; and
- restricted coastal activities (i.e. those requiring Ministerial approval on resource consent applications).

Outright protection is primarily the province of other acts (e.g. the Marine Reserves Act, the Reserves Act, the National Parks Act, and the Conservation Act) but some protection under the Resource Management Act can be achieved through policies and rules in a district plan (section 76), or a Water Conservation Order (sections 199 to 217). All decisions made under the Resource Management Act must, as a matter of national importance, recognise and provide for the preservation of the natural character of the coastal environment, wetlands, lakes, rivers, and their margins.

The Government also has responsibility for publishing national water quality guidelines and standards. To date, the Ministry for the Environment (1992,1994) has produced guidelines for undesirable biological growths and for water colour and clarity, and the Department of Health (1992) has produced guidelines for microbial water quality. National guidelines are not yet available on other aspects of water quality, such as contaminated sediments, environmental flows, in-stream habitat protection, riparian vegetation and agricultural pollution (Hart *et al.*, 1995). Other central government responsibilities in managing the water environment, include:

- the management of water in parks, reserves and other protected land and marine areas by the Conservation Department;
- the issuing of Water Conservation Orders by the Minister for the Environment to protect outstanding water bodies from harmful activities;
- the monitoring of drinking water supplies by the Ministry of Health and local authorities;
- the monitoring of toxic algae in coastal waters by the Ministries of Agriculture and Health;
- the management of commercial fisheries by the Minister of Fisheries in a way which sustains the aquatic environment and protects significant fishery habitat;
- the management of non-commercial freshwater fisheries by the Department of Conservation and Fish and Game Councils;

- the management of marine pollution, particularly large oil spills and those beyond the 12 nautical mile territorial boundary, by the Maritime Safety Authority; and
- the funding of research and development projects to improve water and soil management through the Foundation for Research, Science and Technology (FfRST) and various government departments. Industry and land user groups have also become increasingly active in promoting codes of practice for managing erosion and waste water disposal (e.g. Forest Owners Association, farmers' landcare groups, Pork Industry Board) and monitoring the marine environment (e.g. Fishing Industry Board).

## Responses to pressures on water

### *Pasture run-off and flooding*

Responses to flooding have traditionally focused on forests on steep public land and on controlling and containing flood-prone rivers with channels, stopbanks, and land drainage. Now attention is also focusing on the need to retain and reinstate tree cover (exotic or native) on steep pasture land and river banks. In one very erodible and flood-prone area, the north east of the North Island, the Government is subsidising exotic forest planting through the East Coast Forestry Scheme (see Chapter 8).

Some councils are developing rules through regional plans to help reduce the effects of forest and scrub removal on soil and water, and also, in some cases, the effects of reafforestation on surface water supplies (e.g. resource management plans for the Tarawera River in the Bay of Plenty and the Moutere Plain in the Tasman District). A side-effect of the economic restructuring of the past decade was a decrease in marginal pasture farming. This has been followed by a recent upsurge in forest planting.

### *Irrigation*

Water shortages for agriculture are no longer alleviated by large-scale Government-subsidised irrigation schemes. All existing schemes are now privately or cooperatively owned. New schemes are comparatively small scale. Since 1964, water abstraction has required the approval of the local regional waterboard. Under the Resource Management Act, a resource consent must be obtained from the regional council or unitary authority.

### *Agricultural pollution*

**Non-point sources** of agricultural pollution are broadly affected by the amount of treeless land on a farm and the amount of animal excrement. Formulating a policy response has been difficult because of the diffuse nature of the problem. Responses to date have had a research and advisory focus rather than a regulatory focus. Land use practices that exacerbate farm run-off have been identified and many regional councils advise land owners on methods of managing soil erosion and nutrient and waste run-off. Publications such as the Riparian Management Guidelines (Department of Conservation/NIWA, 1995) provide relevant scientific information and advice. Both the Ministry of Agriculture's Sustainable Agriculture Facilitation Programme and the Ministry for the Environment's Sustainable Management Fund provide funds for on-farm programmes to assess and help manage environmental effects of agriculture.

**Point sources** of pollution from agriculture are mostly from the processing of pastoral products and the discharge of farmyard effluent. $BOD_5$ loadings from these sources were significantly reduced in the 1970s and further reductions probably occurred in the 1980s as economic restructuring saw the closure of some processing facilities.

By 1993, only 15 of the country's 49 meatworks, and 15 of the 32 dairy factories discharged some or all their wastewater directly to rivers (Smith *et al.*, 1993). A sizeable number of meatworks, dairy processing factories and casein plants now dispose of some or all of their effluent onto land. The treatment of farm effluent from dairy sheds and piggeries has also improved with increasing use of land disposal and constructed wetlands. Many regional councils now encourage farmers to dispose of effluent onto land and to also manage the environmental effects.

Many resource user groups have also developed their own programmes or guidelines to manage the impacts of their activities on the environment. Some examples include Federated Farmers' promotion of cooperative farmers' landcare groups and the development of guidelines for sustainable agriculture, and the Pork Industry Board's code of practice for sustainable management. The New Zealand Forest Owners Association has developed a voluntary code of practice for forestry, which includes principles for reducing the impact of forestry operations on soil and water.

***Urban consumption***

In the past, the usual response to urban water scarcity has been to expand dam and reservoir capacity and draw more water from rivers and aquifers. Now several authorities are also attempting to limit consumption by promoting water conservation techniques, installing water meters, charging for water on a user-pays basis rather than a rates basis, and imposing summertime restrictions on garden watering. Wellington City Council, for example, has installed user-pays water meters at about one-third of the city's business premises and will install meters at the remainder over the next three years.

The council is also trialing user-pays in the suburbs with some householders being given the option of a water meter system. Most interest has come from those in higher value homes. They are the ones who stand to save money under a user-pays regime because, under the present rates-based system, payments are based on the capital value of the property rather than the household's actual water use. The council has also decided to make meters compulsory for home-owners with fixed irrigation systems, and for those with swimming and spa pools over 10 cubic metres.

The Ministry of Health's 1995 review of drinking water quality and management, and publication of new standards and guidelines on water management and monitoring have led to improved monitoring and some attempts to upgrade unsatisfactory systems.

***Sewage and stormwater***

From having almost no sewage treatment systems 50 years ago, New Zealand now has very few untreated systems. Wellington and Hutt City are the last major centres to make the conversion, and only a few small communities have yet to do so. An informal survey of sewage disposal methods in 1991 found that two thirds of the local authorities surveyed were reviewing or upgrading their systems (Shields, 1991).

Land disposal and disposal into constructed wetlands are becoming increasingly favoured options for sewage. In situations where land disposal is not feasible, some local authorities are planning and building more sophisticated treatment systems to provide better quality effluent. For example, the Kapiti Coast District Council (north of Wellington) has recently installed ultraviolet (UV) treatment to kill bacteria before effluent is discharged to a local waterway.

Stormwater management is controlled by local authorities through the provision of drains and through controls on new land use activities. Because of its diffuse nature, stormwater is difficult to manage and varies with location and land use. Vegetation changes, new buildings, new paving or roading and new excavation works can significantly change the flow and quality of stormwater. Blockage and leakage in drainage systems can lead to flooding or contamination and are major concerns for many authorities. Progressive local authorities are now retrofitting stormwater treatment systems into retail/industrial areas (for example, in Rotorua) and new residential areas (for example, in Ohope).

***Dams***

Responses to dam pressures on river flows and fish migration are dealt with by regional councils when deciding whether to issue consents for new dams. Nearly all resource consents for dam construction require residual flows to be maintained to protect aquatic life, and many also require fish passes to be built to allow the migration of fish. Regulatory authority for fish passage issues lies with the Department of Conservation. A number of dam proposals are being considered around the country. Hydro dams built prior to the Resource Management Act are generally governed by operating rules which set limits on maximum and minimum flows. The Electricity Corporation of New Zealand, which operates most of the hydro dams, has also sponsored research on ways to ensure fish passage through its dams.

***Pests and weeds***

Laws controlling the introduction of new aquatic organisms to New Zealand include the Biosecurity Act 1993 and the Hazardous Substances and New Organisms Act 1996. Proposals to import new species or to genetically modify existing species are generally subjected to a 'comparative risk assessment' before approvals are given. Freshwater pests and weeds are primarily the responsibility of regional councils, the Minister of Lands, and, within protected areas, the Department of Conservation.

Control of marine pests and weeds is very difficult because of the many ways in which they can enter the country. Only toxic algal blooms are routinely monitored. From 1993 until 31 October 1996, a monitoring programme for marine biotoxins was run by the New Zealand Marine Biotoxin Management Board (made up of representatives of the Ministry of Health, Ministry of Agriculture and Fisheries and the New Zealand Fishing Industry Board). The programme sampled shellfish weekly at an average of 120 coastal sites and cost about $3.2 million in the 1995/96 financial year. From 1 November 1996, separate commercial and public health (non-commercial) monitoring programmes were set up although data from both programmes will continue to be shared. The commercial programme is overseen by the Ministry of Agriculture and the public health programme by the Ministry of Health. The public health programme is introducing phytoplankton sampling as a partial replacement for testing of shellfish flesh where appropriate following a review of the shellfish testing data gathered to date.

Systematic national monitoring for other marine invaders has not yet been developed. Ships entering New Zealand territorial waters are not subject to any regulations on ballast water but are expected to comply with a voluntary Code of Practice which limits discharges in and near harbours. The percentage of vessels claiming to comply with the voluntary ballast controls is 'in excess of 98 percent', though the Ministry of Fisheries acknowledges that the true figure may be slightly lower (Alexander, 1995). If regulations are considered necessary, these could be imposed under provisions in the Biosecurity Act which empower inspectors to search vessels containing 'risk goods', and compels ship masters to obey all reasonable directions and information requests from inspectors regarding 'risk goods'.

#### *Marine pollution*

There are two major international agreements on marine pollution—the London Convention 1972, which sets minimum standards for the dumping and incineration of wastes at sea, and the MARPOL Convention 1973 which, together with its 1978 Protocol, specifies controls on the discharge of oil and oily mixtures, noxious liquid substances, sewage and garbage. For these conventions to be ratified, they must be incorporated into New Zealand law. At present the London Convention has been ratified, but regulations to ratify MARPOL are still being developed.

Recent amendments to the Resource Management Act have strengthened existing controls on pollution from ships and offshore installations. The dumping of wastes or other matter now requires a consent from the regional council and cannot be permitted by a general rule in a regional coastal plan. The regulations to implement MARPOL will be imposed under two different laws. Within the 12 nautical mile zone the regulations will be issued by the Minister for the Environment under the Resource Management Act and enforced by regional councils. Beyond this zone, they will be issued under the Maritime Transport Act and enforced by the Maritime Safety Authority.

Voluntary responses to coastal water quality problems are becoming increasingly important. Local community beachcare groups which deal with issues such as coastal erosion and the re-establishment of native coastal vegetation, are now established in many coastal communities in the North Island.

### The Protection of Natural Waterways

Protection of natural waterways is a shared legal responsibility of the Department of Conservation and the regional councils. The Department is responsible for managing natural waterways in national parks and reserves, collaborating with councils on coastal management, managing native freshwater fish populations and their habitats, and advocating protection for significant waterways which are not on conservation land.

Waterways on conservation land are legally protected from direct interference, but may be vulnerable to outside pressures, such as water removal for irrigation or livestock use, drainage and flood control projects, effluent and nutrients from sewage, stormwater or pastoral runoff, dams and other barriers to water or fish movement (e.g. tide and flood gates), and invasion by exotic plants and livestock from surrounding lands. Managing these pressures requires cooperation between the Department, the councils and the surrounding land and water users.

Waterways that are not on conservation land can be protected by regional and district councils through rules in plans which prohibit damaging activities. Such activities are only permitted subject to a resource consent whose special conditions limit the activities. Section 6(a) of the Resource Management Act requires the councils to recognise and provide for the preservation of the natural character of the coastal environment, wetlands, lakes, rivers and their margins. Most councils now require resource consents for water abstractions, drainage and flood control, point source discharges of effluent, and the damming or obstruction of water movement. However, the more pervasive pressures from livestock, stormwater, pasture run-off and invasive weeds are more difficult to control without voluntary efforts by land and water users. Where appropriate, the Act also allows the Minister for the Environment to impose Water Conservation Orders and Heritage Protection Orders on water bodies which are not on conservation land, but which are of outstanding environmental or cultural significance.

### *Rivers and lakes*

In 1969, the desire to preserve natural waterways led to a huge public campaign to protect Lakes Manapouri and Te Anau from hydroelectric development—the first truly national environmental campaign. A quarter of a million people signed a petition which helped persuade the government to limit the extent to which the lakes could be artificially raised (Peat, 1994). A similar campaign to prevent the flooding of the Cromwell Gorge for the construction of the Clyde dam was less successful.

Nevertheless, the public's strong desire to protect wild and scenic rivers and lakes culminated in the 1981 'Wild Rivers' amendment to the Water and Soil Conservation Act 1967, establishing Water Conservation Orders as a means of protecting water bodies. This provision is now contained in the Resource Management Act 1991. To qualify, a lake or river must have outstanding amenity values (e.g. fishing, scenery, canoeing) or intrinsic values (e.g. special ecosystems or species). To date, eight Water Conservation Orders have been granted under the 1967 Act, covering less than 1 percent of New Zealand's river and lake area. None have been granted as yet under the Resource Management Act , but a number are pending (Table 7.13).

**Table 7.13**
**Current Water Conservation Orders and those under consideration.**

| Water Body | Outstanding Features | Year Granted |
|---|---|---|
| *Motu River* | *Natural character* | *1984* |
| *Ahuriri River* | *Wildlife habitat, fishery* | *1990* |
| *Rakaia River* | *Natural character, habitat, fishery, recreation* | *1988* |
| *Mataura River* | *Fisheries* | *Pending* |
| *Rangitikei River* | *Scenic character, recreation, fishery* | *1993* |
| *Lake Wairarapa* | *Wildlife habitat* | *1989* |
| *Lake Ellesmere* | *Wildlife habitat* | *1990* |
| *Manganuioteao River* | *Natural character, scenic, wildlife, fishery* | *1989* |
| *Grey River* | *Natural character* | *1991* |
| *Buller River* | *Natural character, fishery, recreation* | *Pending* |
| *Mohaka River* | *Natural character, fishery, cultural* | *Pending* |
| *Motueka River* | *Scenic character, cave system, fishery* | *Pending* |
| *Kawarau River* | *Natural character* | *Pending* |

***Wetlands***

Some of the lakes and rivers covered by Water Conservation Orders include significant wetlands (e.g. Lakes Ellesmere and Wairarapa and the Ahuriri River). However, the main responsibility for protecting wetlands lies with the Department of Conservation and the regional councils. The Department and at least one council (Taranaki) maintain wetland databases. Wetland protection can be achieved through rules in District Plans limiting harmful activities, voluntary arrangements with users, and outright purchase from owners.

A National Policy on Wetlands was approved by the Government in 1986 but was largely ignored and is now being reviewed by the Department of Conservation. The mid-1980s decision to end Government funding of irrigation, flood control and drainage schemes may have slowed some pressures on wetlands. Small-scale drainage continues to occur in a number of areas, particularly where dairy farming is expanding or intensifying, but new large-scale drainage schemes were virtually non-existent by 1994 (Ministry of Agriculture, 1994).

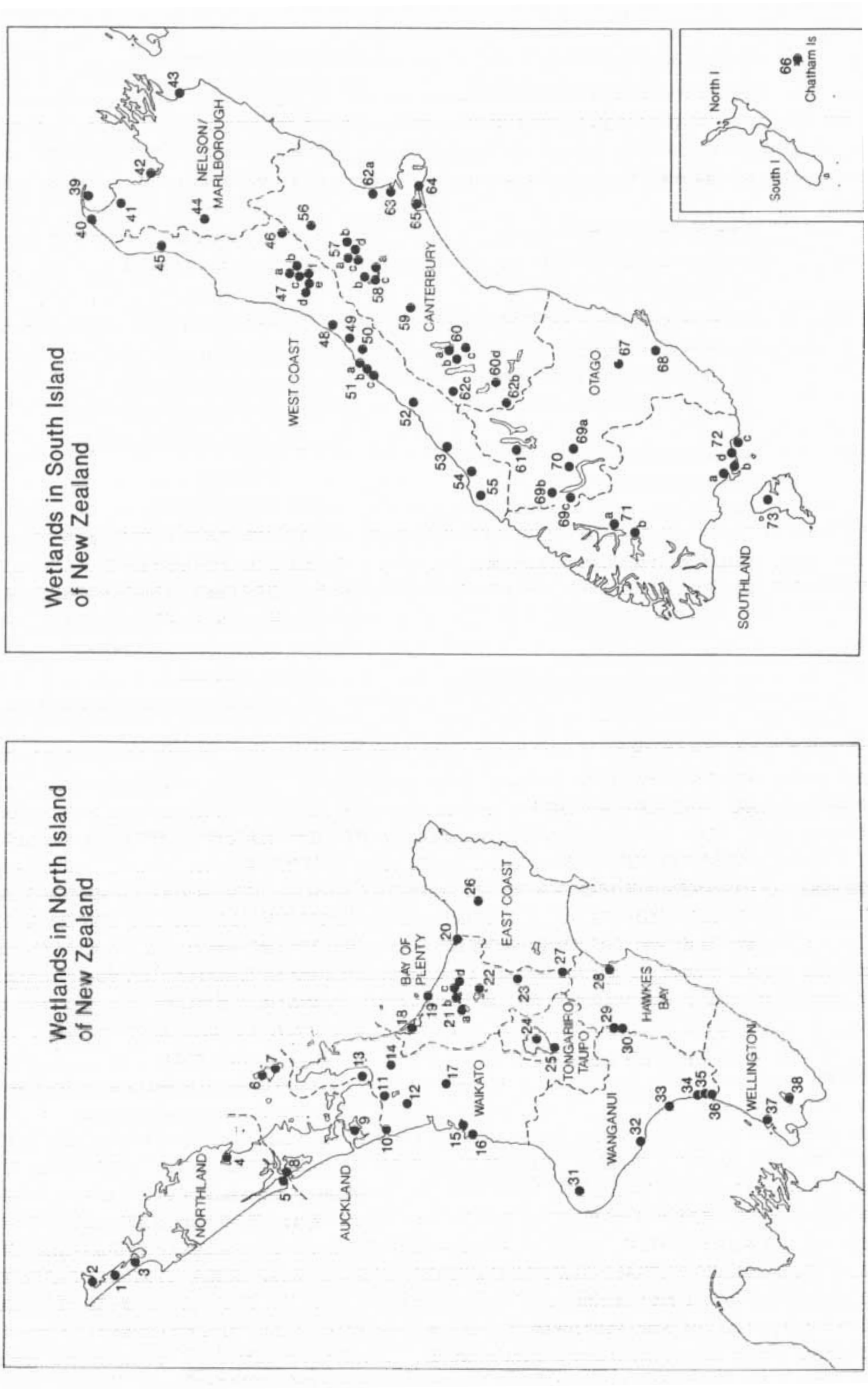
Five of the largest surviving wetlands have been designated as wetlands of international importance for wildfowl habitat under the Ramsar Convention. This convention, which New Zealand ratified in 1976, requires governments to identify at least one representative wetland within their territories that is of international importance, particularly as waterfowl habitat. The five listed wetlands are mostly under Department of Conservation protection or stewardship. They are:

- the Firth of Thames tidal estuary (Waikato) - 7,800 hectares;
- Whangamarino Wetland (Waikato) - 5,690 hectares;
- Kopuatai Peat Dome (Waikato) - 9,665 hectares;
- Farewell Spit (Nelson) - 11,388 hectares; and
- Waituna Wetlands Scientific Reserve (Southland) - 3,556 hectares.

Many more of our wetlands meet Ramsar Convention standards for international quality and are in the process of being listed with the Ramsar Bureau. The Department of Conservation has recently published an inventory describing 73 of these, including the five already listed (Cromarty and Scott, 1996) (see Figure 7.23). A Ramsar listing does not automatically confer protection on a wetland, but it does raise their significance when decisions affecting them are made by government and local authorities.

Many wetlands, including parts of the Ramsar ones, are privately owned or are grazed by livestock from adjacent farmland. Protection measures therefore require cooperation from surrounding landowners. Apart from the Ramsar process, the Protected Natural Areas Programme also seeks to identify wetlands needing protection. A detailed inventory of significant wetlands (WERI) is maintained by the Department of Conservation.

**Figure 7.23**
**Significant wetlands in New Zealand**




*Source: Cromarty and Scott (1995)*

**Key to significant wetlands**

**Northland Conservancy**
1 Aupouri Peninsula Wetlands
2 Parengarenga Harbour
3 Muriwhenua Wetlands
4 Whangarei Harbour
5 Pouto Peninsula Wetlands

**Auckland Conservancy**
6 Whangapoua Wetlands
7 Kaitoke Swamp
8 Kaipara Harbour
9 Manukau Harbour

**Waikato Conservancy**
10 Lower Waikato River and Estuary
11 Whangamarino Wetland
12 Waikato Lowland Lakes and Mineralised Swamp Lands
13 Firth of Thames
14 Kopuatai Peat Dome
15 Kawhia Harbour
16 Taharoa Lakes
17 Waipa Peat Lakes

**Bay of Plenty Conservancy**
18 Tauranga Harbour
19 Maketu-Waihi Estuaries and Kaitena River Mouth Complex
20 Ohiwa Harbour
21 Kaituna Catchment Lakes and Wetland Complex
21a Lake Rotorua
21b Lake Rotoiti
21c Lake Rotoehu
21d Lake Rotoma
22 Upper Tarawera Catchment Lakes and Wetland Complex
23 Arahaki Lagoon

**Tongariro/Taupo Conservancy**
24 Lake Taupo
25 South Taupo Wetland

**East Coast Conservancy**
26 Motu River Catchment
27 Mohaka River and Tributaries

**Hawke's Bay Conservancy**
28 Ahuriri Estuary and Associated Wetlands Wanganui Conservancy
29 Reporoa Bog
30 Makirikiri Tarns

**Wanganui Conservancy**
31 Ahukawakawa Swamp
32 Hawkens Lagoon
33 Whangaehu River Mouth Dune Hollows
34 Pukepuke Lagoon
35 Lake Kaikokopu and Lake Koputara
36 Manawatu River Mouth and Estuary

**Wellington Conservancy**
37 Taupo Swamp
38 Lake Wairarapa Wetlands

**Nelson/Marlborough Conservancy**
39 Farewell Spit
40 Whanganui Inlet and Mangarakau Swamp
41 Waikoropupu Springs and Takaka Marble Aquifer
42 Waimea Inlet
43 Wairau Lagoons
44 Buller River Catchment

**West Coast Conservancy**
45 Karamea Estuary
46 Lake Christabel
47 North Westland Ecological Region Complex
47a Lake Hochstetter
47b Lake Ahaura
47c Lake Haupiri
47d Lake Brunner
47e Lady Lake
47f Kangaroo Lake
48 Groves Swamp and Harman Swamp
49 Shearer Swamp
50 Lake Ianthe
51 Whataroa Ecological Region Coastal Wetland Complex
51a Saltwater Lagoon
51b Waitangiroto Lagoon and Swamp
51c Okarito Lagoon
52 Ohinetamatea Swamp
53 Tawharekiri Lakes
54 Burmeister Morass
55 Hermitage Swamp

**Canterbury Conservancy**
56 Sumner Lakes Complex
57 Waimakariri Lakes Complex
57a Lake Grasmere and Lake Sarah
57b Lake Letitia
57c Lake Pearson
57d Lake Hawdon and Marymere
58 Coleridge Lakes Complex
58a Lake Lyndon
58b Ryton Lakes
58c Lake Coleridge
59 Ashburton Lakes Complex
60 Mackenzie Basin Wetlands Complex
60a Lake Alexandrina and Lake McGregor
60b Tekapo Streams
60c Glenmore and Tekapo Tarns
60d Ohau Moraine Wetlands
61 Central Southern Lakes Complex
62 Canterbury Braided Rivers Complex
62a Ashley River and Estuary
62b Ahuriri River
62c Waitaki Headwater Braided Rivers
63 Avon-Heathcote Estuary
64 Lake Forsyth
65 Lake Ellesmere
66 Te Whanga Lagoon and Lake Wharemanu

**Otago Conservancy**
67 Sutton Salt Lake
68 Lakes Waipori, Lake Waihola and Associated Wetlands
69 Kawarau Catchment Wetland Complex
69a Kawarau River
69b Greenstone River and Caples River
69c Dart River and Rees River
70 Lake Hayes

**Southland Conservancy**
71 Te Anau Basin Wetland Complex
71a Dome Mire and Dismal Swamp
71b Kepler Mire
72 Awarua Plains Wetland Complex
72a New River Estuary
72b Awarua Bay
72c Toetoes Harbour
72d Seaward Moss-Waituna-Toetoes
73 Freshwater

### *Coastal waters*

Legal protection of our coastal waters is mostly administered by the Department of Conservation under the Marine Reserves Act 1971. The Act allows areas of territorial sea (up to 12 nautical miles off-shore) to be preserved for scientific study where they "contain underwater scenery, natural features or marine life of such distinctive quality, or so typical, or beautiful, or unique, that their continued preservation is in the national interest". Anchoring, recreational fishing, and mineral exploration may be permitted in a marine reserve, but prohibited activities include discharges of any sort, commercial fishing, sand and shingle extraction, public works, unauthorised interference with marine life, and shooting.

In addition, the protected area provisions of the Wildlife Act (refuges and management reserves), and the Reserves Act (scenic, scientific, nature, and recreation), have been used to create intertidal protected areas in estuaries. Regional councils use regulatory measures, such as Estuarine Protection Zones, to control damaging activities in coastal waters and on their margins.

For two decades the Marine Reserves Act was interpreted narrowly as having a research rather than a conservation purpose. Only two marine reserves, with a combined area of less than 3,000 hectares, were created up to the end of 1989. During the same period, fisheries regulations were used to create three surrogate conservation reserves. Two of these were marine parks protected by the Fisheries Act 1983 and the Harbours Act 1950, while the third was upgraded in 1991 from a marine park to a special protected area with its own legislation—the Sugar Loaf Islands Marine Protected Area Act 1991—to protect it from oil exploration which the fisheries regulations were powerless to exclude. Although marine parks established under the Fisheries Act 1983 continue to be protected, with the passing of the Fisheries Act 1996, no new marine areas can be protected under fisheries legislation.

Since 1990 eleven new marine reserves have been established under the Marine Reserves Act, beginning with the remote Kermadec Islands which were made a vast reserve of some 748,000 hectares (see Table 7.14). Some 24 additional sites are being considered by the Department of Conservation and other groups. In addition to the marine reserves and parks, two marine mammal sanctuaries were established under the Marine Mammals Protection Act 1978. The Auckland Islands sanctuary was set up in 1993 to protect Hooker's sea lions from trawl nets, though it had been a no trawling zone under fisheries regulations since the early 1980s, and the Banks Peninsula sanctuary was set up in 1988 to protect Hector's dolphins from set nets.

In total the marine conservation area is now over 1 million hectares (nearly 4 percent of our coastal waters). However, the total is misleading because the remote Kermadec and Auckland Islands account for almost 90 percent of it. Excluding them and the Banks Peninsula sanctuary (whose restrictions apply only to set nets) the total marine conservation area is less than 15,000 hectares—well under 1 percent of our mainland coastal waters.

**Table 7.14**
**Marine conservation areas as at November 1995.**

| **Marine reserves (and year gazetted)** | **760,513 hectares** |
|---|---|
| *Cape Rodney to Okakari Point (1975) (includes Goat Island and Leigh reserve)* | *518* |
| *Poor Knights Islands, Northland (1981)* | *2,410* |
| *Kermadec Islands (1990)* | *748,265* |
| *Wanganui-a-Hei (Cathedral Cove) Coromandel (1992)* | *840* |
| *Tuhua (Mayor Island), Bay of Plenty (1992)* | *1,060* |
| *Kapiti, Waikanae (1992)* | *2,167* |
| *Long Island - Kokomohua, Marlborough Sounds (1993)* | *619* |
| *Tonga Island, Abel Tasman National Park (1993)* | *1,835* |
| *Te Awaatu Channel (The Gut), Doubtful Sound (1993)* | *93* |
| *Piopiotahi (Milford Sound) Fiordland (1993)* | *690* |
| *Westhaven (Te Tai Tapu), Karamea-West Coast (1994)* | *536* |
| *Long Bay - Okura, Auckland (1995)* | *980* |
| *Motu Manawa - Pollen Island, Auckland (1995)* | *500* |
| **Marine parks and protected areas** | **3,150 hectares** |
| *Mimiwhangata Marine Park, Northland (1983)* | *2,000* |
| *Tawharanui Peninsula Marine Park, Rodney (1981)* | *350* |
| *Sugar Loaf Islands Marine Protected Area, New Plymouth (1991)* | *800* |
| **Marine mammal sanctuaries** | **335,111 hectares** |
| *Auckland Islands (1993)* | *221,551* |
| *Banks Peninsula, Canterbury (1988)* | *113,560* |
| ***Total marine conservation area*** | ***1,098,774 hectares*** |

*Source: Department of Conservation*

## CONCLUSIONS

To fully assess the state of the nation's water, the main indicators need to be measured in a regular and standardised way throughout the country. Progress toward this is now underway. Fortunately, a large amount of water monitoring is already carried out, both at the regional level and through several national programmes which focus on rivers, shallow lakes, groundwater and piped water supplies. Although their coverage, timeframes and monitoring methods vary, these data allow some general conclusions to be drawn.

From these it is clear that the pressures on our surface waters, coastal waters and groundwaters are intense enough in some areas to cause problems of scarcity, pollution and ecological degradation. However, some of these pressures are probably not as severe as they once were. Most point sources of pollution have become better managed over the last 20 to 30 years. Although urban sewage disposal is still a problem in some areas, very few communities now discharge untreated sewage into water and many are upgrading their treatment systems to better safeguard their rivers, lakes and beaches.

Drainage, dam construction, irrigation and flood control channelling have greatly altered the natural character of our waters. The surrounding land use changes have added to this, through vegetation clearance, run-off and sedimentation. Indigenous fish now live in fragmented habitats, as do wetland birds and plants. Maintaining the natural character of what remains is now identified in the Resource Management Act as a matter of national importance.

Non-point sources of pollution place the greatest pressures on water quality and have, so far, proven difficult to deal with because the solutions lie mostly in land management practices and lifestyle and consumption patterns (particularly our heavy use of motor vehicles). The most significant non-point sources appear to be agricultural run-off into waterways, leached nitrate into groundwater from horticultural and pastoral land, and urban stormwater which is a major source of contamination and debris in many coastal waters. The greatest impact of non-point source pollution is in lowland waterways, shallow lakes and shallow estuaries.

Much of the stormwater pollution in Auckland's estuaries has been attributed to urban runoff, particularly from motor vehicles, and is predicted to get worse.

Water quality is generally high around the coast, in the deep lakes, and in the headwaters of most rivers, and in many cases this is maintained into lowland areas. However, water quality deteriorates in streams, rivers and lakes which drain agricultural catchments, with agricultural run-off causing elevated nutrient and sediment loads. Microbiological contamination from the run-off of agricultural wastes also contributes to the poor condition of many small rivers and streams in agricultural catchments.

Coastal seawater is generally suitable for swimming and other forms of contact recreation. In areas away from urban sewage outfalls, stormwater outfalls and boat effluent, coastal water is also suitable for the gathering of seafood. However, the disappearance of seagrasses in estuaries and the proliferation of sea lettuce (a native seaweed) suggests that elevated nutrients and suspended sediments are affecting some of our estuarine and coastal ecosystems.

Pests and weeds are an increasing threat to freshwater and marine ecosystems. The impacts on people include the potentially negative economic and health effects of toxic algae. Our ability to respond to harmful invaders has been enhanced by recent legislation on new organisms and biosecurity and by improved coastal monitoring for toxic algae.

Nitrate contamination of groundwater beneath pastures appears to be a significant environmental issue. Many shallow aquifers beneath dairying and horticultural land, and beneath organic waste disposal facilities are now contaminated by nitrate at levels that exceed the maximum allowable value for drinking water, and that pose an increased risk of eutrophication to the nitrogen limited lakes of the central North Island. Very limited data indicate that other pollutants, such as toxic metals and even pesticides in some places, may be entering groundwater by seepage from landfills, waste disposal facilities and contaminated sites.

Although the quality of water in our rivers, lakes, estuaries and harbours has probably improved in the past twenty years as point sources of pollution have declined and better treatment systems have been adopted, the pressures from non-point source pollution, introduced species and environmentally harmful development have barely begun to be dealt with. Issues requiring ongoing attention include:

- protecting the natural character of water bodies and water margins (including wetlands, estuaries, and riparian vegetation on riverbanks);
- controlling drainage and degradation of wetlands;
- controlling non-point source pollution of lowland streams and shallow lakes;
- controlling nitrate pollution in groundwater;
- maintaining freshwater and marine ecosystems;
- continuing to upgrade water and waste treatment systems;
- continuing to upgrade drinking-water supplies;
- controlling introduced pests and weeds;
- improving data on aquatic ecosystems; and
- improving data on the quality of groundwater resources.

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THE STATE OF

NEW ZEALAND'S

ENVIRONMENT

CHAPTER EIGHT

# THE STATE OF OUR LAND

## CONTENTS

## THE STATE OF OUR LAND

### Key points

- *New Zealand straddles two tectonic plates whose edges are crunching against each other. The resulting earth movements have produced hilly and mountainous terrain over two-thirds of the land, with frequent earthquakes in most parts of the country and a zone of volcanic and geothermal activity in the central North Island.*

- *Three quarters of New Zealand's land mass consists of geologically young sedimentary rocks which tend to be erodible. The known mineral resources are dominated by coal, gold, silver, and beach sand deposits of iron and titanium. Large amounts of sand, gravel and rocks are used for building, and limestone for fertiliser, building and other purposes. Economic exploitation of other minerals has been slight, though deposits of aluminium, uranium, halloysite clay, potassium and sulphur exist in recoverable amounts.*

- *New Zealand's soils, which mostly evolved under forests, tend to be thin and acidic with low levels of nitrogen, phosphorus, and sulphur. As a result, nearly all soils used for crops and pasture need to be 'developed' and maintained with nitrogen-fixing legumes (e.g. clover), significant inputs of fertilisers, and often lime. In some areas, exotic planted forests also require fertilisers.*

- *Since human settlement approximately 700–800 years ago, the indigenous forests, which once covered about 85 percent of the land area, have been reduced from some 23 million hectares to approximately 6.2 million (23 percent of the land area)—mostly confined to mountain areas and to some low-lying parts of the West Coast, Southland and Northland. In most areas lowland forests have been reduced to fragments and will need considerable expansion if the biodiversity within them is to be sustained.*

- *Of the surviving indigenous forests, 4.9 million hectares are Crown-owned and 1.3 million hectares are privately owned. Most of the Crown forests are on fully protected conservation land (except for 150,000 hectares set aside for timber production on the West Coast). Most of the private indigenous forests are unprotected from conversion to other land uses, but timber production from them is subject to the sustainable management provisions of the Forests Act 1949 (except for 60,000 hectares set aside for economic purposes under the South Island Landless Maoris Act 1906, the management regime for which is currently under negotiation).*

- *The biggest threat to the remaining forests comes from tree and seedling destruction by possums, goats and deer. These pose a serious risk to biodiversity on some 1.8 million hectares of Department of Conservation land. The Department runs pest control operations over about 1.3 million hectares and its pest control funding has been increased. Invasive weeds are also a threat and are subject to control operations.*

- *Duneland ecosystems cover about 50,000 hectares, most of which have been heavily modified by grazing, fires, drainage, coastal development and introduced trees and grasses. A further 250,000 hectares of sand dunes are covered in pasture, pine forests or scrub. The inter-dune wetlands are among our most threatened ecosystems.*

- *Grasslands covered 1–2 million hectares (roughly 5 percent of the land area) before humans arrived but expanded to almost 8 million hectares as a result of deforestation by early Maori fires. Further deforestation in the past 100 years by farmers and timber millers has extended the grassland area to 14 million hectares—over 50 percent of the total land area.*

- *As introduced pasture grasses have expanded, the native grasses have contracted. Today, there are about 3.3 million hectares of 'tussock-predominant' grassland and nearly one million hectares of mixed scrub and tussock. Virtually all of this surviving tussock has been grazed, at least 1.5 million hectares have been degraded by sheep, rabbits and invasive weeds, and at least half a million hectares have been oversown with introduced grasses.*

- *The proportion of New Zealand converted to farmland is large by world standards (52 percent compared to the world's 37 percent in 1993). Although our human population density is comparatively low (13 per square kilometre compared to the world's 43) our livestock density is high (180 sheep per $km^2$ compared to the world's 14, and 35 cattle per $km^2$ compared to the world's 10). This amounts to 13 sheep and 3 cattle for every person, and makes pastoral agriculture the country's main land use.*

- *Although 14 percent of our land is physically able to support crops or horticulture, standing crops of all sorts (e.g. arable grain and fodder crops, market gardens, orchards and vineyards) cover less than 2 percent of this area (compared to the world's 11 percent). Conversely, the area devoted to pasture is twice the world average (50 percent compared to 25 percent).*

- *Besides pastoral farming, the other major land use is forestry based on plantations of exotic conifers. These planted forests cover approximately 1.6 million hectares and are expanding over former farmland at a rate of about 70,000 hectares per year.*

- *Because two-thirds of New Zealand consists of hills and mountains, areas of highly fertile soil and flat to gently rolling terrain are limited. Only about 31 percent of the land can sustain pastoral farming (grazing animals) without significant erosion controls. This includes the 14 percent which could also sustain cultivation. A further 28 percent can support restricted livestock grazing combined with tree planting, farm forestry or other erosion control measures.*

- *Soil erosion has been accelerated in many areas since human occupation, by deforestation and inappropriate land use. National survey data collected in the 1970s, and more recent local studies, indicate that over half the country is affected by moderate to slight erosion. Nearly 10 percent has severe to extreme erosion, mostly concentrated in a few high risk areas (i.e. the eastern North Island, from Wairarapa to Gisborne, plus parts of Taranaki and the South Island high country).*

- *No national data exist on other types of soil degradation, though carbon depletion, nutrient depletion and acidification may be widespread, and compaction and contamination appear to be common but localised.*

- *An estimated 7,800 urban and industrial sites may be chemically contaminated, some 1,500 seriously. Sites associated with contaminating activities include landfills, service stations, sawmills, timber treatment plants, railway yards, engine works, metal industries and chemical manufacturers.*

- *Several thousand of the nation's 80,000 farms, orchards and market gardens may have contaminated sites (e.g. old sheep dips, farm landfills), though no instance of extensive and serious contamination is known. In addition, some orchard soils have heavy metal residues from fungicides and some farms have DDT residues. The latter are well managed and rarely enter the livestock or human food chain.*

- *Among the main land-use issues in New Zealand are:*
  - *the decline in ecological processes and biodiversity caused by habitat fragmentation in agricultural and urban areas;*
  - *the impacts of pests and weeds, especially possums, on ecosystems, crops and livestock;*
  - *the loss of agricultural soils for productive use in North Island hill country and South Island high country;*
  - *the degradation of 'elite' soils by the impacts of intensive farming;*
  - *the loss of 'elite' soils to urbanisation;*
  - *the loss of wetlands to land drainage; and*
  - *the degradation of waterways by run-off from farms, urban streets and subdivisions, and industrial discharges.*

- *The main laws controlling the environmental effects of land use are the Resource Management Act 1991 and the Conservation Act 1987, the former requiring sustainable management and the latter conferring protection on gazetted areas. Other legislation requires sustainable logging in native forests, coherent strategies for pest control and the safe handling of hazardous substances and toxic sites.*

- *Land users, with assistance from regional councils, the Government's Public Good Science Fund and environmental grants, are playing an increasingly active role in developing sustainable land management programmes and codes of practice (e.g. through community-based organisations, including 'landcare' groups, Federated Farmers, and the Forest Owners' Association).*

- *Although much of the information on the national state of our soils, vegetation, and land ecosystems is out of date, incomplete, fragmented or poorly referenced, initiatives are under way to redress some of these deficiencies. They include:*
  - *the Ministry for the Environment's National Environmental Indicators Programme which includes the development of a core set of "state of the land" indicators;*
  - *the National Sustainable Land Management Strategy being coordinated by the Ministry for the Environment;*
  - *the National Science Strategy for Sustainable Land Management being developed by the Ministry of Research, Science and Technology (MoRST);*
  - *the updating of the New Zealand Land Resource Inventory by Landcare Research;*
  - *the collation of existing data in Landcare Research's Spatial Database Index;*
  - *the Biodiversity Assessment Programme being developed by Landcare Research; and*
  - *the development of a national land cover database derived from satellite imagery by Terralink NZ Ltd (formerly part of the Department of Survey and Land Information).*

- *Initiatives are also under way to improve the information base for land managers at ground level. Monitoring programmes and extension services of regional councils play a key role, as do the information networks developed by land user organisations. In addition, the Ministry of Agriculture is developing sustainability indicators to assist farmers. Other research and information projects for better land management are funded through the Government's Public Good Science Fund, the Ministry for the Environment's Sustainable Management Fund and the Ministry of Agriculture's Sustainable Agriculture programme.*

## INTRODUCTION

Our land-based environment consists of soil, the rocks which underlie it, and the vegetation that cloaks it. Being urban dwellers, most New Zealanders could be excused for thinking that their use of land extends no further than the backyard. But vast areas of land are needed to produce and distribute the food, fibres, minerals and manufactured items that are so integral to our daily lives. Seen from this perspective, we each 'use' much more land than we think. We all depend to varying degrees on products and services from farms, planted forests, mines, factories, warehouses, shopping centres, schools, offices, roads and landfills—all of which use land. Many of our recreational activities also use substantial areas of land (e.g. sports fields, golf courses, tennis courts, parks and gardens). All these land uses contribute to our well-being and make New Zealand one of the better places to live. But they also have impacts on the environment and on the native species that were once sovereign here.

Taken together, farming, forestry, transport and urban development occupy some 18 million hectares of New Zealand, nearly two-thirds of the total land area (see Table 8.1). This represents about 5 hectares of developed land per person, and a further 2.5 hectares of wilderness. When we look more closely at our 5 hectares of developed land, we can see that 4 hectares are covered in grass and occupied by sheep and cattle.

Scattered over the remaining hectare are all our other forms of land development. Half this is devoted to forestry (mostly exotic pine plantations), a quarter has roads, towns and cities built on it, and the remaining quarter is a patchwork of crops, horticulture, retired farmland, regenerating scrub and private indigenous forest (much of it cut over). When we consider that nearly all of this land was once indigenous forest teeming with unique birds, bats and frogs it is clear that human society has imposed a heavy 'ecological footprint'. We cannot go back and erase that footprint, but we can learn to tread more lightly from here on and, in so doing, recognise how heavy-footed we have been.

The evidence from buried pollen, charcoal, and bones suggests that human impact on New Zealand's vegetation and soils began with the first arrivals about 700-800 years ago (Anderson, 1991; McFadgen *et al*., 1994; McFadgen, 1994). Pollen analyses from peat bogs around the country reveal that prior to A.D. 1300 forest fires occurred sporadically, ignited by lightning strikes and volcanoes. Then they became frequent and widespread, particularly between 1350 and 1550 (Anderson and McGlone, 1992; McGlone *et al*., 1994; McGlone *et al*., 1995; McGlone and Basher, 1995). The remains of more than 30 extinct birds in Maori food middens also attest to a human impact which was sudden and catastrophic (see Chapter 9).

By the time Europeans arrived, the forests had been reduced from about 85 percent of the land area to 53 percent, and the tussock grassland had expanded from about 5 percent to almost 30 percent. The new settlers triggered a new wave of deforestation. Within barely 100 years, the forests had been further reduced to 23 percent of the land area while the grassland had expanded to just over 50 percent. Today, New Zealand has ten times more grassland than it once had, and only a quarter of its original forests. The landscape has been changed beyond recognition from a dark green forest cloak fringed by tussock, duneland and wetland to a light patchwork blanket of pasture, exotic forests, crops, roads and settlements.

International comparisons come naturally to New Zealanders. Being both an island nation and a trading one, we constantly compare our economic performance, sporting achievements, culture, lifestyle and environment to those of other countries. While such comparisons are often made out of context, they do highlight some of the features which make us distinctive. For example, tourists from more crowded or wooded parts of the world often comment on New Zealand's 'open spaces' and the abundance of sheep. Some are surprised to find such a highly modified landscape in a country with such a low population density (13 people per square kilometre compared to the world average of 43).

What they do not realise is that the human impact on New Zealand's environment is magnified by the size of our livestock populations and by the fact that it is cheaper to feed and accommodate these animals on extensive grasslands than on intensively stocked feedlots. For every person, we have 13 sheep and 3 cattle. Although our sheep

**Table 8.1**
**Estimated land-use areas in New Zealand and outlying islands in 1993.**

| Land use | Land area hectares (millions) | percent |
|---|---|---|
| ***Built-upon land (roads, railways, buildings etc.)*** | ***.89*** | ***3*** |
| *Urban areas (residential, industrial/commercial, roads and railways)* | *.73* | *3* |
| *Rural roads and railways* | *.16* | *<1* |
| ***Domesticated land (occupied farm and forest land)*** | ***17.30*** | ***65*** |
| *Pasture: improved grassland including lucerne* | *9.60* | *36* |
| *Pasture: tussock including danthonia* | *3.92* | *14* |
| *Arable crops (e.g. grains, peas)* | *.18* | *<1* |
| *Fodder crops (e.g. turnips)* | *.14* | *<1* |
| *Horticulture (e.g. fruit, vegetables, vineyards)* | *.09* | *<1* |
| *Fallow land* | *.07* | *<1* |
| *Exotic forests (90% Pinus radiata)* | *1.40* | *5* |
| *Privately owned indigenous forests* | *1.32* | *2* |
| *Other farmland, including retired land (e.g. fern, scrub, tussock and barren land)* | *.42* | *2* |
| *State indigenous production forest* | *.16* | *<1* |
| ***Conservation land (national parks, reserves, protected sites)*** | ***8.10*** | ***30*** |
| *Indigenous forest* | *4.80* | *18* |
| *Tussock and sub-alpine scrub* | *0.70* | *2* |
| *Other (e.g. mountain tops, coastal areas, islands)* | *2.60* | *10* |
| ***Other land*** | ***.76*** | ***2*** |
| *Lakes and river beds* | *.54* | *2* |
| *Land not classified elsewhere* | *.22* | *<1* |
| ***Total New Zealand land area*** | ***27.05*** | ***100*** |

*Sources: Molloy (1980); Ministry of Forestry (1988, 1994a); Statistics New Zealand (1994a, 1995)*

density fell from 260 to 180 per $km^2$ between 1982 and 1995, and is still falling, it is a dozen times higher than the world's combined sheep and goat density of around 14 per square kilometre (World Resources Institute, 1996). Our cattle density, which has fluctuated around 30 per $km^2$ since the 1960s, and has recently risen to 35 per $km^2$, is more than three times the world average of 10 per $km^2$.

To meet the grazing requirements of all these animals, much more of New Zealand's land surface has been converted to farmland than the world average (51 percent compared to 37 percent). Pasture occupies a greater proportion of our land area (50 percent compared to the world's 25 percent) while crops occupy much less (less than 2 percent compared to the world's 11 percent)—even though 14 percent of New Zealand is capable of growing crops.

This preference for animal production over crop production has deep economic and historical roots and explains much about the New Zealand landscape and our 'ecological footprint' on it. Some of the environmental impacts of pastoral agriculture first became apparent last century, within decades of European settlement. They included:

- reduced native biodiversity (i.e. fewer species and varieties of indigenous plants and animals) caused by the removal of forest and wetland and the arrival of alien predators and competitors;
- reduced pasturage (i.e. edible grass) in tussock grasslands as a result of excessive burning, overgrazing by sheep, infestations of rabbits, and the impact of weeds;
- burial of new pasture under wind-blown sand dunes destabilised by fire and grazing; and
- damage to farms and settlements caused by erosion in headwater catchments and flooding and siltation on river flats downstream.

Although data on the current extent of these and other land problems are not very precise, this chapter summarises the available information. It describes the nature of our land, the pressures that we impose on it, the state of the soil and vegetation as far as we can assess it, and society's responses to some of the problems that have arisen. The effects of land use on water are discussed more fully in Chapter 7, and the effects on biodiversity in Chapter 9.

## THE STATE OF THE DATA

Because human settlement in New Zealand has been so recent, widespread evidence of the environmental impacts can be found in sediments, bogs and archaeological sites. Early historical records, from Captain Cook onwards, provide information on both Maori and European interactions with the environment. The first forest surveys were made in the 1840s and provide a basis for comparison with modern times. From these sources, scientists have developed a good understanding of the environmental changes that humans have wrought. However, much of this understanding is still impressionistic and general, rather than quantitative and particular, and precise knowledge of the timing, rate and sequence of change must await more detailed regional studies (McGlone, 1989).

A large amount of information exists on the state of our land in more recent times, but much of this is several decades old, incomplete, scattered or poorly referenced. A comprehensive listing of the nation's main sources of land data is contained in the latest directory of environmental data published by Statistics New Zealand (1996a). Important sources include national soil and vegetation databases, which are largely compiled from field survey data collected by government departments decades ago, and more recent data from local authority monitoring programmes, national statistical series and scientific publications.

These latter sources include: land use statistics published annually in the New Zealand Official Yearbook, whose primary sources are Statistics New Zealand's two-yearly Agricultural Census combined with the Ministry of Forestry's survey-based estimates of timber production, planted forest area and new area plantings; and a variety of information held by local authorities, the Department of Conservation and Landcare Research on problems affecting particular ecosystems or areas. These supplementary data sources allow us to infer some local trends since the national databases were compiled but they cannot provide a full account of the state of the nation's land in the 1990s.

Surveys of soil and rock types were initiated in 1935 and 1940 respectively and took several decades to complete (New Zealand Soil Bureau, 1968). They provide the core data on which our soil and geological maps are based. Since then, other surveys and field studies have supplemented or revised some of this information, but, most of these are now also in need of revision. The soil and geology databases are held respectively by two Crown Research Institutes—Landcare Research and the Institute of Geological and Nuclear Sciences.

Probably the largest of Landcare's databases is the New Zealand Land Resource Inventory (NZLRI). This was developed in the 1970s by the Water and Soil Division of the Ministry of Works for the National Water and Soil Conservation Organisation (NWASCO, 1979). For five years, a small team of land resource scientists travelled over the country, recording details of land slope, soil erosion, soil type, rock type, and vegetation cover. The data were mapped and a land use capability assessment was made for the whole country (NWASCO, 1979). A number of NZLRI publications describing the land and land cover were produced in the 1980s (Crippen and Eyles, 1985; Lynn, 1985; Eyles, 1986; Hunter and Blaschke, 1986; Newsome, 1987).

Data on indigenous forest areas are based on two surveys by the New Zealand Forest Service: the National Forest Survey of 1945–1955; and the Ecological Survey of 1956–1967 (O'Leary, 1986). The area estimates from these surveys have been periodically revised since the early 1970s on the basis of timber production statistics. The current estimate of indigenous forest area (6.2 million hectares) has not changed since the early 1980s (New Zealand Forest Service, 1984). The NZLRI 1975–79 provides slightly lower estimates (around 5.9 million hectares), which vary according to assumptions made about the amount of forest contained within mapping units which include mixed vegetation.

Data on exotic forest areas are produced by the Ministry of Forestry, from a census of those growers known to have more than 40 hectares in exotic forest (Ministry of Forestry, 1994a, 1995). Recently, as the number of small plantations has increased, the Ministry has attempted to improve the information with satellite imagery (Pilaar *et al.*, 1995). The Ministry has joined with Terralink NZ Ltd (formerly part of the Department of Survey and Land Information), the Department of Conservation, the Ministry of Agriculture, and Landcare Research, to develop a Land Cover Database based on satellite images. Funding is adequate to map the nation's forest cover, but additional funds are needed to include other types of land cover. As a result, non-forested land cover is only being added to the database in regions where local authorities are interested in purchasing the information. The database has 'fine grained data', each map unit being one hectare, but has only 15 land cover categories.

The NZLRI, by contrast, has many more vegetation and land cover classes, but has much coarser map units, seldom below 50 hectares, and often containing a diversity of land cover types. The purpose of the NZLRI map units is to depict areas according to their land use capability, regardless of their shape or size. Each map unit can, therefore, include a variety of vegetation types. A recent review by the Foundation for Research, Science and Technology recommended that the five layers of data in the NZLRI be separated into independent databases and updated and refined as necessary to accommodate the changes in erosion and land cover which have occurred in the last two decades. Landcare Research has now completed the second edition NZLRI mapping for Northland, Wellington, part of Marlborough and part of Waikato, and is currently remapping the Gisborne-East Coast region (Dymond, 1996; Stephens *et al*. 1995; Wilde, 1996).

Landcare Research has also recently initiated a national Biodiversity Assessment Programme which will begin with an assessment of our landscape and ecosystem diversity before proceeding onto species and genetic diversity. Landcare is also collating its other databases into a Spatial Database Index.

Terralink is a State Owned Enterprise (SOE) whose core businesses are mapping, surveying, property services, and collecting information and storing it on electronic databases. It provides data and services across the full range of administrative, cadastral, topographic, land cover, aerial photograph and satellite information types. These functions were previously carried out by the former Department of Survey and Land Information (DOSLI).

A variety of ecosystem databases are held by the Department of Conservation but their information tends to be descriptive rather than quantitive and they do not depict ongoing national trends, although some show short-term regional trends (e.g. Anderson *et al.*, 1984). The databases include:

- a national dunelands inventory, which ranks dunelands of regional and national significance, based on surveys conducted in the 1980s by DSIR Botany Division (now Landcare Research) (Johnson, 1992; Partridge, 1992);
- the SSWI database (Sites of Special Wildlife Interest) which is a comprehensive listing of important wildlife habitat based on a nationwide survey by the former Wildlife Service's Fauna Survey Unit between 1977 and 1985, and updated for some regions and sites;
- a national weeds database; and
- an inventory of representative vegetation ecosystems from sites surveyed under the Department's Protected Natural Areas (PNA) Programme.

Although they are not national in their coverage, the monitoring programmes of regional councils are a rich, if uneven, source of data on soil, vegetation, and land use. For such data to be aggregated at the national level, the key indicators need to be measured in a standard way, using common methods and timeframes. The Ministry for the Environment (1996) is trying to develop such common methods for a selected core set of land indicators through the National Environmental Indicators Programme. The programme draws on expertise from Landcare Research, regional councils, and other agencies and organizations.

## THE NATURE OF NEW ZEALAND'S LAND ENVIRONMENT

When we think of land, we think of soil. But soil is a relatively recent feature of the Earth's surface, the child of rocks and living things formed by the fusion of mineral sediment and organic matter. For more than 90 percent of our planet's 4,600 million year history, vegetation and organic soil did not exist. Life was confined to the oceans, rivers, and lakes while the land consisted of bare rock, sand, volcanic ash and dust. It was not until 460 million years ago that photosynthesising sea organisms colonised the shoreline and set the scene for the evolution of soils.

Seaweeds (large algae) and lichens (fungi which harbour microscopic algae) were the first coastal land-dwellers. In time, one line of green algae gave rise to the plant kingdom. The first land plants were bryophytes (liverworts, hornworts and mosses) whose transition from algae to plants probably occurred in tidal marshlands (Niklas, 1994; Palmer, 1995; Stevens *et al.*, 1995). Because they had simple leafless stems, no roots and no vascular systems to transport water and nutrients within their tissues, the bryophytes were confined to moist areas, forming green mat-like carpets on damp sediment and wet rock faces. Fungi, particularly lichens, also colonised these areas, forming symbiotic relationships with the plants.

As each generation of plants and fungi died, they formed matted layers of humus. Over millions of years, these layers of organic matter mixed with eroded rock sediment to form something new on the planet—organic soil. Today the mosses and lichens still occupy damp areas and they still play the role of colonisers on rocks and bare ground where other plants cannot take root.

Around 410 million years ago, a new group of plants evolved from these primitive forms—ferns and similar plants. Because they had vein-like vascular systems, the ferns and other fern-like plants could absorb moisture and nutrients from the soil through their rhizomes (underground stems) and transport the nourishing sap throughout their tissues. They were thus able to grow taller than the bryophytes and intercept more sunlight.

Soon even taller plants, with true roots, had evolved—the first trees. By 360 million years ago, evergreen gymnosperm forests were widespread. The tree roots accelerated soil formation by breaking up rock, loosening sediment, and binding the soil. Soil and vegetation, therefore, evolved together within the last 9 percent of Earth time. As tree seeds were dispersed by wind and water, a green and brown carpet spread slowly over the planet's barren places, establishing a life support system for the land animals that were to follow.

### The geology

When the first soils and trees were evolving on Earth, New Zealand did not exist. It was just a long strip of sea floor off the coast of the supercontinent, Gondwana, near the region that would later split up into Antarctica and Australia. Whereas parts of Australia contain 3.8 billion year old rocks, the oldest New Zealand rocks were formed less than 600 million years ago from sediment washed into the sea by Gondwana's rivers. For millions of years the sediment accumulated, with each layer compressing the ones below into sandstones and other soft sedimentary rocks. Marine animals died and became fossilised in the sediments, leaving a visible record of their life and times. Some of the lower sedimentary layers were compressed into hard metamorphic rocks while volcanic igneous rock was added to the mix by underwater volcanoes near the edge of Gondwana's tectonic plate.

Between 120 and 140 million years ago, the New Zealand region was thrust out of the water by violent buckling of the tectonic plate (Stevens *et al.*, 1995). The new land mass stretched from New Caledonia in the north to Campbell Island in the south, with arms extending eastwards to the Chatham Islands and westwards along the Lord Howe Rise (see Fig 8.1). It was just off the Gondwana coast and formed land bridges with both the Australian and Antarctic parts of the supercontinent. For about 50 million years, this exposed new land mass was rained on, creating silts and sediments which were colonised by various Gondwana plants and animals—ferns, kauri and podocarp trees, dinosaurs, tuatara, large walking birds, primitive spiders, insects and other invertebrates. Mammals had not yet evolved. Nor had snakes.

About 125 million years ago, a new plant group began to spread throughout Gondwana the angiosperms, or flowering plants. Unlike the sombre gymnosperms, these plants relied on animals to pollinate and disperse their seed. They evolved the ability to attract birds and bees using brightly coloured flowers, strong fragances, and sweet pollen, nectar and berries. They proliferated into blossoming trees, flowering shrubs and herbs and grasses. Although they now dominate the plant world, the angiosperms did not become so dominant in New Zealand because they had barely reached the eastern edge of Gondwana when the continent began breaking up. Its underlying tectonic plate, the Indo-Australian plate, began moving east, shunting the New Zealand land mass out to sea.

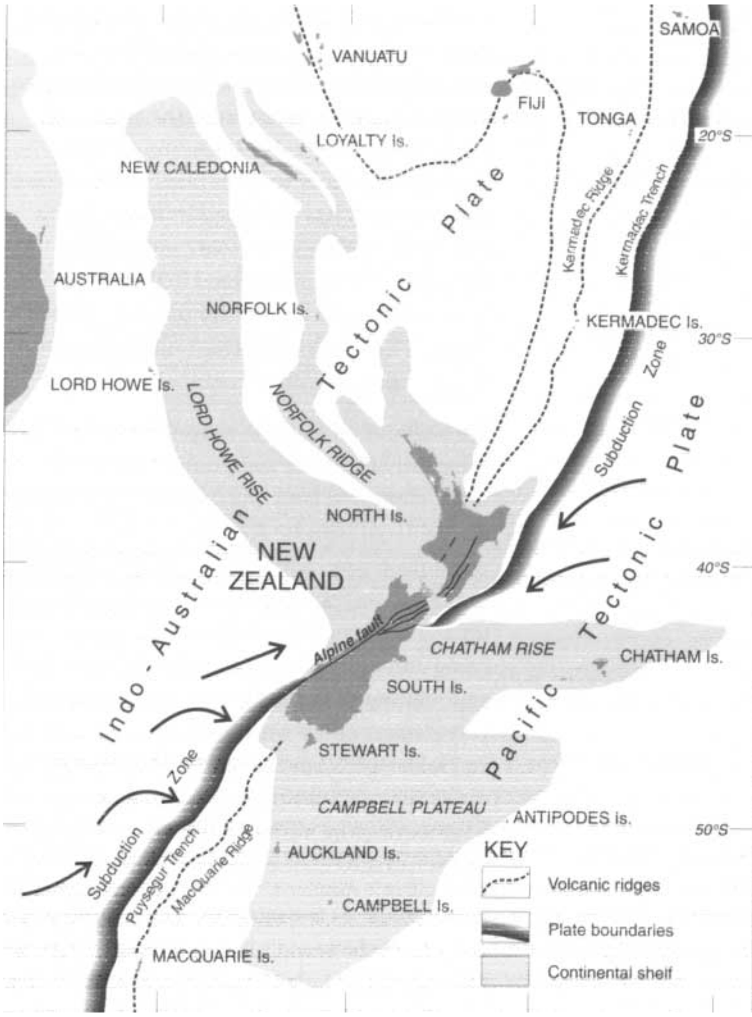
By 80 million years ago, the New Zealand-New Caledonia fragment was on its own, a raft of ferns and dark gymnosperm forests with just a few species of opportunistic angiosperms—notably the high altitude beech forests. The distance from Australia was still very small and a chain of islands still linked New Zealand to Antarctica. These land masses remained in close proximity until about 55 million years ago, allowing a continuing stream of plant and animal colonists to swim, float or fly here. The ancestral seeds of the red-flowered pohutukawa trees, for example, were carried here by birds or wind currents 53–65 million years ago (Stevens, *et al.*, 1995).

The pohutukawa seeds arrived in the wake of a global catastrophe which has not been equalled since. As much as half the world's species became extinct in a geological instant 65 million years ago (see Chapter 9). The most notable victims were the dinosaurs, but many other animals also died out, both on land and in the sea. Plants were less severely affected, but many of these disappeared also. The mass extinction is now generally attributed to gross climatic disturbances caused by the impact of a large asteroid (Ward, 1994).

It took 20 million years for global biodiversity to recover as new species of plants and animals slowly evolved from the survivors. By then, the New Zealand land mass was becoming too remote for new colonisations, though some flying species (birds and bats) continued to arrive. They did so only to face another, more protracted, catastrophe—the Oligocene drowning (Cooper and Millener, 1993).

**Figure 8.1**

**New Zealand in relation to the Indo-Australian and Pacific Plates.**




As the Indo-Australian plate pushed it further out to sea, the New Zealand land mass began to sink. It continued to do so until 25–30 million years ago. At its lowest point, barely a fifth of present day New Zealand may have been above sea level. The remaining plants and animals survived on mountains which became a string of islands. These islands remained separate for millions of years so that their populations had time to evolve into different species—giving rise to 11 or more moas, four or more kiwis, numerous lizards, many invertebrates (e.g. land snails, flatworms, spiders, insects) and plants (e.g. mosses, liverworts, beech trees, and herbs). During the Oligocene drowning many unknown species were probably wiped out completely.

The sinking stopped about 25–30 million years ago as the floating landmass became jammed in the subduction zone between the Indo-Australian and the Pacific plate. Too big to be swallowed, the land mass ground to a halt, precariously straddling the boundary between the two plates. Pushed from the west and blocked from the east, the landmass was squeezed upwards to form ranges of towering mountains. It has remained in this position ever since, with new tectonic movements periodically forcing the land higher while heavy rain works constantly to erode it back down. The latest mountain building period began about six million years ago.

Throughout all this, the shape of the land has constantly changed, sometimes forming a single elongated land mass, sometimes forming several large islands. Ice ages during the last two million years have added a further dimension to these changes. As the land was being forced up, the sea levels around were independently rising and falling in response to the formation and melting of the polar ice caps. Meanwhile vast glaciers of ice were gouging deep valleys and lake basins among the South Island's mountains and the plunging snowline was fragmenting the alpine herbfields, grasslands and scrub into evolutionary islands.

In the midst of the latest ice age, 22,590 years ago, one of the world's largest volcanic eruptions blasted a huge hole in the centre of the North Island, forming Lake Taupo and temporarily obliterating all life in the central and eastern North Island (Carter, 1994). When the ice age ended, around 12,000 years ago, the rising sea flooded the low-lying land bridge between North and South Islands, forming Cook Strait and dividing the land into the shape we know today.

Below us, the plates are sliding under and over each other in opposite directions. The North Island, which is on the leading edge of the Indo-Australian plate, is moving to the north-east, as the Pacific plate dives beneath it. This subduction zone is marked by a line of trenches in the ocean floor running north from the Kaikoura coast up past the east coast of the North Island and beyond the Kermadec Islands (see Figure 8.1).

As the Pacific plate burrows beneath the North Island, it has caused the east coast and the Marlborough region to buckle and fracture into rugged hill country broken by faultlines. It also generates volcanoes and geothermal eruptions in the centre and west of the North Island as its diving edge melts under the intense pressure and friction more than 200 kilometres below the surface. At the other end of the country, the tectonic power struggle is reversed. Beneath the ocean surface, south west of Fiordland, another line of trenches in the sea floor marks another subduction zone. Here, the Pacific plate, on which most of the South Island rides, is moving to the south west, forcing the Indo- Australian plate beneath it. Volcanic activity associated with this is confined to the ocean.

Between the two subduction zones, the opposing forces twist and fracture the landscape, creating the long Alpine Fault in the South Island, and multiple fault lines in the upper South Island and in the lower and eastern North Island (see Figure 8.2). These are the Marlborough, Wellington and Wairarapa fault systems. Fault lines also slice up into Hawke's Bay and Gisborne on the east coast and through the centre of the North Island from Wanganui to the Bay of Plenty. The grinding and shoving of the tectonic plates is also forcing the mountains east of the Alpine Fault to rise. In the Haast area they have risen some 120 metres in the past 16,000 years—a rate of seven to eight millimetres per year (Simpson *et al.*, 1994).

On either side of the Alpine Fault line, the South Island is being pulled in different directions. The west coast is being carried north-east by the Indo-Australian plate, while the rest of the South Island is travelling south-west with the Pacific plate. The extent of the movement is revealed by the red rocks of Nelson (west of the fault line) and those of Southland (east). Once connected, these rocks are now separated by of some 480 kilometres (Wallace, 1995).

### *Earthquakes*

Hundreds of earthquakes occur every year, though most are imperceptible, and very few cause even minor damage. They are most frequent in the east and south of the North Island and in the top half of the South Island. They are least frequent north of Auckland and south of Banks Peninsula (see Figure 8.2).

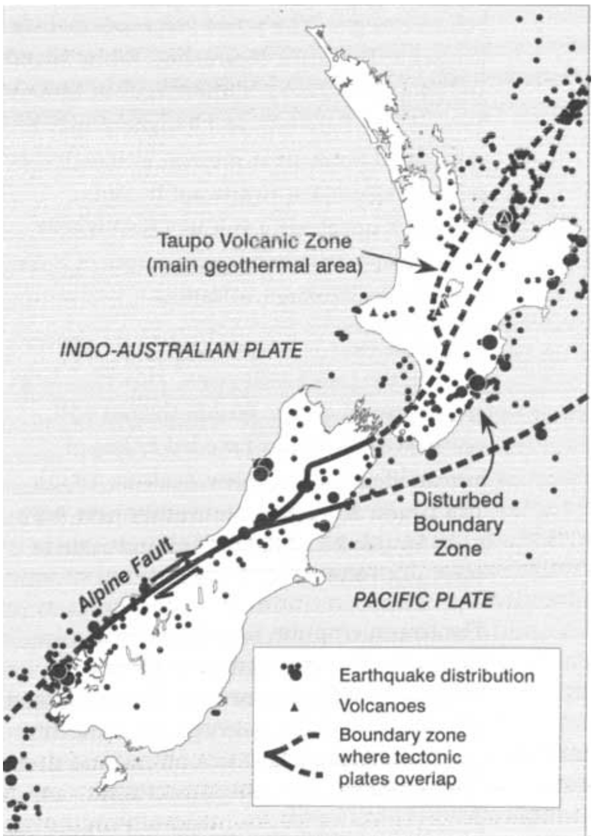
Shallow earthquakes, which occur within the 35–40 kilometre thick crust, are more dangerous and more common than the deep ones. They cause mass movement erosion, landslides, and damage to roads and buildings. Repeated shallow quakes have fractured the soft sedimentary rocks in much of the eastern North Island and Marlborough, making the hills in those areas more susceptible to erosion. Deep earthquakes occur below the crust, down to depths of 200—600 kilometres. They are caused by the subducting plate as it dives beneath the over-riding plate. The deep quakes are frequent in the volcanic zone of the North Island and off the south–western corner of the South Island, but are rarely felt at the surface.

Compared with other parts of the earthquake-prone Pacific rim—such as the Philippines, Japan, California, Mexico and the Pacific coasts of Central and South America—New Zealand has a moderate frequency of earthquakes, with most no greater than 4 on the Richter scale. A shock of Richter magnitude 6 or above occurs on average about once a year, a shock of magnitude 7 or above once in 10 years, and a shock of about magnitude 8 perhaps once a century.

Although one of the fatal Napier earthquakes of 1931 reached 7.8 on the Richter scale, the largest earthquake since European settlement had a magnitude of 8.1. This occurred in 1855 along the Wairarapa faultline, and was centred in Cook Strait. It was felt throughout most of New Zealand and raised the land on the southern coast of the Wairarapa by some 6.5 metres and around Wellington harbour by 1.5 metres (Ansell and Taber, 1996). The Rimutaka range between Wellington and the Wairarapa was badly damaged by landslips which carried away almost a third of the vegetation and much of the soil. Based on the geological evidence of previous earthquakes, scientists estimate that the Wairarapa Fault has a major rupture every 2,000 years while the central Wellington Fault experiences such shakes every 450–670 years. The Wellington Fault's last big movement was 350 years ago. The 7.1 Wellington earthquake of 1942 was not a major rupture.

**Figure 8.2**

**Main fault lines and centres of earthquakes and volcanic activity.**




*Source: NZ Meteorological Sevice*

Many earthquakes have been recorded with magnitudes of between 6 and 7, with widely varying impacts. The 1987 Edgecumbe quake, in the Bay of Plenty, had a magnitude of 6.3. It created ruptures up to seven kilometres long and caused land north-west of the town to drop two metres. The property damage came to more than a billion dollars—four times the cost of New Zealand's most expensive storm, Cyclone Bola, which hit the East Coast the following year (Ministry of Civil Defence, 1994). Conversely, the magnitude 6.6 earthquake which occurred in 1994 near Canterbury's sparsely populated Arthur's Pass, caused slips and road damage, but relatively little property damage.

Earthquakes have occurred more frequently since 1990 than in the previous decade. This does not reflect a worsening trend but merely a return to normal following the relatively low incidence of large earthquakes during the 1970s and 1980s (Statistics New Zealand, 1995).

***Volcanoes***

Active volcanoes are densely clustered in the central and western North Island. Many of the soils and rocks in this area are therefore of volcanic origin. The active volcanoes include Ruapehu, Tongariro, Ngaruahoe, White Island and Mount Tarawera. Others, such as Mount Taranaki (or Egmont), and Rangitoto may be considered dormant at present, although they are still regarded as significant hazards. Auckland sits above a volcanic field whose surface is pockmarked by the domes of more than 60 small extinct volcanoes.

New Zealand's volcanoes have been relatively quiet in the past 1,000 years. However, large eruptions still occur. Within the last 150 years seven eruptions have led to loss of human life (Statistics New Zealand, 1995). The largest eruptions this century have been from Mount Ruapehu in 1945 and again in 1995 and 1996.

The largest eruption since European settlement was that of Mount Tarawera in 1886 which killed more than 100 people and obliterated New Zealand's greatest tourist attraction at the time—two spectacular slopes of waterfalls, pools, and unusual rock formations known as the Pink and White Terraces. All plants and animals, including insects, within an eight kilometre radius of the eruption were destroyed, which led hopeful Tauranga fruit growers to speculate—fruitlessly as it turned out—that the codlin moth may have been exterminated (Grayland and Grayland, 1971). Ash from the eruption spread over 1.4 million hectares, and mud from it now forms the surface soil over a 12,000 hectare area. Despite the immediate effects, vegetation began to regenerate just a few years after the blast and now, a century later, recovery is complete.

A far larger eruption from Lake Taupo about 1,875 years ago (around A.D. 115) flung pumice, ash and rock over a wide area. Though much smaller than the eruption which formed the lake 20,000 years earlier, it devastated approximately two million hectares of forest throughout the central and eastern North Island from Hawke's Bay to the Bay of Plenty. Until recently, it was assumed that most of the area remained deforested for many centuries after the blast. Most maps of New Zealand's prehistoric forest cover still show a large barren area between Taupo, the Bay of Plenty and Hawke's Bay. Recent studies of fossil pollen, however, indicate that the entire area was reforested within 300 years, with tall matai and totara forests taking root in the new pumice soils (Stevens *et al.*, 1995).

***The terrain***

The constant tectonic activity has produced a restless landscape of rising mountains and steep hills interspersed with swift rivers, lakes and flood plains. The steepness of the slopes and the softness of much of the underlying rock, leads to high erosion rates in many parts of New Zealand. Three quarters of New Zealand's land is more than 200 metres above sea level and 14 percent is in the alpine zone, above the forest line. The 18 tallest peaks in the Southern Alps exceed 3,000 metres, with the tallest, Mount Cook, reaching 3,754 metres. The tallest North Island peaks are volcanoes, three of which exceed 2,000 metres.

The erosion of the uplifted mountains by rain and rivers has laid down thick deposits of sediment near river mouths and over large areas of floodplain. Major plains are found in Canterbury, Southland, Hauraki, Hawke's Bay, Bay of Plenty, and Manawatu. However, flat land (i.e. land on a slope of less than three degrees) makes up only 15 percent of New Zealand's total area. 'Rolling' lands (with slopes of from three to 12 degrees) make up a further 15 percent. Nearly all the remaining land, (around 18 million hectares, or two-thirds of New Zealand) is hill country and the vast majority of it is classed as steep land (see Table 8.2).

***The rocks***

Both terrain and soils owe much of their character to the rocks which make up the underlying land mass. The three main rock types are:

- **igneous** rock which originates in molten magma from within the Earth and takes the form of intrusive rock (e.g. granite and gabbro) where the magma has cooled and hardened beneath the surface, and volcanic rock (e.g. rhyolite and basalt) where the rock has formed at the surface following eruptions;

**Table 8.2**
**New Zealand's terrain.**

| | North Island | | South Island* | | New Zealand | |
|---|---|---|---|---|---|---|
| **Types of terrain** | **Area (hectares)** | **%** | **Area (hectares)** | **%** | **Area (hectares)** | **%** |
| ***Topography*** | | | | | | |
| *Flat and rolling land (under 12°)* | *3,741,000* | *32* | *4,151,000* | *27* | *7,892,000* | *29* |
| *Hilly land (from 12° to 28°)* | *3,550,000* | *31* | *2,073,000* | *13* | *5,623,000* | *21* |
| *Steep land (more than 28°)* | *4,096,000* | *36* | *8,757,000* | *57* | *12,853,000* | *48* |
| *Lakes and riverbeds* | *109,000* | *1* | *329,000* | *3* | *534,000* | *2* |
| ***Altitude*** | | | | | | |
| *Land below 300 metres* | *6,474,000* | *56* | *4,731,000* | *31* | *11,205,000* | *42* |
| *Land between 300 and 900 metres* | *4,404,000* | *38* | *6,004,000* | *39* | *10,408,000* | *39* |
| *Land between 900 and 2,100 metres* | *618,000* | *5* | *4,484,000* | *29* | *5,102,000* | *19* |
| *Land higher than 2,100 metres* | *-* | | *191,000* | *1* | *191,000* | *<1* |
| ***Total area*** | ***11,496,000*** | | ***15,410,000*** | | ***26,906,000*** | |

** South Island figures include Stewart Island (177,000 hectares) but exclude Chatham and other off-shore islands*
*Adapted from Molloy (1980)*

- **sedimentary** rock (e.g. sandstone, greywacke, argillites such as mudstone and siltstone, and limestones such as dolomite and chalk) which accumulates from the erosion of other rocks; and
- **metamorphic** rock (e.g. schist, gneiss and marble) which is created when intense pressure, heat or chemical activity changes the structure and texture of a rock, turning limestone, for example, into marble.

Almost three-quarters of New Zealand rocks are sedimentary. The South Island has older rocks than the North Island and a greater proportion of metamorphic rock. Some of its oldest rocks date back to the pre-Gondwana seafloor, more than 570 million years ago. These rocks are found in Fiordland, Westland and Nelson and are relatively resistant to erosion. Although old in human terms, they are very young geologically when compared to the 3,800 million year old rocks found in parts of Australia. Most New Zealand rocks are less than 350 million years old, consisting of sedimentary rocks, such as greywacke and argillite, throughout eastern areas, from Marlborough to East Cape. Metamorphic schist occurs over a large part of Otago.

North Island rocks are mostly sedimentary, and are very erodible in some areas. On the east coast the soft sedimentary rocks have been severely crushed and shattered by repeated earth tremors and fault line movements. This makes them a very unstable base for the soil above. Rocks in the central plateau, and areas around Auckland, the Coromandel Peninsula, and Northland, are of volcanic origin. They, and the young soils they bear, also tend to be erodible.

The combination of sedimentary rock and the erosive effect of water has produced some attractive and bizarre landscape features, such as the karst limestone terrains popular with tourists in many parts of New Zealand. These include glow worm caves in such places as Lake Te Anau in Fiordland and Waitomo in the King Country, the West Coast's Pancake Rocks at Punakaiki and a variety of sculpted pools, caves, arches, and unusual rock formations in various parts of the North and South Islands. The karst landscapes are formed when water dissolves calcium-containing rocks such as limestone and marble.

### *Minerals*

Minerals are an important component of our rocks, sediments and soils. They affect the chemistry of our waters and soils and also provide economically useful materials. Textbooks usually define minerals as inorganic substances that have formed naturally in rock or soil. Industrial definitions tend to include anything that can be mined, including fossilised organic substances such as coal.

The most economically important minerals are aggregates of sand, rock, and gravel (used for road and building construction), gold, silver, coal, and ironsand. Limestone is also important. It is used to make fertiliser, cement, building blocks, and even the backing for 'all wool' carpets. A number of other economic metals exist in small to moderate quantities (e.g. copper, lead, zinc, tungsten, manganese, mercury, uranium, aluminium, antimony, arsenic, chromite, nickel, monazite and rutile). Among the minor non-metals that have been mined at some time are the clays, bentonite (used for filler) and halloysite (used for ceramics), silica sand (used to make glass), sulphur and phosphate (fertilisers), serpentine, feldspar, pumice, woollastonite, magnesite, asbestos and diatomite.

### The soils

The soils which evolved wherever New Zealand's rocks met forests, tussocks and wetlands varied with the terrain, climate, parent rocks and vegetation. The hundred or more soil types can be broadly lumped into three main categories:

- **pumice** soils are derived from volcanic rhyolite and are widespread in the central plateau and geothermal zone of the North Island;
- **ash** soils (e.g. red, brown, and yellow-brown loams, brown granular clays) are derived from volcanic basalt and are common in Taranaki, Waikato, parts of Northland and also western Southland; and

**Table 8.3**

**Sustainable land use capabilities of New Zealand soils.**

| Land classes | Able to sustain the following productive uses: | Area (hectares) |
|---|---|---|
| *I, II, III* | *Multiple use farming (i.e. cropping, orcharding, and other uses based on regular cultivation);*<br>***or*** *Pastoral farming;*<br>***or*** *Forestry;*<br>***or*** *Native vegetation (e.g. forest, scrub, wetland.)* | *3,828,000*<br>*(14% of land area)* |
| *IV,V, some VI* | *Pastoral farming (i.e. permanent pasture in which cultivation is only for pastoral renewal);*<br>***or*** *Forestry;*<br>***or*** *Native vegetation (e.g. forest, scrub, wetland)* | *4,537,500*<br>*(17% of land area)* |
| *VI, some VII* | *Restricted pastoral farming (i.e. pasture with erosion controls, such as tree planting, temporary land retirement etc.);*<br>***or*** *Forestry;*<br>***or*** *Native vegetation (e.g. forest, scrub, tussock, duneland)* | *7,577,600*<br>*(28% of land area)* |
| *VII* | *Erosion control forestry (i.e. forestry requiring specific management systems to minimise erosion);*<br>***or*** *Native vegetation (e.g. forest, scrub, tussock, duneland)* | *3,612,500*<br>*(13% of land area)* |
| *VIII* | *Native vegetation (e.g forest, scrub, tussock, duneland, herbfield)* | *6,219,600*<br>*(23% of land area)* |
| *Not classified* | *Towns, lakes, rivers, islands, and undefined areas.* | *1,274,800*<br>*(5% of land area)* |

*Adapted from Eyles and Newsome (1991) and Eyles (1993)*

- **sedimentary** soils (e.g. yellow-brown and yellow-grey earths, sand and recent silt) are derived from sandstones, siltstones and mudstones, and are widespread on plains, rolling hill country and coastal areas throughout both islands.

Despite their diversity, most of our soils tend to be thin and prone to acidification, with moderate to high carbon levels (reflecting their forest origins) and low nutrient levels (reflecting the geological youth of their parent rocks). From an agricultural or commercial forestry perspective, they are inherently deficient in nitrogen, phosphorus, and sulphur and, to a lesser extent, potassium and boron.

Often lime is needed to reduce acidity, and sometimes trace elements are needed for plant and animal nutrition (e.g. molybdenum, selenium, cobalt). The most widespread group of soils, covering nearly half the country, are those on steep land. Although their structure and chemistry vary, steepland soils are all erosion- prone, particularly when their vegetation cover is removed.

In 1952, following the example of the U.S. Soil Conservation Service, the Water and Soil Division of the Ministry of Works and Development adopted the Land Use Capability (LUC) classification system. This classifies land according to its risk of soil erosion under different land uses. The classification is based on climate, rock and soil type, slope, erosion type and degree, and vegetation cover. The land use classes range from the fertile Class 1 and 2 land, which has a low erosion risk under cultivation and covers a mere 6 percent of the country, to the steep, low fertility, Class 7 and 8 land, which covers 44 percent.

Using survey data from the New Zealand Land Resource Inventory 1975–79, the land use capability classification has been further developed by Eyles and Newsome (1991) who took into account the potential difficulty of erosion control and the assessed rate at which land would naturally revert to indigenous vegetation. From this, they were able to estimate the areas of New Zealand which could sustain particular activities (see Table 8.3). They concluded that barely 32 percent of New Zealand is capable of sustained pastoral use (i.e. grazing) without significant erosion control measures being applied. Some of the erodible pasture land is in eastern parts of the South Island, but most is in the North Island.

### The vegetation cover

New Zealand's vegetation cover has changed considerably in the past 700 years, with the most dramatic changes occurring in the past century. Each of the major vegetation types is described briefly below, but the primary distinction is between the indigenous vegetation, which evolved here over millions of years, and the exotic vegetation which was introduced very recently by human beings.

The **indigenous vegetation** is predominantly rainforest, but a variety of other vegetation types exist too, resulting in a diverse range of land-based ecosystems. This is recognised in the Department of Conservation's Protected Natural Area Programme which divides New Zealand into 268 'ecological districts', localities where the geology, topography, climate, and biology, as well as the broad cultural pattern, inter-relate to produce a characteristic landscape and range of biological communities (Myers *et al.*, 1987).

Only 2.5 million hectares (9 percent) of New Zealand was originally above the treeline (McGlone, 1989). Perhaps half of this alpine area carried tussock, herbfields and scrub. The rest was bare rock and ice. Below the treeline, pockets of tussock and scrub also occurred in areas where the forest cover had been permanently inhibited by such factors as temperature, infertile soil, salty conditions, low rainfall and poor drainage, or temporarily removed by windfall, volcanoes, earthquakes and lightning strikes. In these zones low, profusely branching (divaricate) shrubs and a variety of herbs and grasses were dominant. These non-forest ecosystems took many different forms, often occupying the buffer zone at forest edges or forming highly adapted plant communities in extreme zones near the ice caps and on the coastline.

In total, the grass, herb, and low shrubland communities seem to have covered no more than 5–10 percent of New Zealand's land area, flourishing mostly in the wettest, driest or highest areas, such as river terraces subject to regular flooding, frost-prone valley floors, steep cliffs, active sand dunes, leached shallow soils, and areas temporarily deforested by wind, fire, volcano or earthquake. A working figure for this report assumes an original land coverage of approximately 5 percent tussock grassland and 5 percent scrub, though this may be an overestimate.

Many of the non-forest plants were ecological opportunists, specialising in the temporary occupation of disturbed sites after landslips, dune movements or forest fires, but others were more stolid, forming the permanent vegetation cover in areas that were hostile to forests. Despite their relatively limited area these smaller vegetation communities contain a large proportion of New Zealand's plant biodiversity.

Away from these marginal zones, the land was covered by an unbroken blanket of evergreen forest and tall shrubland. The actual percentage of New Zealand that was under forest before humans arrived has been variously put at 78 percent (Wendelken, 1976; Molloy, 1980; King, 1984; Froude *et al.*, 1985), 85-90 percent (McGlone, 1989) and 90 percent (Flux, 1989; Anderson and McGlone, 1992). The lower estimates date from a time when it was thought that the deforestation of the central North Island by the Taupo eruption had been more extensive and long-lasting than it was. For this report, a working figure of 85 percent is used (23 million hectares), though the actual forested area may have been anywhere between 80 percent (21.5 million hectares) and 90 percent (24.3 million hectares).

The **exotic vegetation** cover that has replaced large areas of forest, tussock, and wetland now extends over 45 percent of the country. It includes some 9.6 million hectares of exotic grasslands, 1.6 million hectares of exotic forests, and almost a million hectares of crops, horticultural land, suburban lawns and gardens, golf courses, sports fields, public parks and road verges.

Although almost 2,000 exotic plant species (out of some 25,000 introductions) are known to have become established in New Zealand, with the possible total running as high as 6,000, only a few of these are widely grown (Halloy, 1995). Generally, the area of exotic plant cover has low biodiversity, with fewer than 50 species dominating more than 95 percent of the domesticated land area.

The vast majority of exotic plant species exist either as weeds or as cultivated plants in gardens, nurseries and scientific collections. As weeds, they can sometimes reach higher levels of biodiversity on conservation land than on farmland, even outnumbering native species. For example, the Whitiau Scientific Reserve at the mouth of the Whangaehu river, has one of the most diverse native dune plant assemblages in the region (120 species) but an even greater diversity of exotic weeds (134 species) (Ogle, 1996).

The most widespread exotic species, covering most of the pasture grasslands, are ryegrasses (*Lolium* spp.) and clovers (*Trifolium* spp.) sown in a roughly 80 percent to 20 percent ratio. In some places, depending on climate, soil and terrain, these may be accompanied or replaced by any of 20 other exotic pasture species. Outside the pasture land, the dominant exotic species is radiata pine (*Pinus radiata*), which covers 90 percent of the planted forest area. Beyond the pasture and forest areas, 95 percent of the remaining exotic area is dominated by just 19 plant species, of which the most widespread is barley (*Hordeum vulgare*) (Halloy, 1995).

The following is a brief description of the main types of indigenous and exotic vegetation cover in New Zealand.

### *Tussock grasslands*

Before human settlement the natural tussock grasslands were very limited in area. They probably extended over no more than 1.5 million hectares (roughly 5 percent of the country), mainly in the high country of the South Island. The total area is hard to quantify because much of the 2–3 million hectares potentially available for tussock also bore low shrubland, alpine scrub and bare scree.

Most of the pure grassland was in the sub-alpine zone above 1,200 metres, where snow tussocks (*Chionchloa* spp.) predominated, some species growing as tall as 1.5 metres. At lower altitudes, various short tussocks, growing up to half a metre, were predominant. They included hard and alpine fescue tussock (*Festuca* spp.), blue and silver tussock (*Poa* spp.), and bristle tussock, or danthonia (*Rytidosperma* spp.). These short tussocks occurred in small patches in lower-lying dry or water-logged areas, such as the Cromwell Basin and the banks of regularly flooding rivers like the Upper Ahuriri in the McKenzie Country, the Travers Valley of Nelson Lakes National Park, and the gravels and lapilli fields formed by volcanic debris in the Tongariro National Park.

In very dry seasons or areas (e.g. Central Otago), large patches of scrub and forest were burnt off at least once or twice every thousand years by lightning strikes and (in the North Island) volcanic eruptions. Tussock grassland quickly colonised the burnt out areas. Over subsequent centuries the forests would slowly regenerate and replace the tussock only to be eventually struck down again by fire.

This natural cycle has been interrupted over the past 600–700 years by repeated human-lit fires which allowed the tussock to expand greatly at the expense of scrub and forest. Snow tussock became widespread below the 1,200 metre contour, extending down to 900 metres. Below this, fescue and silver tussock became dominant, though the tall red tussock (*Chionochloa rubra*) became widespread in the wet soils of Southland and the central North Island. Following European settlement, sheep and rabbits entered the grasslands, fires were lit even more frequently, and the snow tussocks began to retreat. In many areas they were replaced by short tussocks which, in turn, are now being replaced by exotic grasses, ground-hugging rosette herbs called hawkweeds (*Hieracium* spp.), and native alpine cushion plants called scabweeds (*Raoulia* spp.).

In summary, most of the tussocks below 1,200 metres are colonisers that took advantage of forest fires lit by humans. Outside the driest parts of Central Otago, only human fires and grazing animals have prevented reversion back to scrub or forest. If allowed, native trees such as Hall's totara, kanuka and beech would slowly re-establish in many South Island areas. Similarly, most of the red tussock grassland of the central North Island is fire-induced and is now developing into scrub. Despite their cultural origin, however, the expanded tussock grasslands have great ecological importance, providing secure habitat for unique plants and animals formerly restricted to very small areas (Ashdown and Lucas, 1987).

#### ***Dunelands***

Dunelands consist of dry sand ridges (dunes) and the damp hollows between them (slacks). New Zealand has over 300,000 hectares of sand dunes but only a small area of this has natural duneland vegetation. Most of the dunes are covered in pasture or exotic forest, except for some 50,000 hectares of foredunes (i.e. dunes directly adjacent to the sea), which are dominated by sand-binding dune grasses, and a further 40,000 hectares of backdunes which are covered in scrub (Hunter and Blaschke, 1986; Newsome, 1987).

At the time of Polynesian settlement, the coastal foredunes may have had an area of 60,000 hectares (King, 1984). Behind them, the extensive backdunes were covered in scrub and native forest. There is evidence of widespread movement of the North Island sand dunes both before and after Maori colonisation (McGlone, 1983; McFadgen, 1985). Climatic factors, such as tropical storms, played a significant role (McFadgen, 1985, 1989; Anderson and McGlone, 1992) but human firing of forests and dune vegetation appears to have contributed as well, leading to dune destabilisation and sand drift (McGlone, 1983, 1989; Anderson and McGlone, 1992).

The foredunes were dominated by the endemic sand-binding sedge, pingao (*Desmoschoenus spiralis*) and the native dune grass, raumo or spinifex (*Spinifex sericeus*). The back dunes, which sometimes extend hundreds of metres inland, were occupied by other indigenous species such as the sand grass *Austrofestuca littoralis*, sand convolvulus (*Calystegia soldanella*), pohuehue (*Muehlenbeckia complexa*), clubrush *(Isolepsis nodosa*), sand coprosma (*Coprosma acerosa*) and tauhine (*Cassinia leptophylla*). These plants restrict wind action on the sands and build up soil humus levels until the dunes are stabilised. At that point, the back dunes would be colonised by scrub and forest in wet areas, and native grasses in dry areas (Partridge, 1992).

Between the dunes, the presence or absence of water has a marked effect on the vegetation communities which form. In dry areas, where the sand is windblown, vegetation is often absent or restricted to such species as pimelea

(*Pimelea arenaria*), a sand daphne, and scabweed (*Raoulia australis*), a cushion plant. In dune slacks (moist hollows) wetland plants such as *Selliera radicans*, *Leptocarpus similis*, or harakeke flax, take root. In wetter areas dune lakes form, often fringed with the native reed, raupo.

Among the specialised dune animals are several native moths and butterflies, some of which are restricted to the dune environment, as well as the sand dune hopper, whose paddle-like legs are adapted to sand digging, the speckle-coated sand beetle and the nocturnal sand scarab beetle. The dune slacks and lakes often have aquatic insects and may even contain rare fish. For example, the Northland dune lakes are the only habitat of the dwarf inanga (G*alaxias gracilis*) a threatened species of indigenous fish.

Today, most of the dune ecosystems have been replaced by introduced pasture grasses and exotic pine forests (Newsome, 1987). In most of the 52,000 hectares that remain, introduced marram grass (*Ammophila arenaria*) is now the dominant sand-binder, assisted by the nitrogen-fixing lupin, *Lupinus arboreus*. The roots and stems of the marram grass are more effective sand-binders than pingao, and were deliberately planted in many areas to stabilise dunes whose original vegetation had been burnt off or grazed by livestock.

#### *Herbfields*

The 'pure' alpine and sub-alpine herbfields cover nearly 200,000 hectares, though many of the herb species within them are also present over two million hectares of high altitude tussock and scrub. They are dominated by various species of alpine daisies, notably those of the genus C*elmisia*, as well as buttercups, cushion and mat shaped herbs and grasses, rosette shaped herbs, lichens, and, in areas of poor drainage, rushes, sedges and umbrella ferns.

Despite their small area, the herbfields have considerable plant diversity, with more than 600 species. Although many are closely related, more plant species are found here than in the forests (Dawson, 1988). Their harsh environment has created many opportunites for evolutionary divergence from the ancestral populations. The inhospitable conditions have also provided some protection from human, stock and weed invasions. Despite this, the larger herbs have been depleted by introduced deer, goats, chamois, tahr, and hares which run wild in these mountains.

#### *Shrublands or scrub*

Shrublands, commonly called scrub, are dominated by ferns, bushes and small trees. They have always been an important part of New Zealand's vegetation cover, harbouring much of our plant biodiversity, though their original area was probably no more than 1.5 million hectares. Sometimes shrublands are the dominant vegetation in marginal sub-alpine and coastal environments. In other cases they are a successional stage in the regeneration of indigenous forest, particularly on disused or neglected farmland.

In the North Island and moister areas of the South Island, the scrub communities are dominated by mixed broadleaved shrubs, manuka (*Leptospermum*) and kanuka (*Kunzea*) trees and bracken. In the drier parts of the South Island, matagouri (*Discaria toumatou*) dominates. These days, introduced species, such as gorse (*Ulex europaeus*), broom (*Cytisus scoparius*), and sweet brier (*Rosa rubiginosa*) also dominate in some localities.

Before human settlement, scrub occurred mostly in sub-alpine and coastal zones, around wetlands and lake edges, on the Canterbury river flats, and in areas of forest regeneration following natural events such as windfall and lightning strikes. With deforestation and the establishment of extensive grasslands, scrub has increased considerably in cutover forest, on forest margins, in unimproved or abandoned pasture, and in disturbed dunes and wetlands. Introduced browsing animals, namely possums, goats and deer, have also turned many areas of mature forest into scrub and fern ecosystems. These animals eat young plants and shoots, preventing new young trees from replacing old dying trees. They also kill some mature trees outright.

Around 7.5 million hectares of scrub-associated vegetation were mapped in New Zealand a decade ago, though in much of this scrub was not the dominant component of the vegetation. On around 4.2 million hectares the scrub occurred on pastoral grassland. On almost one million hectares it was scattered among sub-alpine tussock. On a further 1.3 million hectares it was part of regenerating forest vegetation. Only about one million hectares were classified solely as scrub communities (Newsome, 1987).

### *Indigenous forests*

The forests which covered about 85 percent of New Zealand contained over 100 identifiable forest types, distiguishable to the expert eye by the mix of tree species within them (Nicholls and Herbert, 1986). A simplified classification for non-experts identifies three major forest classes: **kauri**-dominated forests in the north**, beech** forests at higher altitudes and much of the south, and **podocarp-hardwood** forests at lower altitudes and stretching from one end of the land to the other. Being conifers, kauri (*Agathis australis*) and podocarp trees are distant relatives of the northern hemisphere pine trees (*Pinus radiata*) which now dominate our commercial forest industry.

#### *Kauri forests*

The kauri forests flourished at the top of the North Island from the Bay of Plenty, through Auckland to Northland. Although they sometimes occurred in pure stands, the kauri trees were mostly intermingled with podocarp-hardwood forests at densities of about four trees per hectare (Fleet, 1984).

Few trees in the world reach the imposing size of the kauri. Growing from 30 to 50 metres tall, with a tremendously thick cylindrical trunk, kauri became a prized timber tree, particularly sought after by boat builders because it is naturally durable and easily worked. Left to themselves, the trees are very long-lived. Some of those felled in the past century had started their lives more than 2,000 years ago.

#### *Podocarp-hardwood forests*

The podocarp-hardwood forests are New Zealand's major forest type, occurring in many variations up and down the country. They contain an unusual mixture of cone-bearing trees (the podocarps or 'softwoods') and many species of flowering trees (the 'hardwoods' or 'broadleafs'). Although podocarps occur throughout the southern hemisphere, the 20 or so species found here are unique to New Zealand. With the associated hardwoods, they made an unusual type of forest which looked more tropical than temperate.

The podocarps include the rimu, or red pine (*Dacrydium cupressinum*), often the dominant species in a forest, and the kahikatea, or white pine (*Dacrycarpus dacrydioides*), which pre-dominated in areas of poor drainage. These trees can reach heights of 50 metres, with some kahikatea reaching 60 metres. Other prominent podocarp species are totara and Hall's totara (*Podocarpus totara* and *P. hallii*); matai and miro (*Prumnopitys taxifolia* and *P. ferruginea*); pink pine (*Halocarpus biformis*); silver pine (*Manoao colensoi*); yellow-silver pine (*Lepidothamnus intermedius*); tanekaha or celery pine, toatoa and mountain toatoa (*Phyllocladus trichomanoides*, *P. toatoa* and *P. alpinus*).

The hardwoods are, in many cases, related to tropical families. They include pohutakawa and southern and northern rata (*Metrosideros excelsa*, *M. umbellata* and *M. robusta*); tawa and taraire (*Beilschmiedia tawa* and *B. tarairi*); hinau (*Eleaocarpus dentatus*); kamahi (*Weinmannia racemosa*); black maire (*Nestegis cunninghamii*); pukatea (*Laurelia novae-zelandiae*); puriri (*Vitex lucens*); and rewarewa (*Knightia excelsa*).

Podocarp-hardwood forests are sometimes referred to as 'lowland' forests because they tend to predominate at lower altitudes (i.e. below 800–900 metres in the North Island, below 650 metres in large parts of the South Island, and below 450 metres in the southern South Island and Stewart Island). The hardwood tawa was often the dominant tree in the North Island at lower altitudes and the podocarp rimu was dominant at higher altitudes. In the South Island, rimu was generally dominant. Some areas, however, were dominated by hardwoods—the red-flowered rata and the white-flowered kamahi. Even where these hardwoods were not dominant they were well represented. In fact, kamahi is often regarded as the most abundant native tree in New Zealand.

When the Europeans arrived, the podocarp-hardwood forests had a luxuriant, impenetrable, jungle-like appearance particularly in high rainfall areas. Below the tall tree canopy, a profusion of shorter trees, shrubs, vines and ferns vied for space, and below them lichens and mosses spread over the ground and the trunks of fallen trees, except in the wet kahikatea forests, where they vanished into dark, still water.

*Beech forests*

The beech forests generally grow in cooler environments than the other forests, though in many areas they intermingle with the podocarps and hardwoods. Pure beech forests occur in the North Island mountain ranges from the Raukumara Range to the Huirau Range, and in the South Island, along the main ranges from north-west Nelson to southern Fiordland and Te Waewae Bay. They have never grown on Stewart Island.

The beech trees are hardwoods, members of the angiosperm group. The New Zealand ones belong to the genus *Nothofagus* which evolved shortly before the break-up of Gondwana. Species of *Nothofagus* also occur in Tasmania, Australia, New Guinea, New Caledonia, and Chile. Four species exist in New Zealand: red beech (*N. fusca*); hard beech *(N. truncata*); silver beech (*N. menziesii*); and black beech *(N. solandri*), which also includes the subspecies mountain beech (*N. solandri cliffortioides*). Beech forests are generally sparser than the podocarp-hardwood forests. Their understorey may contain only young beech saplings, ferns, and mosses. The lacy quality of light from filtered sun gives these forests a different ambience to the more densely packed podocarp-hardwood forests.

All the New Zealand forests were characterised by a general absence of bright colours, with the small hardwood flowers dwarfed by subdued shades of green foliage. The main speckles of colour came from the red-flowered rata and pohutukawa, and several other angiosperms with tropical relatives (i.e. kakabeak, puriri, rewarewa, mistletoe, kowhai and, on the forest edges, flax). The young Charles Darwin found New Zealand's forests fascinating, but rather gloomy, when he visited the country in 1832 (P.H. Armstrong, 1993).

***Exotic grassland***

The mainstay of New Zealand's pastoral farming system has been the combination of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*), or, in drier areas, ryegrass and subterranean clover (*Trifolium subterraneum*). These species require high levels of nutrients and low soil acidity. As a result, considerable effort and expense has gone into 'developing', 'improving', and maintaining pasture soils through the regular addition of phosphate fertiliser, lime, and various other nutrients and trace elements (Goh and Nguyen, 1991).

Ryegrass needs large amounts of nitrogen. This is provided by the clover, which is a legume whose roots contain *Rhizobium* bacteria. These bacteria convert the air's nitrogen into soil nitrates which can then be absorbed by the ryegrass. Clover, however, requires high amounts of phosphorus and cannot tolerate soils which are too acidic. As a result, the sustainability of the ryegrass/clover association depends on widespread applications of phosphate fertiliser and, in many areas, lime. The lime reduces acidity and also supplies calcium as a nutrient.

Dessication can also be a problem for the pasture grasses. In dry parts of the South Island, irrigation is necessary. In recent years, new mixes of grasses (such as cocksfoot) and legumes (such as lucerne) have been tried in various pasture mixtures, and plant breeders continue to develop new strains of pasture grasses that will thrive in different soil conditions—wet, dry, acid, or alkaline.

When properly maintained, the exotic pasture grasses form dense swards with extensive root systems that are good for the soil. The matted roots are shallow but provide organic matter and a greater degree of erosion protection and run-off control than do unimproved grasses. On plains, easy slopes, and in moist areas, the ryegrass-clover association is the dominant pasture vegetation.

In hill country and drier areas, however, these species are often joined by various other grasses, such as cocksfoot (*Dactylis glomerata*), timothy (*Phleum pratense*), browntop (*Agrostis capillaris*), sweet vernal (*Anthoxanthum odoratum*), dogstail (*Cynosurus cristatus*), and Yorkshire fog (*Holcus lanatus*). In the northern North Island, where the temperature is higher, the dominant species may include paspalum (*Paspalum dilatatum*), the native carpet grass (*Chionochloa australis*), Kikuyu grass (*Pennisetum clandestinum*) and ratstail (*Sporobolus africanus*).

In many areas the pasture grasses are perennial and do not enter an annual seed phase. They are replenished by oversowing of new grass seed. However, in semi-arid parts of the South Island, and on steep, dry, north facing slopes, annual grasses do better than perennial ones. They cope with dry conditions by putting their limited resources into seed production for the following season rather than into tissue growth. These species include rapidly establishing, bulky grasses and clovers, such as the short rotation Manawa and Italian ryegrasses (*Lolium* spp), red clover (*Trifolium pratense*), subterranean clover, brome grasses (*Bromus* spp.), hairgrasses (*Vulpia* spp.), lotus (*Lotus subiflorus*), and lucerne (*Medicago sativa*). In less fertile land native grasses may also be present (e.g. danthonia, and short tussock).

#### *Crop and horticultural land*

New Zealand has about 3.8 million hectares of Class I, II and III land physically capable of regular cultivation. However, at any one time, most of this is in pasture and the total area in crops (peas, grain, fodder, orchards, vineyards, and market gardens) covers less than 500,000 hectares. The standing crop area has actually declined since the early days of this century when large oat crops were needed for horses.

In recent years, the area devoted to horticulture has expanded by 40 percent (from 88,000 hectares in 1990 to 124,000 in 1995). This is reflected in our trade figures. Although we import half our wheat, we export a wide range of horticultural products. The horticultural sector includes fruit production (e.g. apples, oranges and lemons, peaches, apricots, nectarines, kiwifruit and other berries etc.), market gardening (e.g. green vegetables, tomatoes, potatoes and other root vegetables etc.), wine production (i.e. grapes), and floriculture (for the cut flower market).

While the standing crop area shows the amount of land used for cropping at any one time, it dramatically understates the total amount used over longer periods. This is because many pea, grain and fodder crops, and some vegetable crops, are grown in rotation with pasture. Under this mixed cropping system, a field will produce crops for several years and then be returned to pasture to replenish the soil. A new field will then be converted from pasture to cropland. After several crop rotations, the total area used for cropping is several times larger than the standing crop. In parts of the South Island, rotations of nine to ten years are often favoured, but in very dry areas, rotations are as short as two to four years.

About 40 percent of the standing cropland area is devoted to rotational crops of grain (barley, wheat, maize, and oats) and peas. A further 20 percent is devoted to crops of fruit and vegetables (principally kiwifruit, apples, grapes, potatoes, onions, and squash). The remainder is divided between fodder crops (e.g. hay, rape, turnips) which provide food for livestock when winter pasture growth in the South Island is insufficient, and fallow land which has been left to recover after a period of repeated cropping.

The main cropping areas are in the fertile coastal plains. Wheat, barley, and oats are grown mostly in Canterbury, Otago, and Southland, though significant amounts of barley are also grown in the Manawatu. Maize is grown mostly in Waikato and the Bay of Plenty, and to a lesser extent in the Manawatu-Wanganui region. Areas of significant fruit production occur in Northland, Auckland, Bay of Plenty, Gisborne, Hawke's Bay, Nelson, Marlborough, Canterbury and Central Otago, though orchards, berry gardens, and vineyards exist in other parts of the country as well (e.g. vineyards in the southern Wairarapa).

Crops, orchards and market gardens, as well as dairy and fat lamb pastures, are generally classified as intensive forms of land use, requiring high inputs of fertilisers, mechanical energy, labour, pesticides and herbicides, and often putting considerable pressure on soils. Indigenous biodiversity is virtually nil in these systems. Of all the forms of cropping in New Zealand, market gardening probably keeps the land in most continuous production and requires the most careful soil management.

#### *Exotic forest land*

Because they grow faster and taller in New Zealand than anywhere else, including their native California, radiata pine trees (*Pinus radiata*) are the dominant timber tree here. They make up 90 percent of the 1.6 million hectares of exotic forest. The rest of the exotic tree stock consists of 5 percent Douglas fir (*Pseudotsuga menziesii*), 2 percent eucalypts (*Eucalyptus* spp.), and a variety of special purpose species, such as blackwood (*Acacia melanoxylon*), black walnut (*Juglans nigra*), macrocarpa (*Cupressus macrocarpa*), ponderosa pine (*Pinus ponderosa*) and Corsican pine (*Pinus nigra*).

Most exotic forests are planted as single species crops. The fast-growing pine crops are harvested in short rotations of 25–35 years. Wide-spaced planting and intensive pruning and thinning are now widely adopted as the standard management practice (Purey-Cust and Hammond, 1995). Herbicides are often used in site preparation and during the first few years, mostly to reduce competition from aggressive exotic weeds, such as blackberry, bracken, broom, gorse and grasses (Davenhill, 1995). Young forests in wet humid areas are occasionally sprayed with copper-based fungicides to combat the growth-debilitating needle blight fungus (*Dothistroma pini*) which reached New Zealand several decades ago (Gadgil *et al.*,1995). Occasionally, fertilisers are applied to plantation soils where nutrient levels are low, most commonly nitrogen, phosphorus and boron (Mead, 1995).

Exotic forests were first planted on a small scale in the 1890s. Large scale planting began in the 1920s when it became apparent that native timber supplies would eventually run out. The first plantings were mostly on low fertility pumice land in the central North Island (Purey-Cust and Hammond, 1995). Tourists travelling through the centre of the island are often impressed by these extensive tracts of dark pine forest.

A second planting boom, which began in the 1960s, was more scattered. Many plantations were established throughout the country, often replacing cutover native forest and regenerating scrub. A proposal to convert extensive areas of Crown-owned beech forest to pine plantations led to a prolonged confrontation between foresters and environmentalists during the 1970s until the proposal was finally dropped.

The third planting boom is a 1990s phenomenon, triggered among other things, by high export returns from pine logs and low returns from sheep. As a result, most new forest planting has been on pasture, about a third of it on hilly and steep land that was cleared of native forest in earlier decades. The direct replacement of native forests by exotic plantations had virtually halted by the 1990s, due mainly to economic constraints, but also to agreements between environmentalists and the forest industry. However, in some regions, indigenous scrub was still being converted to exotics, mainly by smaller forestry companies (McLaren, 1995).

Because they are not indigenous and are managed and tended as monocultural crops, exotic forests are sometimes seen as 'biodiversity deserts'. However, a number of studies have found moderate to high levels of indigenous plant, insect and bird diversity in pine forests (Clout and Gaze, 1984; Ogle, 1976 and 1989; Allen *et al.*, 1995; Ledgard, 1995; McLaren, 1995; Spellerberg and Sawyer, 1995). In most cases these are opportunisitic species, such as weeds and exotic birds, that invade the site shortly after harvesting and then become rarer as the site ages.

However, on fertile and wet sites where trees are older than 25 years and are well spaced out pine forests often have a dense, varied, understorey, sometimes including rare native plants and animals. A number of native birds have colonised pine plantations. Grey warblers, fantails and silvereyes are common. Robins, whiteheads, wekas, harrier hawks, kingfishers and shining cuckoos can also be found. However, birds which eat nectar and berries or which nest in holes and old logs are rarely present.

A dramatic example of a native bird colonising a pine forest is the North Island brown kiwi in Waitangi Forest, Northland (Colbourne and Kleinpaste, 1983). Medium to high densities live and breed there. After logging, they retreat for several months to forest remnants in gullies and swamp margins and then re-establish territories in adjacent pine stands. Sensitive forest management is attempting to accommodate the birds (Steven, 1995).

Clearly, older pine forests are not biodiversity deserts. On the the other hand, they are far from biodiversity havens (Rosoman, 1995b; Spellerberg, 1996). Plantation forests have two major limitations as habitat for native animals (Steven, 1995). First, most species have evolved behaviour which is especially adapted to the native forests. Pine plantations have fewer suitable eating, nesting and breeding sites. Second, the short harvest cycles of plantation forestry mean that any native understorey which does develop provides only temporary habitat.

Although the biodiversity of pine plantations is less than that of indigenous forests in similar locations, foresters often point out that much of New Zealand's high altitude beech forest consists of even-aged single-species stands that have little understorey and few other vascular plants present (McLaren, 1995; Rosoman, 1995b). Of more significance, though, is the fact that exotic forests support more indigenous species than the pastures they are now replacing. While it is true that some of the areas being planted today would have reverted to native forest and scrub if left alone, many other areas would have remained in pasture had they not been converted to pine forests. Many environmentalists now see pine forests as playing a positive role in that they take the logging pressure off native forests and also enhance soil and water quality on farms by stemming erosion and reducing run-off.

## PRESSURES ON THE LAND

Floods, drought, wind, earthquakes, lightning strikes and volcanoes are all natural pressures which affect soil and vegetation. At various times before and after the last ice age these pressures have briefly affected different parts of New Zealand, damaging forests, causing periods of accelerated erosion or laying down the foundations of new soil layers. Since the arrival of humans, however, these pressures have been augmented, and even overshadowed, by a sustained battery of additional pressures associated with human activities. The main human-induced pressures on New Zealand's land have been from:

- **vegetation change**, principally deforestation, but also draining of wetlands, modification of tussock grasslands, and conversion of dunelands to pasture and exotic plantation forests;
- **land use pressures**, principally the effects on soil and biodiversity of farming practices, but also forestry, and urban, industrial, and transport activities; and
- **pests and weeds**, both the exotic species which threaten the biodiversity of natural ecosystems, and the exotic and indigenous species which threaten the productivity of pasture, crop, or forest land.

### Vegetation change pressures

Polynesian and European settlers, and their descendants, put considerable pressure on the indigenous forests. In the space of 650–750 years (roughly 20–30 generations), humans reduced the indigenous forest cover from approximately 85 percent of the land area (23 million hectares) to about 23 percent (6.2 million hectares) (see Figures 8.3 & 8.5 and Box 8.1).

The period of early Maori deforestation had a dramatic impact on our biodiversity (see Chapter 9) and seems to have caused erosion and sand drift in some areas but not others (McGlone, 1989).

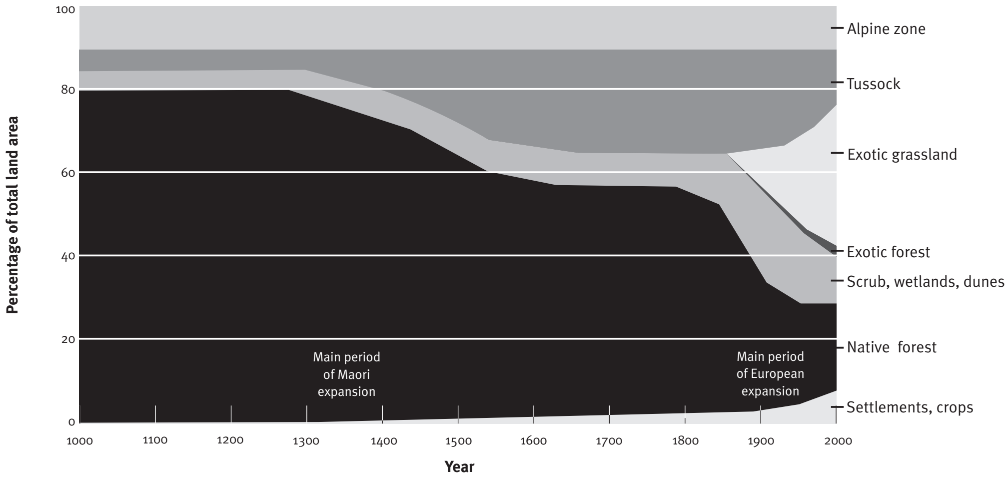
Soil and pollen studies have revealed that firing of the forest in the inland basins of the South Island was followed by erosion (Molloy, 1977). Research on estuary sediments shows that deforestation often led to a 3–4 fold increase in sedimentation (Hume and McGlone, 1986). In Canterbury, the increase may have been ten-fold (McSavaney and Whitehouse, 1989). Dunes also seem to have been affected (McGlone, 1983, 1989; Anderson and McGlone, 1992), though the extent of this is debated (McFadgen, 1985, 1989).

However, forest fires did not cause significant erosion everywhere. A study of sediment layers from Lake Tutira north of Napier found that, although the surrounding land (which is steep and erosion-prone) had been deforested in Maori times, erosion did not increase until European farmers arrived in the late 1800s (Trustrum and Page, 1991). The sediment record revealed that the natural erosion rate before human settlement was 2.1 millimetres per year. This remained unchanged throughout the period of Maori settlement, despite forest fires. Then, in the last 110 years, the erosion rate soared seven-fold to 14 mm per year. The reason for this appears to lie in the different types of vegetation change that occurred. In the Maori period, the forests were replaced with deep-rooted bracken fern and scrub, but in the European period they were replaced with shallow-rooted pasture grasses. It seems, therefore, that Polynesian forest fires only initiated large-scale erosion in areas of soft, weaker, rocks where the replacement vegetation was unable to sufficiently absorb rain or bind sand and soil (McGlone, 1989).

Although forests were the most extensive ecosystems to be dramatically affected by the pressure of humans and their farm animals, the native grasslands, wetlands and dunelands have also been heavily modified. All the major changes to these ecosystems have occurred in the past 150 years as a result of the expansion of farmland and the development of urban settlements near rivers and the coast. Drainage and flood protection schemes have been almost constant throughout this period.

**Figure 8.3**

**The recent history of New Zealand's land cover[1].**




[1] Vegetation areas and timing of changes are approximations only

**Figure 8.4**

**Production of indigenous and exotic rough-sawn timber, 1876-1994.**

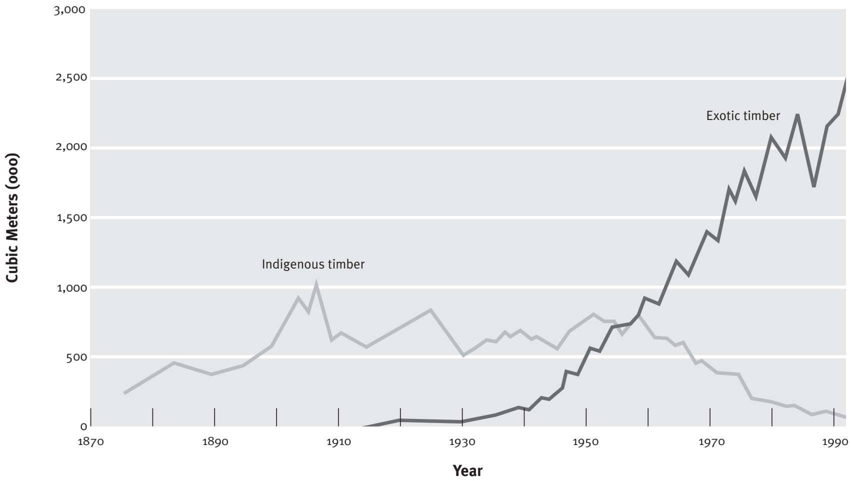
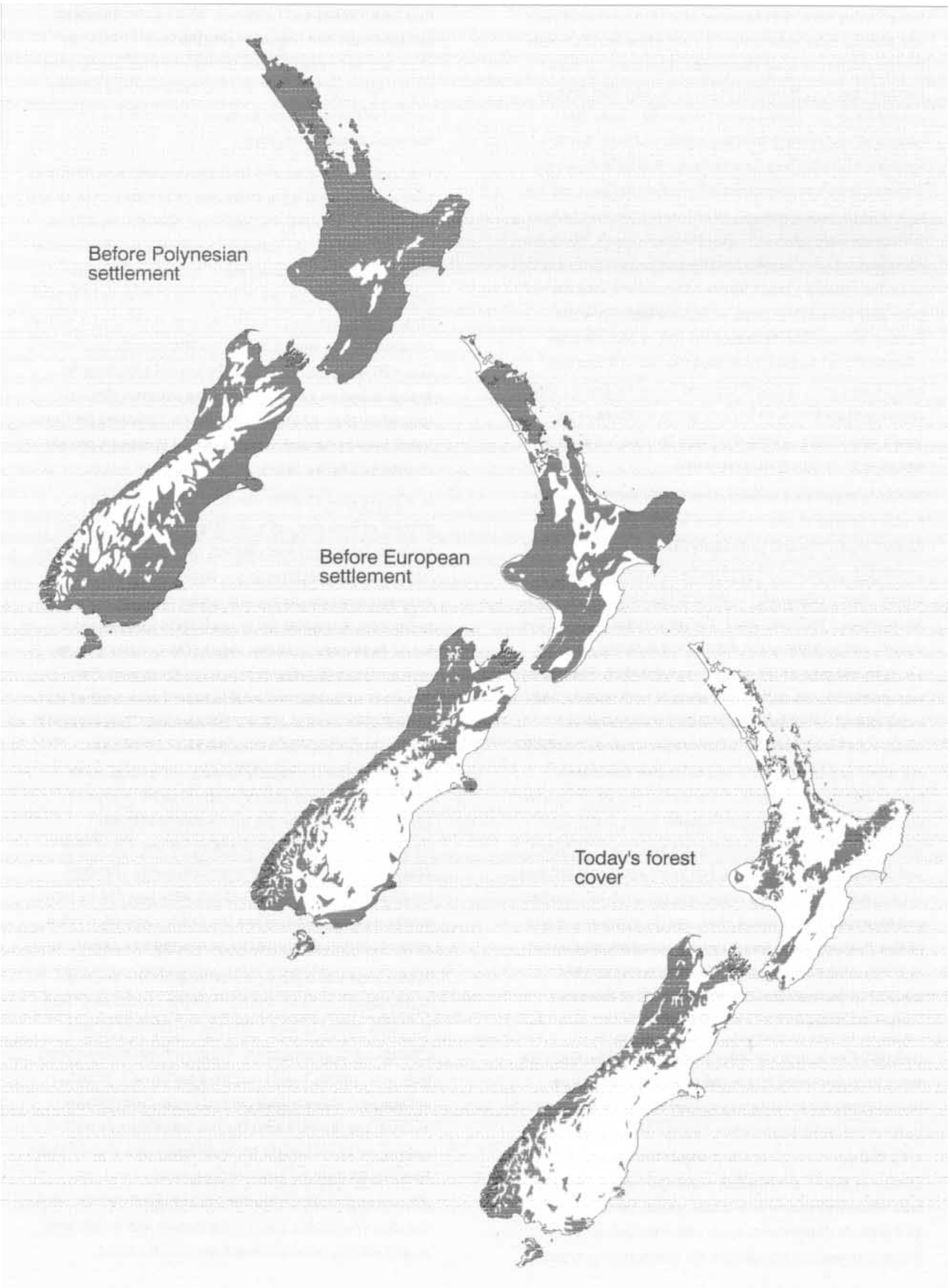


**Figure 8.5**
**Human impacts on New Zealand's natural forest and tall shrubland.**




*Source: McGlone (1989), New Zealand Map Service 262 (DOSLI)*

**Box 8.1**

### *Deforestation - past and present*

Since leaving the African savannas tens of thousands of years ago, humans have been turning the rest of the world's forests into grasslands or open woodlands. Explorers, such as Hanno in 500 B.C., Magellan in A.D. 1520, and Abel Tasman around A.D. 1640, remarked on the smoke clouds that emanated respectively from the coasts of Africa, South America, Australia, and New Zealand. People everywhere, it seems, from hunter-gatherers to modern farmers, set fire to forests to 'open them up', often leaving the fires to burn indiscriminately (Stewart, 1956; Flannery, 1994). There are many reasons why: to clear land for gardens and settlements, to encourage new growth for prey or domestic animals, to drive prey animals into traps, to improve visibility while hunting or travelling, to reduce the risk of ambush from predators and enemies, to remove the risk of forest fires near settlements, to dispel the near universal anxiety that comes with darkness, to fulfil religious or recreational needs, and simply to keep the flame burning lest it go out and have to be laboriously recreated.

The early Maori were no exception to this pattern, and the firestick formed an important part of their travelling kit (Walsh, 1896). Fire was particularly useful in encouraging the growth of bracken fern whose starchy rhizomes (underground stems) were a staple part of the diet (McGlone, 1978, 1983; Anderson and McGlone, 1992; Flannery, 1994; McGlone and Basher, 1995). Most of the destruction occurred between A.D. 1350 and 1550 as the population expanded. The impact was greatest in the dry eastern areas of both islands, and in the central South Island high country where tall red tussock and snow tussock replaced beech forests (at higher altitudes) and totara, matai and kahikatea dominated forests (at lower altitudes). From around 750 years ago, the inland Kaikoura Range was repeatedly burnt until it was dominated by bracken, tussock grass and scrub (McGlone and Basher, 1995). Beginning 600 years ago, repeated fires in Central Otago converted forests and tall scrub into bracken and then tussock (McGlone *et al*., 1995). In the drier parts of New Zealand, some forest types were nearly eliminated (e.g. dry inland conifer-broadleaved forests) or were reduced to unrepresentative fragments (e.g. lowland matai-totara forests).

Deforestation appears to have ceased after 1600, but large areas of regenerating forest and scrub continued to be burnt. Extensive burning was carried out along the east coast of the North Island when Captain Cook sailed by in 1769 (Salmond, 1992), and increased after European contact as Maori communities expanded their gardens to take advantage of new vegetables, crops, farm animals, and markets (Hargreaves, 1963; Cameron, 1964). Some Maori entrepreneurs began market gardening for export to New South Wales and California. Meanwhile, European entrepreneurs had begun logging the kauri forests. By 1840, just before large scale British and Irish immigration began, the total forested area had been reduced from 85 percent of the land-cover to about 53 percent (14.3 million hectares) (Wendelken, 1976).

The European settlers and their descendants saw forests as both an obstacle to agriculture and an inexhaustible source of timber (Fleet, 1984; Halkett, 1991; Memon and Wilson, 1993; Park, 1995). As European numbers grew, particularly from the 1860s on, farming aided by timber production began to take a huge toll on the forests. Pasture increased rapidly from less than 70,000 hectares in 1861 to 1.4 million hectares by 1881 and 4.5 million hectares in 1901 (Department of Statistics, 1990). Banks Peninsula in Canterbury, for example, had 20 sawmills operating between 1860 and 1900 which reduced the luxuriant totara-dominated podocarp forest from 75 percent of the land area to about 5 percent (Norton and Fuller, 1994).

In a single intensive decade, from 1890 to 1900, 27 percent of New Zealand's existing forest (or 13 percent of the total land area) was cleared, reducing the forest area from 13 million hectares to 9.5 million hectares. The deforestation rate during this period was four times the recent rate in tropical Asian rainforests (Glasby, 1991; World Resources Institute, 1992). The number of farms rose quickly from around 10,000 in 1871 to more than 80,000 in 1921 when the total occupied area reached its natural limit—some 17.6 million hectares. This occupied land included several million hectares of remnant indigenous forests, mostly in marginal (steep) areas, many of which were subsequently cleared to expand pasture. Burning was the prime means of forest clearance, accounting for probably 90 percent of New Zealand's deforestation (Purey-Cust, 1986). Pastoral landscapes that look idyllic today were clouded by wood smoke a century ago. When the smoke cleared, it left a vista of blackened hillsides and charred tree skeletons.

Timber production played a smaller role than fire, but a highly significant one. Profits from the 10 percent of logs that were milled helped offset the overall cost of land clearance and development. Kauri and the tall podocarps (e.g. rimu, totara, kahikatea) were particularly prized. Indigenous timber output peaked in 1907 with smaller peaks in the decades after the two world wars as many returned soldiers sought to create farms on marginal forest land provided by the government (see Figure 8.4). An attempt was made to slow the pace of forest destruction in the 1874 Forests Act, but this legislation was widely seen as an obstacle to development and was repealed.

Subsequent amendments to the Lands Act made provision for preserving steepland forests on erosion-prone public land, and also for the establishment of scenic reserves, but did nothing to impede deforestation on potentially productive land. In fact, the Department of Lands actually considered it improper to leave trees standing on any land that might be farmable.

Although two national parks and a number of small reserves, were established towards the turn of the century, they were in the mountains or in other areas with little or no agricultural potential. Not until 1919, when virtually all the usable land had been occupied, was a State Forest Service established to husband what remained of the loggable public forests, and to protect four to five million hectares of steepland forest for erosion and flood control. These protection forests form the bulk of today's remaining indigenous forest.

With only 30–50 years of timber supply remaining in the loggable forests, the Forest Service aimed to manage them for sustained yield while planting fast-growing exotic species to meet future timber needs. Sustained yield management came to be seen as impractical, however, due to the slow growth of the indigenous trees. Podocarps take hundreds of years to reach maturity. Beech trees take 60–120 years and are of poor timber quality. Exotic pine trees, by contrast, take only 25–35 years. As a result, most of the loggable forests were not managed for sustained yield but for immediate economic and employment objectives, and exotic forests were planted over large areas to meet the next generation's timber needs.

A germinating environmental movement began to challenge the Forest Service in the 1930s over the fate of one forest—Waipoua kauri forest. The campaign intensified in the 1940s and the government finally declared the forest a sanctuary in 1952. Six new national parks were established over the next decade, bringing the total number to ten by 1964. Like the first parks, these were limited to mountainous areas.

During the 1950s, forests on private land began to be felled with greater intensity following a wool boom triggered by the Korean war. This contributed to the last great surge of the indigenous timber industry. By 1960 it was on the wane, overtaken by exotic timber from the Forest Service's first pine forests. From then on, exotic timber output increased as indigenous timber production declined (see Figure 8.4). Export controls were placed on kauri and podocarp logs as supplies dwindled. From over 700,000 cubic metres ($m^3$) in the mid 1950s, production of rough sawn native timber declined to less than 70,000 $m^3$ by 1993. In three decades, from 1960 to 1990, indigenous timber declined from 50 percent of total timber production to less than 5 percent.

The environmental movement contributed significantly to this decline. By the 1970s, it had become a force to be reckoned with, and clashed head-on with the Forest Service over plans to clearfell some 340,000 hectares of beech and podocarp forest in the South Island (New Zealand Forest Service, 1971; Searle, 1975). The beech scheme was shelved in 1975 following wide public opposition, but subsequent battles raged over the fate of individual forests—Okarito, Pureora and Waihaha, Whirinaki, Paparoa and Waitutu. In 1987 the Government disbanded the Forest Service as part of a more general restructuring of the public sector. Existing national parks and reserves together with virtually all the Forest Service's indigenous forests were allocated to the newly created Department of Conservation—except for 152,000 hectares on the West Coast of the South Island and 12,000 hectares in Southland which were kept in timber production for employment purposes.

In the late 1980s, the attention of government and environmentalists turned from public forests to the 1.3 million hectares of privately owned native forest. Around 2,000 hectares were being cleared annually for farmland. In the North Island's Mamaku Plateau, this forest clearance was self-funded by the sale of tawa to the Kinleith pulp and paper mill. At both ends of the South Island it was funded by the export of beech woodchips to Japan. The Government responded by extending the earlier export controls on podocarps and kauri to include hardwood (e.g. beech) logs and woodchips, and by announcing that it would develop new legislation. It also set up two funds: the Forest Heritage Fund and Nga Whenua Rahui, to purchase key private forests or pay the owners to protect them. By mid-1995, about 60,000 hectares of private forest were formally protected, with a further 60–70,000 hectares committed for protection through these funds.

Finally, in 1993, the Government passed the Forests Amendment Act which requires that, from mid-1996, indigenous wood products may only be produced from forests with an approved sustainable management plan or permit. The Act also contains export controls on indigenous timber. While these measures were being developed, a separate initiative was undertaken by several environmental organisations and the major forest companies. They signed the New Zealand Forest Accord in 1992, with the industry representatives agreeing not to replace indigenous forest with exotic plantations and the environmentalists agreeing to support exotic forests as a renewable, environmentally friendly, alternative to the logging of native forests. The Accord does not bind all forest owners, but has significantly modified the behaviour of the larger companies.

**Today, it is still legal to replace private indigenous forest with pasture or exotic forests, but to do so is generally uneconomic, particularly as the returns from sheep farming have been declining for some time. Furthermore, clearfelled indigenous forest can no longer be sold as timber. As a result, clearfelling for timber or woodchips has declined from several thousand hectares annually to just several hundred. The clearfelling which continues is confined to a few specially approved areas covered by the West Coast Accord and the South Island Landless Maoris Act 1906. Most of the remaining indigenous forest is now protected or is not on usable farmland. The main pressures now come from the degenerative effects of forest fragmentation and the impacts of alien plants and animals, particularly possums, goats and deer.**

### Land use pressures

Modern land uses impose a range of pressures on soil and vegetation. Agriculture has the greatest effect because it covers the largest land area (see Table 8.1), but virtually all land uses involve some removal or disturbance of vegetation and soil. The main land use pressures are from agriculture; forestry; urban, industrial and transport activities; and mining.

#### *Agricultural land use pressures*

The most obvious effect of agriculture on the land has been the reduction in natural vegetation cover which occurred as vast areas of forest and wetland were replaced by exotic species of grass and crops and domestic grazing animals were introduced. In modern agriculture, biodiversity is deliberately reduced, and forest regeneration is suppressed, so that energy and nutrient flows can be channelled into a narrow range of plant and animal products.

The impact on soils has been mixed. In many areas, soils have been improved by the development of dense grass cover using applications of lime and fertiliser and, where necessary, irrigation water. The organic carbon content of some soils has also been improved, as has the nutrient cycling capacity and the water-retention properties of others. However, in some areas, soil quality has come under a variety of pressures. These pressures can be broadly grouped as: too many animals; too much cultivation; too few deep-rooting plants (especially on hill pasture and newly ploughed fields); too little soil replenishment (in the form of fertilisers, lime, irrigation, organic matter); or (rarely) too many toxic substances (e.g. pesticide residues).

Farming in New Zealand spans a continuum from 'extensive' through to 'intensive' production systems. These terms refer to the amount of material and energy which pass through the system in a given period. At the extensive end of the continuum is a large land area with relatively few inputs of energy and material, while at the intensive end is a smaller land area with many more inputs.

Extensive pastoralism, for example, carries relatively few animals per hectare (mostly sheep with some beef cattle) but extends over large areas—about 12 million hectares (44 percent of the total land area). It is 'low cost', with relatively low applications of fertiliser and grass seed. In contrast, intensive forms of agriculture cover barely two million hectares (7 percent of the land). Three-quarters of this is pasture, mostly carrying dairy cows, some beef cattle and deer. The remainder is mostly crop and horticultural land. A very small area is devoted to factory farming which, in New Zealand, is restricted to pigs and poultry. Chickens are now our most numerous stock animals, but their accommodation uses very little land.

The two types of farming have significant but different impacts on the land. Intensive farming produces more biomass per hectare, higher concentrations of animal waste, fertilisers and pesticides, and makes more use of irrigation water. It therefore has a greater risk of contaminating soil, groundwater and streams and of reducing river flows. In addition, high stock densities, or the frequent use of heavy machinery, increase the risk of soil compaction, while the removal of high volumes of plant and animal products increases the risk of carbon and nutrient loss.

Extensive pastoralism puts less concentrated pressure on soil and water but, because of the vast area involved, it has had a greater impact on natural ecosystems and biodiversity. Also, because this sort of farming is often located on hilly terrain where the soils are naturally more susceptible to erosion and nutrient depletion, it has caused accelerated erosion in many areas and sedimentation of streams and rivers. Erosion and stock losses have often been exacerbated where hilly land has been managed for maximum production (through increased pasture area and stocking rates) rather than for minimum risk from climatic events, such as floods, droughts or unseasonal snowstorms.

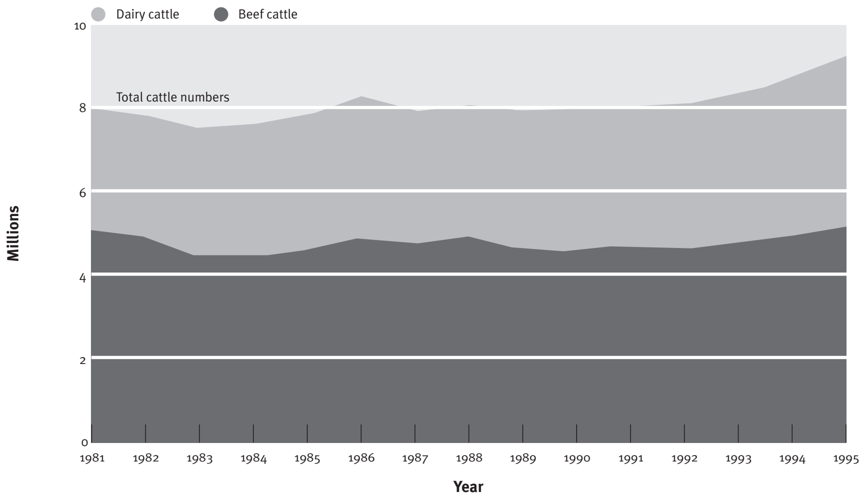
Some farmers, through choice or the limitations imposed by terrain, have sustained natural forests or wetlands on their properties. In the past the overwhelming economic incentive was to convert as much land as possible to productive commercial use, even the natural riverbank vegetation, which normally protects waterways, soils and forest and aquatic biodiversity. Today, only a small area of land is being converted, such as in parts of Northland where the increase in dairy farming has led to some streambanks being cleared of native vegetation.

Agricultural pressures on the land are driven largely by economics and have fluctuated with export prices and past government subsidies. High market prices caused farmers to convert forest to pasture during the 1950s wool boom, and government subsidies for pastoral farming had the same effect in the 1970s and early 1980s. Since the incentives ended in the mid-1980s, sheep numbers have declined and several hundred thousand hectares of pasture has been converted to exotic pine forests. An even larger area of marginal pasture on steep erodible slopes has been left to regenerate in scrub and native forest.

Economic forces cut both ways, however. Recent studies of farmer attitudes and behaviour reveal that many farmers tend to respond to economic pressures by cutting back on maintenance expenditure, such as erosion control and pasture improvement, while continuing to maximise their stocking rates (Wilkinson, 1994; Wilson, 1994; Smith and Saunders, 1996). One study investigated the behaviour and attitudes of 25 hill country farmers in the Taranaki Region, where 20 percent of hill farmland is managed in a potentially unsustainable fashion (Taranaki Regional Council, 1996; Wilkinson, 1994). Most of the farmers managed their pasture to suit the stock rather than the land. Although they were generally aware of the long-term environmental risks of their management practices, they tended to feel constrained by more immediate economic factors.

**Figure 8.6**

**Changing cattle numbers, 1981-1995.**




*Source: Statistics New Zealand*

Another example of economic forces intensifying environmental pressure was the classic boom and bust in goat farming during the late 1980s. During the boom, feral female goats were rounded up and captured for breeding stock. By 1988, the domestic goat population had quadrupled to a market-driven high of 1.3 million (Department of Statistics, 1990). The market crashed soon afterward and, by 1994, farm goats numbered less than 284,000 (Statistics New Zealand, 1996b). Because the market for goat meat is small and 90 percent of the goat population was bred for fibre production (e.g. mohair) and 'scrub control', most of the unwanted animals were simply released into the scrub and forest where their mothers had come from. The number of feral goats then soared, intensifying the pressures on native vegetation and regenerating forest (Parkes, 1993).

In the past decade, extensive pastoralism has declined while there has been an increase in intensive forms of agriculture. Between 1981 and 1995 sheep numbers fell by 30 percent, from a subsidy-driven peak of around 70 million to just under 49 million. However, cattle numbers rose to an all-time high of 9.3 million, largely reflecting the 40 percent increase in dairy cattle whose population went up from 2.9 million to 4.1 million (see Figure 8.6).

The most notable areas of dairy increase have been at opposite ends of the country, in Northland and Southland. However, dairy herds have also expanded markedly in many other parts of the country, including the South Island regions of Canterbury, Otago and the West Coast. Expansion has been less dramatic in the North Island, since large areas were already devoted to dairying, but dramatic increases have occurred in some districts (e.g. around Taumaranui), and even traditional dairying areas, such as Taranaki, have shown a steady increase. Taranaki's dairy cattle population has grown by 16 percent since 1975 and its density has increased by 19 percent from 1.43 cows per hectare to 1.70 (Taranaki Regional Council, 1996). This nationwide increase in the dairy herd has raised concerns about the impacts on soil and water of animal urine, nitrogen fertilisers and stock trampling.

Beef cattle numbers have shown little overall change since 1981, despite falling prices, but their distribution has undergone some change in response to expanding dairy herds and shrinking sheep flocks. Although beef cattle declined during the 1980s they increased again in the 1990s, replacing the even less profitable sheep in many hill farms. This shift has aroused some concern because of the greater pressure which cattle place on soil and water in hill systems. Compared to sheep, cattle produce more waste, their grazing causes greater soil nutrient loss and more vegetation disturbance, and their trampling poses a greater threat to erodible pasture and stream banks (Lambert *et al.*, 1985; Sheath, 1992).

Another pressure associated with the expansion of dairying comes from nitrogen fertiliser. Many dairy farmers are now applying large amounts of nitrogen fertiliser to their soils (Roberts *et al.*, 1992a; Bolan and Podila, 1996). Until recently, nitrogen fertilisers were used mostly for crops, while pastures derived their nitrogen from clover, with a just a light application of fertiliser in winter. In the past six years, however, as dairy farming has led to more intensive pasture use, nitrogen fertiliser sales have more than trebled (see Figure 8.7). Most dairy farmers are now applying 25–100 kilograms of nitrogen fertiliser per hectare per year, and some are applying more than 200 kg/ha/yr. The use of nitrogen fertiliser on dairy pasture boosts grass growth, is cheaper than feed supplements, and returns $1.93 for every $1 spent (Bolan and Podila, 1996).

**Box 8.2**

### *Farming with Care*

The impacts of farming on animal welfare, human health and the environment are coming under closer scrutiny from the general public, law-makers and consumers. Issues of concern include water pollution, pesticide residues, soil erosion, wetland drainage, forest clearance, greenhouse gas emissions (i.e. methane), the treatment, shelter and transport of farm animals, and the perceived health effects of agricultural chemicals. An increasing number of farmers are responding to these concerns by modifying their farming practices. Examples include planting trees on erodible land, fencing off riparian vegetation on erodible stream banks, improving methods for disposing of dairyshed effluent, controlling pests through integrated pest management, and adhering to voluntary codes of practice on such issues as pesticide spraydrift and animal welfare.

Some of these responses are driven by law reforms which began in 1991 with the Resource Management Act and continue with the Biosecurity Act 1993, the Hazardous Substances and New Organisms Act 1996, the Agricultural Compounds Bill, the proposed Animal Welfare Bill, and the proposed Primary Produce Bill. The Agricultural Compounds Bill for example aims to "assist in managing risks to trade in primary produce, animal welfare, and agricultural security, and compliance with domestic food standards associated with the use of agricultural compounds" (Ministry of Agriculture and Fisheries, 1995). Economic factors contributing to the changes include lost production from soil erosion, the good prospects for farm forestry, and the fear that New Zealand's access to some export markets (e.g. the European Community) may be subjected to stringent animal welfare and pesticide residue standards. A further economic factor is the growth of niche markets for humane and chemical-free products, particularly in Europe and North America where organically grown produce, for example, accounts for just 1-2 percent of all food sold but is increasing its market share by up to 20 percent each year (Ministry of Agriculture and Fisheries, 1993a).

**Humane products** are those which cause no preventable animal suffering in their production. Humans, other mammals, birds, reptiles, amphibians, fish, and 'higher' invertebrates (e.g. squid and lobsters), share similar neuro-physiological mechanisms for pain perception (Ministry of Agriculture and Fisheries, 1991). Animal scientists have also recorded behavioural and physiological evidence of stress and similar emotional reactions in many species (Dawkins, 1993; Griffin, 1976, 1992; Masson and McCarthy, 1994; Mayes, 1979). These findings are reflected in growing concern for animal welfare, both in New Zealand and overseas. In Britain, for example, 77 percent of those polled oppose the export of live farm animals for slaughter (Worcester, 1995). In recognition of this trend, the Minister of Agriculture and Fisheries established the Animal Welfare Advisory Committee (AWAC) in 1989 to develop animal welfare policies and enable New Zealand to take a proactive role in animal welfare matters. AWAC undertook a review of the Animals Protection Act 1960 and, after wide consultation, recommended that it be replaced by new legislation (Ministry of Agriculture and Fisheries, 1990, 1991). A draft Animal Welfare Bill has been prepared and is awaiting introduction to Parliament.

The 1960 Act gives domestic animals some protection against deliberate cruelty but is limited or silent on such issues as: the lack of farm shelter belts to give shade in summer and shelter in winter, early lambing and shearing (which can result in stress and death in cold weather), stressful transport in lorries and on ships, the restrictive confinement of pigs and chickens in 'factory farms', and amputations performed without anaesthetic (e.g. docking cows' tails, removing the highly sensitive velvet from deer antlers, dehorning cattle, castrating pigs, mulesing merino lambs, and trimming the beaks and toes of chickens). Because of its scale, the treatment of battery hens is particularly controversial. With more than 60 million birds, poultry are our most abundant livestock. Most are bred for meat. About 2.4 million are egg layers. Although a niche market exists for eggs from uncaged hens, its influence has been limited. About 4 percent of all eggs sold are from free-range hens and a further 3 percent are barn-laid, but their higher prices deter most shoppers.

Some farmers have developed their own animal welfare measures. To reduce winter suffering and losses, for example, they plant shelter belts, use snow combs to shear ewes, and put jackets on calves. But many are less proactive, so nearly 20 welfare codes and minimum standards have been developed by AWAC to cover such practices as mulesing, tail docking, deer velvet removal, treatment of bobby calves, and live sheep exports (e.g. the live export of lambs under 10 months was banned in 1994 following high death rates en route to Saudi Arabia). The codes will underpin the new Animal Welfare Act and will be updated regularly to reflect changes in scientific knowledge, farm practices, and public attitudes (Ministry of Agriculture and Fisheries, 1996).

**Chemical-free products** are technically non-existent as everything contains chemicals. However, as generally used, the term means products that are free of synthetic pesticide residues. Pesticides are widely used in New Zealand because of the stringent food hygiene requirements of export markets. Statistics on agricultural chemicals are not published so it is not possible to say whether pesticide use has increased or declined from the 3,500 tonnes applied annually in the 1980s (McIntyre *et al.,* 1989). However, food and groundwater monitoring show that pesticide residues in our food and water are generally very low and pose no detectable risk to health (Dick *et al.,*1978; Pickston *et al.,* 1985; Close, 1994; Ministry of Health and Environmental Research Services Ltd, 1994; Reeve, 1994; van Oort *et al.,* 1995a). Despite this, consumers are increasingly concerned about chemical residues (Jolly, 1994). As a result, the agricultural industry is modifying the way it does things. Newer chemicals have been developed which decay quickly and leave few residues, and pesticide users are being taught to apply chemicals more safely and selectively. Following the revelation several years ago that less than 1 percent of those applying pesticides had any training (MacIntyre *et al.,* 1989) the industry developed an *Agrichemical Users Code of Practice* and set up the New Zealand Agrichemical Education Trust. The Trust's one-day training and accreditation programme, labelled 'Growsafe', is aimed at reaching all pesticide users in New Zealand (New Zealand Agrichemical Education Trust, 1994). In its first year, about 3,000 (5 percent) did the programme.

Some farmers and growers are choosing to reduce their reliance on chemicals. **Integrated Pest Management** (IPM) uses multiple methods of pest control, with the emphasis on biological and low-cost methods (Croft and Penman, 1989). Under IPM, pesticides are used sparingly and greater use is made of crop rotations and soil tillage (to stop pests building up), selective breeding (for pest-resistant crops and livestock), biocontrol species (to parasitise or prey on pests and weeds), and crop biodiversity (to reduce the risk to any one crop). IPM programmes using biocontrols have been developed for several pasture and horticultural pests, particularly in apple orchards. The Apple and Pear Marketing Board's Integrated Fruit Production programme and the Kiwifruit Marketing Board's 'Kiwigreen' programme both use the IPM approach.

**Organic** and **biodynamic** farms go further than IPM. They reject chemical pesticides and mineral fertilisers (e.g. superphosphate) and use only biological methods and approved organic pesticides and fertilisers (Fisher, 1989; Ministry of Agriculture and Fisheries, 1993a). Their methods include enhancing crop biodiversity, recycling nutrients (e.g. compost, animal waste, wastewater), and protecting soil by growing longer pasture cover, planting shelterbelts, avoiding overstocking and animal trampling, growing green crops between arable crops, digging in straw and other organic matter to improve soil structure, and using mulches, grass/herb cover and contour plantings in orchards. Most New Zealand organic farmers are registerd with BioGro NZ Ltd which requires them to follow strict production standards and to pay all inspection and certification costs. Despite these requirements, and the time and effort required to produce export quality organic produce, the number of registered BioGro producers in New Zealand rose from 90 in 1989 to over 230 in early 1997. Because of its small scale, the industry lacks an organised marketing, research, and information network so the New Zealand Trade Development Board (TRADENZ) has set up an Organic Products Export Group to assist exporters through market research and trade missions.

At present, many conventional farmers are still driven to environmentally unsustainable practices by short-term economic priorities (Wilkinson, 1994; Wilson, 1994; Smith and Saunders, 1996). However, in the past two years, environmental self-help groups, variously called landcare, farmcare, watercare and land management groups, have mushroomed in rural areas (Ministry of Agriculture and Fisheries, 1996). Many have partnership arrangements with regional councils and Crown Research Institutes (e.g. Landcare Research and AgResearch) and receive funding assistance from their regional council, the Ministry for the Environment's Sustainable Management Fund, or the Ministry of Agriculture's Sustainable Agriculture Facilitation Programme. Their main emphasis is on improving soil and water management.

Besides the sustainable agriculture programmes run by central and local government, industry groups, such as the Pork Industry Board, the Agricultural and Marketing Research and Development Trust, the New Zealand Dairy Board, Federated Farmers, and agrichemical users are also taking initiatives to promote sustainable agriculture. In recent years, too, a small number of farmers have become active conservationists by restoring wetlands on their farms or placing formal protection covenants on their surviving forest stands with funding from the Forest Heritage Fund, Nga Whenua Rahui, or the Queen Elizabeth II National Trust.

Increasing nitrogen use is part of a worldwide trend in which humans have dramatically altered the Earth's nitrogen cycle (Wedin and Tilman, 1996). The rate at which nitrogen is extracted from the air and fixed in the soil by legumes is now twice the natural rate. In the northern hemisphere, the rate at which atmospheric nitrogen is deposited on the land has increased more than tenfold in the past 40 years. Because some plants respond better to nitrogen than others, the increasing amount of nitrogen in the environment appears to be changing some grasslands and reducing their species diversity. A recent 12-year study in North America found that, under long-term continuous nitrogen use, weedy, cool-season, grasses tend to replace warm-season grasses (Wedin and Tilman, 1996). Because they have less root mass and slightly different chemistry, the weedy species contribute less organic matter to the soil, resulting in lower levels of soil carbon.

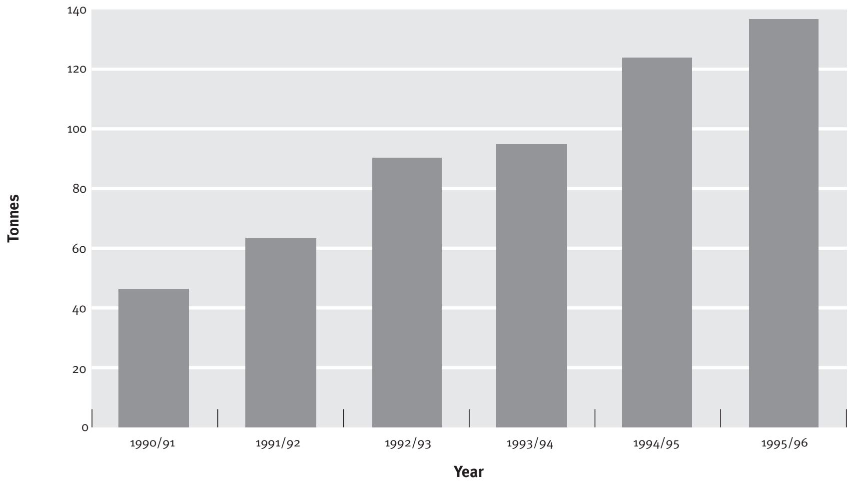
High levels of nitrogen can also make soils more acid, though this depends on the type of nitrogen. It is estimated that 1.7, 4.1 and 5.2 kg of lime are needed to overcome the acidity produced by 1 kg of nitrogen applied respectively as urea, diammonium phosphate and ammonium sulphate, (Bolan and Podila, 1996). Nitrogen also has impacts off the land by leaching through the soil into groundwater or washing off the land surface into streams (see Chapter 7).

In summary, the main agricultural pressures on the land include:

- the conversion of native ecosystems to pasture (though this has largely ceased and native scrub is now regenerating in some unproductive steep areas);
- the impacts of stock animals (namely sheep, cattle and goats) on natural forests, tussock grasslands and dunelands;
- accelerated soil erosion (through insufficient deep-rooting vegetation on erodible soils, steep slopes, and ploughed fields exposed to wind, frost or heavy rain);
- soil compaction (from loss of soil structure, continuous ploughing, or stock treading, when wet);

**Figure 8.7**

**Recent trends in nitrogen fertiliser use.**




*Source: Bolan and Podila (1996)*

- nutrient depletion (from insufficient fertiliser inputs to offset nutrient removals in plant and animal products and in unevenly deposited animal waste);
- acidification of soil (through the increased leaching of nitrates from animal waste, legumes, and nitrogen fertilisers);
- chemical contamination of soil (from farm landfills, trace elements in fertilisers, and pesticide residues—though these are minor compared to urban and industrial contamination sources).

### *Forestry pressures*

Compared to pastoral farming, forestry is a minor land use, but it still covers a substantial area and has impacts on the environment, some positive and some potentially negative. Each year about 20,000 hectares of forested land are harvested and replanted, and about 70,000 hectares of new forest are planted over disused pasture or regenerating scrub. Only a few hundred hectares of indigenous forest are now logged and these are left to regenerate naturally.

The total area of standing forest potentially available for timber production exceeds 2 million hectares. About 1.6 million hectares of this is exotic forest, 600,000 hectares is privately owned indigenous forest, and some 150,000 hectares is Crown-owned forest which has been allocated to Timberlands West Coast Ltd for timber production. However, most of these forests are not harvestable at present because roughly half the exotic trees are still maturing, and some three-quarters of the indigenous trees are regenerating from previous logging and land clearance.

The environmental effects of production forestry vary with the type of forest, the terrain, and the preceding land use. The effects can often be positive. Many exotic forests are now being established on erodible farmland where they can reduce soil erosion, stream sedimentation and flooding (see Chapter 7). The planting of forests on farmland also increases the amount of carbon dioxide which is absorbed from the atmosphere, thus helping to counteract the 'greenhouse effect' (see Chapter 5). Being primarily timber crops, New Zealand's exotic forests also remove the pressure to unsustainably log native forests, thus allowing these to be reserved for biodiversity habitat and recreational purposes.

Despite these advantages, production forestry can also have negative effects on soils, water, biodiversity and scenery. Soils on slopes face a risk of erosion in the first six years or so after planting when the young tree roots are becoming established. Because commercial forests are planted as single-age crops, they have no older trees to provide support and cover. However, this risk is no worse than if the site had remained in pasture. Soils can also be damaged by machinery and roading at harvesting time, with both erosion and soil compaction resulting.

Established forests, particularly after several planting and harvesting rotations, may cause changes in soil nutrients and acidity. Nutrient depletion, especially of nitrogen, is most likely in sandy soils. However, in more fertile soils, nutrients, particularly phosphorus, sometimes show an increase. Nutrient depletion associated with forestry is mainly caused by such poor practices as removing topsoil and humus. These practices are increasingly uncommon. In many instances, such as the exotic forests of the pumice-based central plateau, the organic matter has actually increased, improving soil fertility. Soils have occasionally been found to become more acidic under pine forests, but this is not common and the processes which create acidic humus under exotic forests are similar to those which occur under indigenous forests. A more indirect impact on soil chemistry may arise at the processing end of the forestry operation where toxic chemicals are often used to protect radiata pine from fungi and insects. Spills and leaks can contaminate soil at sawmills and timber treatment sites.

In most cases forestry pressures on water are probably offset by the benefits of flood and sediment reduction. Nevertheless, negative impacts can include sedimentation during harvesting, reduced flow levels in streams and rivers following the establishment of new forests (and increased flows following harvesting), and the contamination of groundwater and streams near contaminated timber treatment sites. Harvesting impacts are short term in relation to the effects over the whole of a forest rotation.

Forestry can also put pressure on biodiversity because logging removes the habitat of forest-dwelling species. The clearfelling of native forests is very rare today but caused considerable destruction to large areas of native habitat in the past. The clearfelling of exotic forests is less destructive to biodiversity because fewer native species live in them. Biodiversity concerns with exotic forestry have generally focused on the establishment phase of the plantation rather than the harvesting phase. In the past, many exotic forests were planted in cutover native forest, shrublands, tussocklands, or dunelands. This effectively reduced the area of native habitat. These days, however, the majority of new plantings are on pasture land and are probably beneficial to indigenous biodiversity by relieving the logging pressure on native forests and allowing indigenous habitats to regenerate on forest margins and beneath forest canopies.

Another impact of forestry is the unsightly landscape which can result where logging and road construction are visible from roads and tourist walking tracks (Kilvert, 1995). This aesthetic impact can also have an economic impact because much of New Zealand's tourism is based on the attractiveness of our pastoral and forest scenery. Three quarters (74 percent) of the respondents in a 1994 public opinion survey by the New Zealand Forest Owners Association, thought that most exotic forests are a pleasure to look at, but 45 percent felt that clearfelling ruins landscapes and soil (New Zealand Forest Owners Association, 1995).

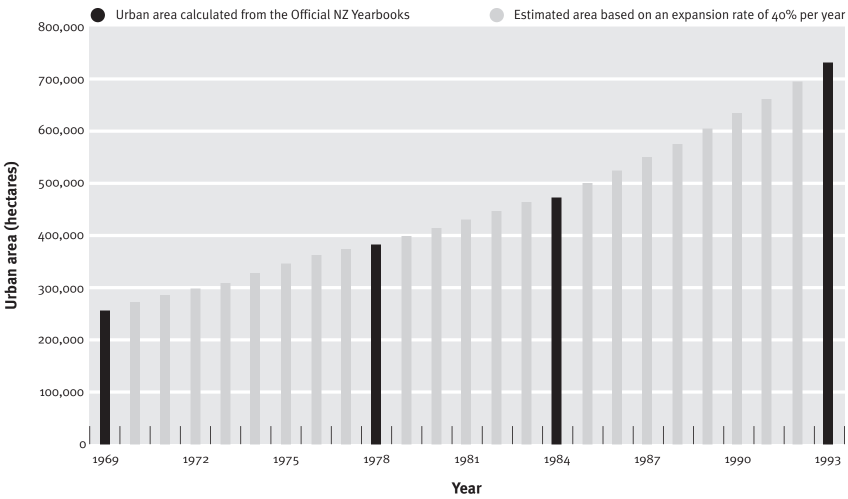
In recent years, Government and industry have adopted measures to limit the pressure which forestry can have on the environment. Under the indigenous forests provisions of the Forests Act 1949 (which were introduced through the Forests Amendment Act 1993), most indigenous timber production must to be subject to a sustainable management plan or permit. The only significant exceptions are several defined areas on the West Coast and in Southland, totalling less than 200,000 hectares. Under the New Zealand Forest Accord 1992, the main forestry companies have agreed not to replace native forest, regenerating scrub or other significant natural habitats with exotic forests. The forestry industry also has safeguards for soil, water, scenery and native habitats in its Forestry Code of Practice. The effectiveness of these measures has yet to be assessed. The 1993 amendment to the Forests Act only came into full effect in mid-1996 and the Forest Accord is a voluntary agreement which applies to the large companies but not to farmers and small landholders who are doing most of the new planting.

In summary, forestry exerts a range of pressures on vegetation and soil (Hunter and Douglas, 1984; Vaughan, 1984; Hunter *et al*., 1988; Ledgard, 1988; Davis and Lang, 1991; Balneaves and Dyck, 1992; Dyck and Bow, 1992; Hawke and O'Connor, 1993; Smith, 1994; McLaren, 1995; O'Loughlin, 1995; Rosoman, 1995b). These pressures include:

- restricted biodiversity (but only where plantations replace native ecosystems; biodiversity is enhanced where they replace pasture land);
- temporarily increased erosion potential after harvesting (particularly on erodible hill country soils), associated with the exposure of bare soil, the construction of roads and tracks, and the time between the decay of the roots of the harvested trees and the establishment of a complete root mesh by the replanted trees (i.e. the period from 3 to up to 10 years after harvest);

**Figure 8.8**

**The expansion of New Zealand's urban area.**




*Source: Department of Statistics (1970; 1978; 1985; 1994)*

- soil compaction (near roads, tracks, and, to a lesser extent, logging sites);
- nutrient depletion, especially of nitrogen (less dramatic than on agricultural land and more likely in sandy soils than fertile soils and where forestry operations are practiced poorly);
- acidification of soil (to which most of the South Island and large parts of the North Island are susceptible);
- chemical contamination of soil from the treatment of radiata pine at sawmills and timber treatment plants;
- unsightly landscapes where logging operations and road construction are within sight of walking tracks, tourist routes and main roads; and
- invasion of wilding exotic trees into tussock, dune, and forest ecosystems (mostly lodgepole pine, *Pinus contorta*, in the central North Island, but also radiata pine in coastal areas and *Pinus contorta* and *Pinus nigra* in South Island high country ecosystems).

***Urban, industrial, and transport pressures***

Urban, industrial and transport land covers almost 900,000 hectares—nearly double the current area of crops and orchards, and about 3 percent of the total land area. Urban areas, as classified by Statistics New Zealand, include any town, suburb or city with more than 1,000 people. They are currently estimated to cover 730,000 hectares while the nation's network of non-urban railways and roads is estimated at 160,000 hectares.

Although the urban population has increased by only 30 percent since 1969, the area of land classed as urban has almost trebled. Some of this will reflect the redrawing of administrative boundaries and, in particular, the growth of small towns over the 1,000 person threshold. Other contributing factors include social changes such as the increasing number of one-person households, and the expansion of industrial and commercial land. In contrast, the area taken up by rural roads and railways is approximately the same as in 1965.

When averaged, the rate of urban expansion over the past 25 years has been around 4 percent per year, increasing from nearly 270,000 hectares in the late 1960s to 730,000 hectares (see Figure 8.8). This represents an average expansion of around 15,000 hectares per year through the 1970s, rising to 30,000 hectares by the early 1990s. The fact that many urban areas are located on floodplains and estuaries suggests this expansion has been at the expense of some of the nation's wetlands and more fertile, or "elite", soils. Of the nearly half million hectares of rural land urbanised since the mid-1960s, it is not known how much contained Class 1 and 2 soils, nor how much contained natural forest, wetland or duneland.

Also unknown is the extent of soil contamination in urban, industrial and transport land, though an estimated 7,800 industrial sites, transport sites and landfills may be contaminated (Ministry for the Environment, 1993). Investigations are under way to assess the full extent of the problem and the number of sites that will need cleaning up.

Apart from their direct effects on land, urban areas also have a pervasive influence on other land uses. Their highly concentrated populations provide the market, and hence the economic justification, for much agricultural land use. Urban gardens are also the major source of introduced plant species that can become noxious weeds in indigenous forests, wetlands and agricultural systems. Auckland is both the largest and fastest growing urban area as well as the main entry point for most alien plants and insects into New Zealand.

In summary, the main pressures on land from urban, industrial and transport activities include:

- loss of biodiversity where urban development and roads have encroached on natural ecosystems;
- soil erosion from excavation and construction sites;
- soil coverage and compaction from roads, buildings and other hard surfacing;
- soil contamination from landfills, industrial sites, and domestic sources; and
- indirect pressures from the activities and consumption patterns of large urban populations.

### *Mining pressures*

Stone tools and ornaments were vital to Maori culture and economy. Argillite, obsidian and West Coast jade or greenstone (pounamu) were quarried to make tools and artefacts which were sharpened on coarse sandstone grinding stones. Clays were used to obtain blue, yellow and white pigments. A complex distribution system of gifts and exchange ensured that this stoneware was used all over New Zealand.

Traditional Maori use of minerals seems to have caused little disturbance to the environment (Barker, 1994). In contrast, the much larger scale of modern mining creates considerable disturbance to soil and vegetation which can be very significant at the local level (Ministry of Commerce, 1991). At the national level, however, the affected area is very small, totalling about 25,000 hectares since European settlement, or less than 0.1 percent of the land surface (Barker and Hurley, 1993). In addition, most modern mines are now subject to strict environmental standards which require waste water and sediment to be safely treated or stored and mined landscapes to be rehabilitated.

The total amount of sediment ever disturbed by mining in New Zealand is estimated to be around seven billion cubic metres, or around 15-20 billion tonnes. Averaged over the last 150 years this amounts to about 15 percent of the natural erosion rate (Fricker, 1986; Glasby, 1991). These estimates cover all types of mining, as well as quarrying and sand and gravel extraction. They also include an allowance for off-site effects, such as access roads and processing plants.

Most of the land disturbance was caused by alluvial gold mining in Central Otago and the West Coast which began in the 1850s. The total area affected by gold sluicing and dredging was around 15,000 hectares, and the total volume of sediment removed about five billion cubic metres (Glasby, 1991). This represents 60 percent of the total area disturbed by mining, and 70 percent of the total sediment disturbed by mining since European settlement. Today's hard rock gold mines, by contrast, affect barely 1,000 hectares (Barker and Hurley, 1993).

While these figures put the scale of mining impacts into national perspective, they do not change the fact that local impacts may be considerable. Access roads can cause erosion and stream sedimentation and the piles of waste rock and slurry can contain elevated levels of heavy metals which may enter surrounding soils and streams (Carter, 1982). This is often a problem with disused sites where waste piles were not subject to modern waste handling procedures. The Tui mine near Te Aroha in the Coromandel is a prime example. Abandoned in the early 1970s, its tailings pile continues to contaminate land and water (Morrell *et al.*, 1995). Contamination is also a potential problem at another Coromandel mine, Golden Cross near Waihi, whose vast waste pile is situated on land subject to sub-surface movement of several millimetres per year. The regional council would like the tailings pile relocated. In the meantime, the mining company has spent some $20 million on stabilising the slope.

Mining activities can also disrupt ecosystems and landscapes, such as forests, dunelands, karst landscapes and glow-worm caves. For example, commercially valuable ironsand reserves occur on about 30 beaches along the western North Island, ranging from Kaipara in the north to the Wanganui and Whangaehu Rivers in the south (Stokes *et al.*, 1989). Half of these beaches also contain rare and ecologically important dunelands (Partridge, 1992).

On one of these beaches, Taharoa, New Zealand Steel is mining the ironsands. Several Maori historical sites among the dunes have been protected and the foredunes have been left undisturbed. However, the inland dunes have been extensively modified. Marram grass, lupin, and pine trees have been planted and some tailing mounds converted to pasture. The ecological status of the mined area at Taharoa has been scored at 1 out of a possible 20, compared to a score of 12 for the undisturbed, though still ecologically modified, foredunes (Partridge, 1992).

Mining in New Zealand requires permission from the local authorities which sets the environmental standards that must be adhered to. Mining also requires permission from the land owner. If a mining or exploration site, or access to it, happens to be on Conservation Department land, the Minister's permission is required. Although exact figures are not available, several hundred licences or permits for mining-related activities are currently in effect on conservation land. However, this gives a misleadingly high impression of the amount of mining-related activity on conservation land, as the majority of permits and licences are for exploration and prospecting, rather than mining and, at any one time, only a relatively small proportion of licences and permits are actually being used.

In the late 1980s, the Minister received more than 160 applications per year to mine or prospect on conservation land for periods ranging from one to ten years. Approval was granted in about 90 percent of cases. By 1994, the number of applications had fallen to fewer than 30, partly because of the new environmental management regime ushered in by the Crown Minerals Act 1991 and the Resource Management Act 1991, with their provision for Planning Tribunal appeals against licences, and partly because of changing commodity prices.

Mining activity increased between 1975 and 1989 as coal and gold exploration intensified and improvements in mining technology made lower grade ores and deposits more

**Table 8.4**
**Economically significant minerals in New Zealand, 1995.**

| Mineral | Quantity mined (tonnes) | Value ($ million) | Estimated size of remaining resource (tonnes) |
|---|---|---|---|
| *Gold* | *12.1* | *249* | *approx. 1,190* |
| *Silver* | *27.8* | *8* | *approx. 90* |
| *Ironsand* | *2.4 million* | *24* | *1.4 billion* |
| *Coal* | *3.4 million* | *161* | *8.6 billion* |
| *Aggregates* | *22.6 million* | *415* | - |
| *Limestone* | *3.2 million* | *36* | - |
| *Other* | - | *298* | - |
| ***Total*** | **-** | ***911*** | **-** |

*Source: Ministry of Commerce (1996); Barker and Hurley (1993)*

recoverable. The trend for mining activity in New Zealand is similar to world trends which have shown an increase as more minerals have become recoverable.

The world's currently known mineral resources are considered adequate to supply a growing global population and meet rising consumption for the next 100 years and are expected to expand further with more intensive exploration and advances in mining technology (Hodges, 1995). Between 1950 and 1990, world consumption of six major base metals (aluminium, copper, lead, nickel, tin and zinc) increased more than eight-fold. Yet, even as consumption increased, the estimated recoverable reserves of three of these (copper, lead and zinc) became three to five times larger, while known aluminium reserves increased eight-fold. Known gold reserves have also increased, despite rising consumption, from about 31,000 tonnes in 1971 to some 42,000 tonnes by 1990 (Hodges, 1995).

In New Zealand, low-grade hard rock ores and alluvial deposits became recoverable with the development of new methods of extraction. Between 1978 and 1988, local and overseas companies spent about $100 million on gold exploration. As a result, gold resources increased from apparently negligible amounts in the 1970s to around 1,210 tonnes in 1993 (820 "proven" tonnes and 390 "potential" tonnes). This is enough to maintain the current rate of production for more than 100 years (Barker and Hurley, 1993).

Gold production was one of New Zealand's first industries. Discoveries in the 1850s and 1860s led to gold rushes in Coromandel, Central Otago, the West Coast and Nelson. Alluvial gold (which occurs as grains or nuggets in gravel and sediment) was panned by swarms of miners and then dredged from river beds from the 1880s to the 1940s. Miners also sought veins of hard rock gold in underground mines. Up until 1915 annual production regularly exceeded 10 tonnes. By 1955 it had slipped below one tonne, and in 1975 fell to only 80 kilograms.

Today output again exceeds 10 tonnes. Renewed exploration led to three new hard rock mines being established in the late 1980s, one at Macraes Flat in Central Otago and two at the base of the Coromandel Peninsula—Martha Hill and Golden Cross. A fourth, the Globe Progress mine near Reefton on the West Coast, may be developed later. Reserves in the Nelson area are also being assessed for mining potential.

The Macraes and Martha Hill mines are open-pit mines where ore is mined by excavating a large crater in the earth's surface. Golden Cross also has an open-pit but its main production is from an underground mine. Alluvial mining, in riverbeds, has increased on the West Coast and in Otago.

In 1993, for the first time in nearly 80 years, gold production exceeded ten tonnes and is expected to continue doing so for at least the next decade. Although gold is the most valuable mineral mined in New Zealand, coal, ironsand and aggregates of rock, sand and gravel have a greater combined value (see Table 8.4). Limestone and dolomite are also valuable.

New Zealand coal ranges from high-grade bituminous, through sub-bituminous, to low-grade lignite. Total annual coal production in 1995 was 3.4 million tonnes. Nearly 30 percent of this was exported, and a quarter consumed by the Glenbrook Steel mill. The remainder of our annual coal production is consumed by factories, households, cement manufacturers, power stations and other users (Barker, 1994).

The main coal production areas are Waikato and Taranaki, Buller and Greymouth on the South Island's West Coast, Southland and Central Otago. With increasing exploration, coal reserves have 'increased' from 1,400 million tonnes in 1975 to 8,600 million tonnes in 1994. This is sufficient to maintain the current level of output for several hundred years (Barker and Hurley, 1993).

Ironsand containing titanomagnetite occurs along the west coast of the North Island. This black sand has eroded over thousands of years from the Taranaki volcanoes. All the current production is dredge-mined by New Zealand Steel at Taharoa Beach or at Waikato North Head. A similar sand mining operation near Wanganui ran from 1971 to 1987. The resource is estimated to be at least 1.4 billion tonnes, sufficient to maintain the current rate of extraction for several hundred years.

Aggregates of rocks, sand, and gravel are used for building, road construction, ship ballast and harbour fill. They are produced at several hundred mostly small quarries located throughout the country. Very large quantities of suitable material occur in many parts of the country but shortages occur near some urban areas, such as Auckland, where most of the suitable local rocks have been exhausted. Aggregates are transported from other regions, and in recent years sand and gravel have been dredged from the sea bed to maintain supplies (Barker and Hurley, 1993).

Limestone also is widely available. It is used in a variety of applications from cement production to carpet making, as well as lime fertiliser. The other minerals are mostly sand and clays used in manufacturing. Their distribution is often limited to one or two localities, and extraction is generally not on a large scale.

In summary, the main potential pressures on land from mining and mineral exploration are:

- removal of topsoil and vegetation, including destruction of plant and animal habitat;
- changes to the landscape and scenery;
- contamination of soil and water;
- destruction of fossils and archaeological sites; and
- changes to water channels, resulting in disturbance of aquatic ecosystems.

**Pressures from pests and weeds**

Pests and weeds are unwanted organisms, though use of the term often depends on the situation. On farmland, regenerating native vegetation may be unwanted, while weeds in native forest, tussock or dunelands may include exotic pasture grasses. The important point is that both natural and planted vegetation are vulnerable to invasion by unwanted species. Table 8.5 lists the main animal and plant pests monitored by one regional council.

In our indigenous ecosystems, the invaders are nearly always exotic plants and animals—though, in some cases, native species can proliferate into pests where the natural environment has been disturbed or modified. Examples are: the sub-alpine herb scabweed, which is widespread in tussock pasture lands; algae and the native reed raupo, which have proliferated in eutrophic lakes and wetlands; and pinhole borer beetles (*Platypus* spp.) which normally parasitise beech trees without killing them but can proliferate after catastrophic events to cause die-off in beech stands.

The indigenous trees have co-evolved with their parasites and have reached a mutual tolerance. Fungi, such as the leaf parasite *Corynelia tropica* on totara, the rust *Caeomoa peltatum* on tanekaha, and the gall-forming fungi, *Cyttaria* spp., on silver beech are common, but cause little damage (Gadgil *et al.*, 1995). Native insects, such as the moth *Proteodes carnifex*, and the beech leafroller moth (*'Epichorista' emphanes*) can cause periodic defoliation of mountain beech stands but this does not cause lasting damage. No introduced insects have yet caused serious problems to indigenous forests. The main pests and weeds in indigenous ecosystems are a dozen or so alien mammals and numerous exotic plants (see Chapter 9).

Exotic forests are vulnerable to several dozen insect pests, such as the introduced wood wasp (*Sirex* spp.) which used to be a serious problem in some untended stands, and also some moth and beetle larvae. However, the most serious pests are various fungi which can infect pine needles, leaves or roots, and sometimes cause dieback of the tree canopy

**Table 8.5**
**Pests and weeds monitored in Canterbury region.**

| Pest or weed | Environmental or agricultural impact |
|---|---|
| *Rabbit* | *Competes with grazing animals and destroys vegetation in dry areas.* |
| *Rook* | *Destroys emerging grain crops.* |
| *Wallaby* | *Destroys native bush and snow tussock and competes with grazing animals.* |
| *African Feather Grass* | *Unpalatable to stock. Replaces palatable grasses, especially in moist areas.* |
| *African Love Grass* | *Unpalatable to stock. Of limited distribution, but invades pasture.* |
| *Baccharis* | *Competes with native plants on arid rocky sites, mainly Banks Peninsula.* |
| *Barberry* | *Invades lightly or ungrazed areas forming impenetrable thickets.* |
| *Bogbean* | *Aquatic weed with potential to choke waterways.* |
| *Bur Daisy* | *Burs contaminate wool and injure stock. Of very limited distribution.* |
| *Coltsfoot* | *Can dominate in waterways and lightly irrigated land. Of very limited distribution.* |
| *Egeria densa* | *Aquatic weed with potential to choke waterways.* |
| *Entire marshwort* | *White-edged Nightshade* |
| *Lagarosiphon major* | *Aquatic weed with potential to choke waterways.* |
| *Grecian Thistle* | *Competes with more palatable species. Of limited distribution.* |
| *Hawthorn* | *Spreads into lightly or ungrazed areas impeding stock access.* |
| *Nassella Tussock* | *Invades dry low producing areas, excluding more productive plants.* |
| *Nodding Thistle* | *Excludes more productive plants.* |
| *Old Man's Beard* | *Vine climbs over trees, excluding light, and eventually kills them.* |
| *Ragwort* | *Toxic to most stock.* |
| *Saffron Thistle* | *Excludes more productive species. Limited distribution.* |
| *Spanish Heath* | *Potential to spread into and exclude tussock.* |
| *Taurian Thistle* | *Potential to exclude more productive plants, but so far limited to one site in New Zealand.* |
| *Variegated Thistle* | *Excludes more productive plants.* |
| *White-edged Nightshade* | *Suspected poisonous plant and may exclude other vegetation.* |

*Source: Canterbury Regional Council (1995)*

(Alma, 1986; Gadgil *et al.*, 1995). The worst of these is an introduced fungus, *Dothistroma pini*, which causes needle blight in young pine trees in warm, wet, areas. Another is a genus of related species, *Cyclaneusma* spp., which were introduced last century. They cause needle cast which destroys about 2 percent of each year's total pine needle production.

Up to a dozen other fungi can damage pine trees, including some native species. Two of these belong to the genus *Armillaria*. They cause a serious root disease, particularly in tree crops planted over cutover indigenous forest. Some pine plantations have lost half their trees to the disease within the first five years.

Other exotic trees are also victimised by pests (Alma, 1986; Gadgil *et al.*, 1995). Douglas fir trees are vulnerable to native pinhole borer and several species of leafroller moths as well as to an introduced fungus called *Phaeocryptopus gaeumannii* which causes Swiss needle-cast. This fungus was first recorded near Taupo in 1959 and is now widespread throughout the country. Eucalypts (gum trees) and acacias (blackwoods), which are grown in some areas for timber, are vulnerable to a wide range of insects and fungi, mostly of Australian origin. Poplars, which are generally grown as windbreaks, are little troubled by insect pests, but a rust fungus,

**Table 8.6**

**The area of Department of Conservation land at risk from browsing mammals.**

| Likely impact if no control operations were in place[1] | North Island (hectares) | South Island (hectares) | Total DoC estate (hectares) |
|---|---|---|---|
| *Total forest collapse*[2] | 245,000 | 305,000 | 550,000 |
| *Major composition change*[3] | 364,000 | 681,000 | 1,045,000 |
| *Major loss of biodiversity*[4] | 20,000 | 149,000 | 169,000 |
| ***Area at risk of major change*** | **629,000** | **1,135,000** | **1,764,000** |
| *Minor loss of biodiversity*[5] | 213,000 | 1,100.000 | 1,313,000 |
| ***Area at risk of major or minor change*** | **842,000** | **2,235,000** | **3,077,000** |

*Source: Department of Conservation*

1 *In fact, control operations covered 1.3 million hectares in the 1995/96 year, 70 percent of the major risk areas.*

2 *Total canopy loss, significant species loss, replacement of forest by shrubland/grassland.*

3 *Significant canopy and species loss, change in forest structure from complex to simple.*

4 *Significant species loss and change.* 5 *Some species loss and change.*

*Melamspora larici-populina*, has almost eliminated semi-evergreen poplars and necessitated their replacement by rust-resistant varieties.

Elm trees, which are popular in urban areas, are vulnerable to the lethal Dutch elm disease which was discovered here in 1989. It is caused by the fungus *Ophiotoma novo-ulma* which is transmitted by the small elm beetle (*Scolytus multistriatus*). Fruit trees in orchards are particularly vulnerable to a wide range of insect and fungal pests which attack fruit and leaves. Fruit and vegetable growers account for a considerable portion of the fungicide and pesticide use in New Zealand.

Agricultural land is also under siege from pests and weeds, ranging from the native vegetation patiently striving to regenerate in its home soil, through to exotic weeds, and a variety of animals and fungi of both native and exotic origin. Among the more serious exotic weeds in pasture and crop land are nodding thistle (*Carduus nutans*), Californian thistle (*Cirsium arvense*), ragwort (*Senecio jacobaea*), gorse (*Ulex europaeus*), broom (*Cystisus scoparius*), giant buttercup (*Ranunculus acris*), fat-hen (*Chenopodium album*), willow weed (*Polygonum persicaria*), and hawkweed (*Hieracium* spp). Fungal diseases, such as stripe rust, also affect crops.

The most significant pasture pests are native insects which cause millions of dollars worth of lost production each year. Grass grub, which attacks ryegrass, is the larval or immature form of a native chafer beetle (*Costelytra zealandica*). The porina caterpillar, which attacks ryegrass and other grasses, is the immature form of several closely related native moths (*Wiseana* spp.). Several species of *Sitona* weevil attack the grass grub resistant pasture legume, lucerne.

Another, much larger, pasture pest is the European rabbit (*Oryctolagus cuniculus*) which also affects young forest plantations. It was introduced last century and is now found over some 15 million hectares of farmland and light scrub. Throughout most of their range, rabbit numbers are controlled by climate, harrier hawks and introduced predators such as cats, ferrets and stoats (Robson, 1993). However, they are a serious pest over on about 1.2 million hectares of pastoral tussock land and are an 'intractable' problem on some 300,000 hectares of this (Kettle, 1996).

The Australian brush-tailed possum (*Trichosurus vulpecula*) is an even more widespread pest. Possums are well known for their impact on indigenous vegetation, orchards and cropland (see Tables 8.6 and 8.7). However, they also affect pastoral agriculture by transmitting the highly contagious bovine tuberculosis bacterium (*Mycobacterium bovis*) to cattle and deer. Possums are not the only carriers of bovine Tb, but they are the most numerous, outnumbering all the other vectors combined—pigs, cats, stoats, ferrets, deer, hares, and feral goats.

**Table 8.7**

**Typical possum densities and impacts in various habitat types - natural and modified.**

| Habitat | Density (possums/ha) | Conservation Risk | Tuberculosis Risk | Other Risk |
|---|---|---|---|---|
| *Mixed forest-scrub-pasture margins* | *5–>15* | *medium* | *very high* | - |
| *Tree-lined waterways on farmland* | *5–15* | *low* | *high* | - |
| *Small isolated forest patches* | *5–15* | *medium-high* | *medium* | *Tourism losses from lost scenery and biodiversity* |
| *Rata/kamahi and mixed hardwood forests* | *5–15* | *high* | *low* | *Tourism losses from lost scenery and biodiversity* |
| *Lowland indigenous podocarp forests* | *2–5* | *low* | *low* | - |
| *Alpine shrublands* | *2–5* | *low* | - | - |
| *Exotic forests* | *1–3* | - | *low* | *Browsing of young trees, replanting costs* |
| *Beech forests* | *<2* | *low* | *low* | - |
| *Alpine grasslands* | *<2* | *low* | - | - |
| *Open pasture and cropland* | *<2* | - | *high* | *Lost production through eating pasture and crops.* |
| *Erosion control tree plantings* | *?* | - | *medium* | *Browsing of plantings; increased soil erosion* |
| *Horticultural and ornamental crops* | *?* | - | - | *Lost production (generally localised)* |

*Sources: Department of Conservation (1994); Parliamentary Commission for the Environment (1994)*

Other important livestock pests include about five species of blowfly (*Lucilia* spp.) which kill an estimated 200,000–250,000 sheep annually by laying eggs in the fleece which then hatch into maggots that feed on the animals' flesh. All the pest blowflies are from overseas, as are the common houseflies which arrived on fly-blown meat in the European migrant ships. New Zealand's only native blowfly, a large blue species which lives in tussock country, is a vegetarian.

Parasitic nematodes or roundworms are also serious pests. Nematodes are a very successful group of animals. Most are free-living inhabitants of ocean mud, soils and water, in environments which range from tropical forests to deserts and polar regions. However, a significant number are intestinal parasites, living inside other species. Most of New Zealand's nematodes are harmless soil-dwellers, and some are even beneficial, but about 50 parasitise humans, and even more parasitise our livestock, impairing their growth and health and costing large sums of money in lost production.

### *Pest control pressures*

Controlling pests and weeds is a large and costly component of agriculture and nature conservation in New Zealand and requires a formidable arsenal of animal poisons, insecticides, herbicides, fungicides and parasite-killing drenches. These diverse toxins are collectively referred to as 'pesticides'.

New Zealand has more than 900 registered pesticide products, using at least 270 different active ingredients (MacIntyre *et al.*, 1989). In 1993, around $150 million was spent on pesticides—including $90 million to control weeds (estimated to cause about $340 million in lost production each year), and $20 million to control roundworm parasites (which cause losses of around $260 million in reduced animal production). Most of the remaining $40 million was spent on fungicides to control fungal pests in gardens and orchards. These figures do not include the roughly $50 million spent by the government on controlling possums, nor the sums spent on controlling other mammalian pests such as rabbits, goats, deer, rats, cats and mustelids (ferrets, stoats and weasels).

Three-quarters of the pesticides sold in New Zealand are used in the North Island. About two-thirds are used by orchardists and market gardeners. About a third are used by pastoral farmers. This reliance on chemical weapons began with two innovations in the 1940s. Laboratory-made organochlorines, such as DDT, replaced the earlier generation of heavy metal pesticides, such as the highly toxic arsenates. At the same time, the Second World War produced a crop of experienced pilots able to drop bulk quantities of fertiliser and apply pesticides from light aircraft. The idea was first pioneered in New Zealand in the 1920s but not taken up on a large scale until the 1940s. Following the passing of the Soil Conservation and Rivers Control Act 1941 bulk quantities of fertiliser began to be dropped on steeper country to improve the pasture cover. Later, pesticides and poison baits also began to be air-dropped.

Synthetic pesticides, and air-dropped fertilisers, triggered an agricultural revolution through the 1950s and 1960s, and ended the insect attacks which had destroyed large areas of crops in the 1920s and 1930s. But when DDT was withdrawn because of its health and environmental impacts in the 1970s the resurgence of grass grub and porina led to annual agricultural losses of up to $100 million (MacIntyre *et al.*, 1989). Research then swung dramatically back toward biological means of controlling pests. In fact, of all the alien species introduced to control pests between 1870 and 1990, 31 percent were released in a single decade, as organochlorines were being withdrawn (Cameron *et al.*, 1993).

Today research into biological control methods is increasing. One approach is to breed pest-resistant strains of livestock and crops (e.g. the recent development of a Romney sheep which is 70 percent resistant to roundworms). The other is to introduce biocontrol organisms that can kill pests and weeds—either predators, which eat them from the outside, or parasitoids, which eat them from within. Parasitoids are tiny insects (often wasps) which are only parasitic during their larval stage. The adults lay eggs inside a target organism and, when the eggs hatch, the larvae eat their way out, finally emerging as adult insects from the remains of their host.

Biocontrol organisms have always been economically attractive because, once established, they require little maintenance or re-application. Two new factors have added to their appeal: increasing public concern about the potential effects of pesticides, and the evolution of chemical resistance in some pests and weeds. So far, four New Zealand weed species are known to have developed resistance to herbicides. Two of these, fat-hen and willow weed, affect cropland. The other two, nodding thistle and giant buttercup, are pasture weeds. Now drench-resistant roundworms and insecticide-resistant blowflies are appearing in livestock.

The move to biological methods is not new. At least 321 alien species have been introduced to New Zealand since 1874 to control pests and weeds and in some cases to disperse animal dung. Of the 75 biocontrol species that became established, 36 have had significant impacts on 26 of the 70 or so pests they were targeting (Moller *et al.*, 1993; Cameron, 1994). Six of these pests are now fully controlled and 11 partially controlled. They include major pests of barley and small grain cereals, pasture grasses and maize or sweet corn, lucerne, white clover, forage brassicas, greenhouse crops, apples, citrus fruit, eucalypts and radiata pine trees (Cameron *et al.*, 1993; Hill *et al.*, 1994).

One example is a moth (*Mythimna separata*) whose caterpillar, known as army worm, attacks grain crops. Since 1972, it has been controlled by an introduced parasitoid wasp (*Apanteles ruficrus*) for an annual saving of $4–10 million. Another pest, the *Sirex* wasp in pine forests, is controlled by a multi-species team of four parasatoid insects and a sterilising nematode (*Beggingia siricidicola*). One of the eucalypt tree pests which has succumbed to biocontrols is the gum-tree scale (*Eriococcus coriaceus*) which is controlled by a combined effort from the ladybird (*Rhizobius ventralis*) and a predatory caterpillar (*Stathmopoda melanochra*).

Biocontrols for pasture pests include a bacterial control agent for grass grub (Jackson *et al.*, 1993) and the ragwort flea beetle which was introduced from Oregon in 1983 to control the weed, ragwort. Ragwort reduces the area of pasture suitable for dairy production, as it is toxic to cattle and taints milk. Other weeds for which biocontrols are being researched are gorse, broom, nodding thistle, Californian thistle, hawkweed, old man's beard, heather and buddleia (Zhang *et al.*, 1993; Hill *et al.*, 1994).

New biocontrol organisms are being tested and proposed all the time. Most are insects, but fungi, bacteria and even viruses are also under investigation. The best known viruses are probably the controversial *Myxoma* virus and its even more controversial replacement, a calicivirus which causes Rabbit Haemorrhagic Disease (RHD). The *Myxoma* virus was released successfully in several countries, including Australia, forty years ago and caused outrage among animal welfare groups because of the prolonged suffering it caused the rabbits.

Myxomatosis had a high short-term impact on the rabbit populations but became less potent as rabbits and viruses evolved tolerances to each other. It failed to establish in New Zealand and several applications to re-release it have been declined on both humanitarian and ecological grounds. Work is currently underway in Australia on the development of a genetically modified *Myxoma* strain which causes sterility rather than a painful disease. As of late 1996, however, this work was overshadowed by the premature release of RHD in Australia and applications for its release in New Zealand (see Box 8.3).

A careful evaluation process for RHD has been necessary before deciding whether or not to allow it into New Zealand because, in the past, pesticides and biocontrols have sometimes had unintended environmental impacts. DDT residues, for example, turned out to be highly persistent, accumulating in animal fat rather than breaking down. Today's pesticides are designed to decompose more rapidly, though the effects of their breakdown products on soil organisms and stream life are still poorly understood.

Biocontrols have sometimes hit non-target species harder than the pest they were meant to control. The hedgehog was introduced to control the introduced garden snail but also preys on native snails and insects (Moller *et al.*, 1993). Stoats, ferrets and weasels were introduced to control rabbits, but they also attack native birds and reptiles. However, biocontrol scientists are quick to distinguish between these introduced mammals and the biocontrol invertebrates. Although little research has been done on their ecological impacts, few recently introduced biocontrol species seem to have penetrated into native bush (Cameron, 1994; Barratt, 1996).

**Box 8.3**

### *Viral control of rabbits*

The virus that causes Rabbit Haemorhagic Disease (RHD) reached Australia very recently (Munro and Williams, 1994). In fact it arrived in the world very recently, first appearing in China only a dozen years ago (in rabbits imported from Europe). It belongs to a family of viruses called caliciviruses. The five known calicivirus groups contain some strains which infect only one species and others which can infect several different species (e.g. pigs and sea lions). Some caliciviruses can cause infections in humans (Matson and Smith, 1996).

Since its appearance in China, the RHD strain has spread to more than 40 countries on four continents, killing millions of rabbits in the process but apparently causing no problems to humans or any other species. It was accidentally released from a joint New Zealand/Australian research facility in Australia in September 1995 and quickly spread to many parts of the country (Anderson 1995a, 1995b; Drollette, 1996). For media purposes, the disease began to be referred to as Rabbit Calicivirus Disease (RCD), rather than by its formal name. As of early 1997, the New Zealand Government was considering an application under the Biosecurity Act from five regional councils, Federated Farmers and the Commissioner of Crown Lands, to have the RHD virus released here.

In deciding whether or not to approve the release of the virus, the Government has had to consider such issues as: its humaneness; any possible effects (harmful or beneficial) that it may have on New Zealand's natural resources, including its possible impact on other species (including rare indigenous species); and its likely effectiveness in actually reducing rabbit populations. The Government has also had to consider the possible advantages of a controlled release over an accidental or unauthorised release.

Scientists and animal welfare organisations are in broad agreement that the virus is relatively humane. Blood clots form in vital organs and the adult rabbits die quietly of respiratory failure within 30-70 hours. Young rabbits are unharmed. In fact, once exposed, those under 5–8 weeks acquire life-long immunity. In parts of Europe a significant number of immune adult rabbits have mysteriously developed antibodies before being exposed to the disease. This has led researchers to speculate that the virus may be a mutant strain of some pre-existing rabbit calicivirus which is harmless and so has remained undiscovered. Others have speculated that it may have mutated from a calicivirus which normally infects other species. One possible candidate is the virus which causes European Brown Hare Syndrome (EBHS). At present, nobody knows for sure and this raises the most controversial question about the virus: how might it affect other, non-rabbit, species?

Although 'species jumping' has not been observed in the 12 years since the virus was discovered, estimates of the risk vary among the scientific community, with some scientists judging it to be small and others, significant. In Australia, 30 species have been tested, including the North Island brown kiwi and the New Zealand short-tailed bat. Antibodies developed in the blood of five species (dog, fox, human, kiwi and mouse) but, due to perceived irregularities in the tests, scientific opinion is undecided as to whether this constituted infection. The Australian Government finally approved the controlled release of the virus in October 1996.

Apart from the risk of infection, however, there is also a risk that the virus may harm other species through ecological disruption. Rabbits are a major food item for predators such as stoats, ferrets, cats and harrier hawks. If rabbit numbers were to fall dramatically, the predators may switch to hunting other species. Scientists are unable to predict whether these changed predation patterns would drive starving ferrets and cats to eat more native birds and reptiles, thereby increasing the pressure on them, or eat more rats, thereby reducing the pressure on native species. Early results in Australia show an increase in indigenous animals and a sharp fall in predators (Drollette, 1997). Cat numbers in some areas have fallen by 90%. Most had bellies full of insects, indicating that they were unable to quickly learn how to target new prey.

As for the virus's impact on the rabbits themselves, the results from overseas have been variable, depending on such factors as the season (and hence the number of young that become immune), the percentage of adults with pre-existing immunity, and the presence or absence of suitable carriers (e.g. mosquitoes, bush flies). In parts of Australia rabbit numbers have fallen by 95%, but there are concerns that the reduction may only be temporary if other methods are not used to eliminate the survivors (Drollette, 1997). New Zealand's Ministry of Agriculture has pointed out that, while there are many uncertainties about RHD, one certainty is that it will not be a 'magic bullet'. It's use in New Zealand would need to be accompanied by other methods, such as poisoning, shooting, and 'other control technologies' in an integrated pest management strategy (Kettle, 1996).

To date the only introduced insect biocontrol known to have become established in non-target native species is the bristly tachinid fly, *Trigonospila brevifacies*. Tachinid flies belong to a family which can parasitise a wide range of insects. This particular tachinid was introduced into orchards to control leafroller caterpillars. At the time, the impact on native insects was of little concern. The parasitoid has since infected six different families of harmless native moths. It is not known whether any of the affected species have declined as a result (Atkinson and Cameron, 1993; Cameron *et al.*, 1993; Cameron, 1994).

Today, efforts are made to ensure that new organisms will not harm non-target species. Unpredictable impacts still occur, but, to date, they have involved other introduced species rather than native ones. Recently, for example, it was found that an exotic parasitoid, *Microtonus aethiopoides*, introduced to control *Sitona* weevils, is parasitising another biocontrol insect, *Rhinocyllus conicus*, which was introduced to control nodding thistle (New Zealand Science Monthly, 1995).

In order to maximise the effectiveness of pest control programmes, the concept of Integrated Pest Management has become more widely accepted in recent years. It involves a mix of measures, including not only biocontrols, selective breeding and selective use of pesticides, but also environmental measures, such as changing crops or grazing regimes to reduce exposure to pests and weeds.

In summary, the pressures which pests and weeds put on our land include:

- reducing indigenous biodiversity, through predation and competition;
- reducing production from livestock, pasture and crops; and
- necessitating the use of pesticides and biocontrols which carry a risk of unintended environmental impacts.

**Table 8.8**

**Estimated incidence of soil degradation on agricultural land.**

| Region | Erosion | Compaction | Nutrient decline | Contamination |
|---|---|---|---|---|
| *Northland* | *local* | *local* | *widespread* | *probable* |
| *Auckand* | *negligible* | *local* | *local* | *probable* |
| *Waikato* | *negligible* | *local* | *local* | *probable* |
| *Bay of Plenty* | *negligible* | *negligible* | *local* | *probable* |
| *Gisborne* | *widespread* | *negligible* | *widespread* | *possible* |
| *Hawkes Bay* | *local* | *local* | *widespread* | *possible* |
| *Taranaki* | *local* | *negligible* | *local* | *probable* |
| *Manawatu-Wanganui* | *local* | *local* | *local* | *possible* |
| *Wellington* | *local* | *negligible* | *widespread* | *possible* |
| *Nelson-Marlborough* | *local* | *negligible* | *widespread* | *possible* |
| *West Coast* | *negligible* | *negligible* | *local* | *possible* |
| *Canterbury* | *widespread* | *local* | *widespread* | *probable* |
| *Otago* | *widespread* | *local* | *widespread* | *probable* |
| *Southland* | *local* | *local* | *local* | *probable* |

*Source: Clough and Hicks (1993)*

***Widespread:*** *occurs in many parts of the region.*
***Local:*** *occurs in several parts of the region.*
***Negligible:*** *occurs in few parts of the region.*
***Probable:*** *site-specific, probably more extensive than reported.*
***Possible:*** *site-specific, possibly more extensive than reported.*

## THE STATE OF OUR LAND ENVIRONMENT

Soil and vegetation cover have been heavily modified by the pressures imposed by human society. While most land users are sustainably managing their soils, and many are now trying to maintain what remains of their native vegetation cover, problems of one sort or another exist in many areas.

Signs of declining soil productivity abound in many parts of the South Island high country and the North Island hill country, as well as in some intensively cropped low-lying areas. Contaminated sites are a problem in some urban and industrial areas. And, in many parts of the country, the native vegetation has become so fragmented that active restoration may be necessary for any protection to be effective.

### The state of our soils

Although most problem areas are known to local authorities, soil scientists, and the affected land owners, their overall scale and distribution have not been surveyed. Surveys formerly carried out by government agencies such as the DSIR's Soil Bureau and the Ministry of Works and Development's Water and Soil Division ended when those organisations were disbanded in the mid-1980s (Clough and Hicks, 1992).

The Crown Research Institutes (e.g. Landcare) inherited the old maps and data, but have only now been able to begin updating them. In the absence of recent survey data, the incidence of soil problems must be inferred from the earlier surveys, local examples and case studies (see Table 8.8).

Soil degradation takes many forms. **Erosion**, or the physical removal of soil, is probably the most serious and the least reversible, but soils are also degraded by **nutrient depletion** and **acidification**, which causes them to lose their fertility, by the loss of **organic matter (i.e. carbon depletion)** and **compaction**, which causes them to lose their structure, and by **contamination** with toxic substances which can make them a health risk to humans and other species. Salinisation, which is a problem in some other countries, has not emerged as a problem here.

Some soil degradation is often inevitable with land use, but generally it can be minimised or even reversed by sustainable land management practices (see Box 8.4). The extent of such practices is not known nationally, but surveys in the North Island between 1989 and 1992 indicated that about 80 percent of hill country farmland needed erosion control measures and that measures existed on about two-thirds of it (Clough and Hicks, 1992). The same surveys, however, showed that most of the measures are being ineffectively applied and that some 55 percent of the erodible North Island hill country farmland is not receiving adequate treatment.

**Box 8.4**

***Soil conservation techniques***

Many of the techniques for reducing or reversing soil degradation are well known. Others have been developed more recently. Nutrient decline can be addressed by applying fertilisers and, in the case of nitrogen deficiency, planting legumes. Acidification can be reduced by applying lime. Various methods exist for combating erosion and soil breakdown. Erosion on cropland can be reduced by minimum tillage, mulching crop residues or harvest stubble rather than burning it, contour ploughing (i.e. going across slopes rather than up and down them), sowing grass in rills and other depressions to slow the flow of rainwater, and planting trees for windbreaks (Hicks, 1995).

On pasture land, the erosion control techniques include maintaining adequate vegetation cover (i.e. avoiding over-grazing and maintaining a dense grass mat through regular applications of fertiliser and grass seed), spaced tree planting on slopes (at distances of up to 12 metres), close tree planting (at densities of 300 stems per hectare or more), reversion (i.e. allowing natural forest to regenerate on erodible land), fencing off river bank grazing strips, planting trees on unfenced banks, controlling grazing by moving stock before pasture becomes depleted, and building debris dams to slow water flows in gullies (Hicks, 1995).

Similarly, techniques to limit compaction include minimum tillage, shallow or variable depth ploughing, retaining crop residues and adding organic matter to the soil, avoiding concentrated pressure on wet soil from machinery or stock, providing drainage systems for susceptible paddocks, avoiding fallow periods where land is left bare for one or more seasons, rotating crops with pasture, and subsoil ploughing to break up already compacted soil (Haynes, 1994).

***Erosion***

On a human time scale and often on a geological one, soil can be considered a non-renewable resource because rates of soil formation are so slow. It takes one to four centuries for nature to build a single centimetre of topsoil, and 3,000 to 12,000 years to develop sufficient soil to form productive land (Dailly, 1995). These rates apply to most soil types, though extremes occur beyond both ends of the range.

Volcanic ash, for example, has very fast rates of soil formation. A mere 100 years after the massive 1883 eruption of Krakatau island in Indonesia, soil 25 centimetres deep had formed on a daughter island, Rakata (Dailly, 1995). In North Island New Zealand, soil and vegetation recovered equally as fast after the massive Taupo volcanic eruption of 1,850 years ago (Stevens *et al.*, 1995).

In most cases, however, topsoil formation is much slower and is currently offset by the much faster erosion rates in many areas.

Although vegetation returns within a few years on an eroded site, the growth is generally less productive than before because the underlying soil is thinner and holds fewer nutrients. After hill country slip erosion, for example, pasture production takes approximately 20 years to recover to within 70–80 percent of its pre-erosion levels and some land may never achieve more than 70–85 percent of its pre-erosion potential (Trustrum *et al.*, 1990). In severely eroded areas only a few stress-tolerant weeds may be able to survive. After repeated erosion, sites may become barren.

Soil erosion is a natural process which occurs on all land, but has been accelerated by deforestation and unwise land use practices. At least 25 percent and possibly up to 80 percent of the world's agricultural land now has moderate to severe erosion (Pimental *et al.*, 1995a, 1995b; Crosson 1995). About 30 percent of agricultural soils in the United States have been abandoned, largely because of erosion. Croplands are most susceptible because their soil is repeatedly tilled and left without protective vegetation cover. About half the world's pasturelands are also subject to erosion because of overgrazing (Pimental *et al.*, 1995a).

Erosion rates in northern temperate countries (e.g. the United States and Europe) average 13–17 tonnes per hectare per year on cropland and about six tonnes per hectare per year on pasture (Pimental *et al.*, 1995a and 1995b; Crosson 1995). This is relatively low by global standards, but is much higher than the rate in undisturbed forests (less than half a tonne per hectare per year) and greatly exceeds the average rate of soil formation—about one tonne per hectare per year (Pimental *et al.*, 1995a).

Average rates of erosion and soil formation are not known for New Zealand, but a number of studies have shown that more soil has been lost than gained since European settlement (e.g. Hewitt, 1996; Trustrum and Page, 1991). The main forms of erosion have been:

- **surface erosion**, which occurs when wind, rain or frost detach soil particles from the surface, allowing them to be washed or blown off the paddock;
- **mass movement erosion**, which occurs when gravity combines with heavy rain or earthquakes to cause whole slopes to slump, slip, or landslide;
- **fluvial erosion**, which occurs when running water gouges shallow channels (rills) or deeper gullies into the soil; and
- **streambank erosion**, which is a special case of fluvial erosion that occurs when banks which have been cleared of tree cover become unstable and collapse because of trampling by livestock and gouging by flood flows.

Surface erosion can occur on any land where bare earth is exposed to wind and rain (e.g. after ploughing, or the burning of crop residues or stubble after harvest, or excessive grazing). If unchecked, surface erosion causes ongoing reductions of crop yield and pasture growth amounting to at least 20 percent and in extreme cases more than 60 percent (Hicks, 1995).

Most hill slopes steeper than 15 degrees are susceptible to mass movement, and those steeper than 28 degrees generally have a severe potential. Storms are generally the primary triggers (Fransen and Brownlie, 1995). Mass movements initially reduce pasture growth by 40 percent to 80 percent. After they have

**Table 8.9**

**Erosion susceptible land in New Zealand.**

| Region | Area at risk (hectares) | At-risk area being farmed | Percentage of farmland that is: stable | erodible |
|---|---|---|---|---|
| *Northland* | *874,300* | *521,100* | *30* | *70* |
| *Auckand* | *263,300* | *150,600* | *52* | *48* |
| *Waikato* | *945,900* | *511,700* | *63* | *37* |
| *Bay of Plenty* | *682,400* | *153,500* | *56* | *44* |
| *Gisborne* | *697,700* | *497,300* | *17* | *83* |
| *Hawkes Bay* | *967,400* | *537,900* | *38* | *62* |
| *Taranaki* | *341,400* | *116,000* | *72* | *28* |
| *Manawatu-Wanganui* | *1,299,800* | *809,700* | *42* | *58* |
| *Wellington* | *454,300* | *279,100* | *42* | *58* |
| *Nelson-Marlborough* | *1,686,600* | *528,900* | *18* | *82* |
| *West Coast* | *1,865,200* | *16,700* | *90* | *10* |
| *Canterbury* | *3,309,300* | *2,288,400* | *11* | *89* |
| *Otago* | *2,791,800* | *1,616,800* | *10* | *90* |
| *Southland* | *2,202,800* | *653,300* | *40* | *60* |
| ***New Zealand*** | ***18,382,200*** | ***8,681,000*** | ***32*** | ***68*** |

*Adapted from Clough and Hicks (1993)*

**Table 8.10**

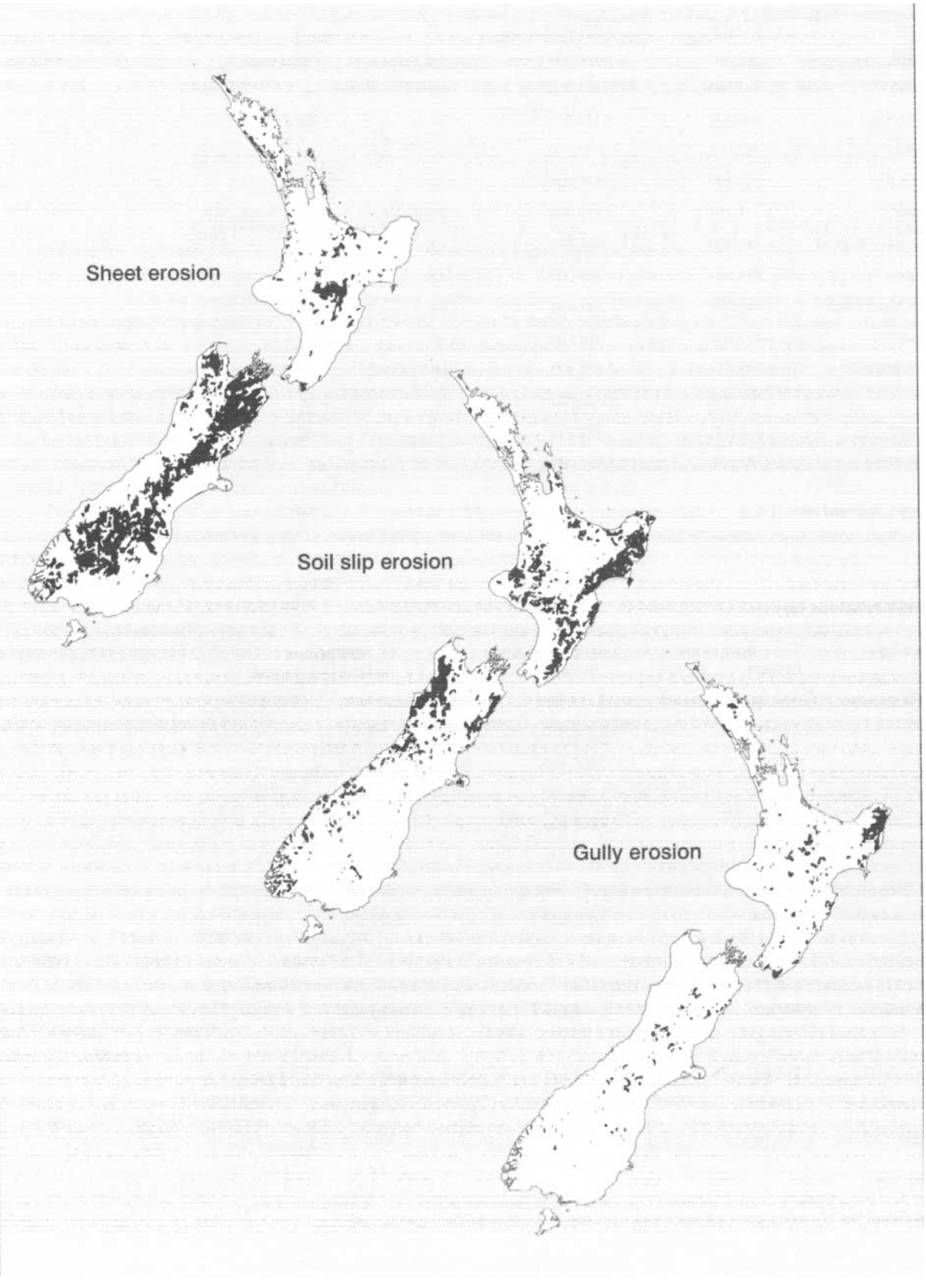
**Areas affected by erosion, 1975-79[1].**

| Erosion Type | North Island Hectares | North Island Percent | South Island Hectares | South Island Percent | New Zealand Hectares | New Zealand Percent |
|---|---|---|---|---|---|---|
| ***Surface erosion*** | ***2,662,600*** | ***23*** | ***11,150,000*** | ***74*** | ***13,812,600*** | ***52*** |
| *Sheet* | *2,117,400* | *19* | *8,318,400* | *55* | *10,435,800* | *39* |
| *Wind* | *526,900* | *5* | *2,865,800* | *19* | *3,392,700* | *12* |
| *Scree* | *417,200* | *4* | *3,259,900* | *22* | *3,677,100* | *13* |
| ***Mass movement*** | ***5,038,200*** | ***44*** | ***4,602,000*** | ***31*** | ***9,640,200*** | ***36*** |
| *Soil slip* | *3,397,000* | *30* | *3,615,800* | *24* | *7,012,800* | *26* |
| *Earth slip* | *280,300* | *3* | *58,500* | *<1* | *338,800* | *1* |
| *Debris avalanche* | *1,218,900* | *11* | *1,603,000* | *11* | *2,821,900* | *11* |
| *Earthflow* | *1,011,500* | *9* | *33,300* | *<1* | *1,044,800* | *4* |
| *Slump* | *65,800* | *<1* | *44,100* | *<1* | *109,900* | *<1* |
| ***Fluvial erosion*** | ***1,621,900*** | ***14*** | ***1,440,100*** | ***10*** | ***3,062,000*** | ***12*** |
| *Rill* | *13,700* | *<1* | *56,400* | *<1* | *70,100* | *<1* |
| *Gully* | *1,157,400* | *10* | *803,500* | *5* | *1,960,900* | *7* |
| *Tunnel gully* | *327,600* | *3* | *98,700* | *<1* | *426,300* | *2* |
| *Streambank erosion* | *240,400* | *2* | *491,100* | *3* | *731,500* | *3* |

*Source: Eyles (1983)*

[1] *Areas are those of mapping units in which the erosion occurs and not of the individual erosion scars. The total area of erosion cannot be derived from this table because different erosion types may occur within the same mapping unit.*

**Figure 8.9**
**Erosion in New Zealand, 1975-1979.**




*Source: New Zealand Land Resource Inventory 1975-79 (Landcare Research)* been re-grassed, growth may completely recover but, more often, it remains depressed by 10 percent to 40 percent. Mass movement also damages fences, tracks and drains, and occasionally buildings (Hicks, 1995).

Fluvial erosion can cause rills even on flat land if ground cover is depleted. On sloping land it also causes gullies which can cut deep into the underlying subsoil or undermine surrounding soils. The sediment is washed into streams. Gullies create long narrow scars which do not usually cause much loss of crop or pasture but may disrupt vehicle and stock movements around the farm (Hicks, 1995).

The susceptibility of land to erosion is determined by soil characteristics, geology, and slope. Erosion itself, however, is often triggered by external pressures from climate and land use. Although two-thirds of New Zealand and its farmland are erosion-susceptible (see Table 8.9), areas with potential for very severe or extreme erosion are restricted to unstable hill country. Whether erosion actually occurs in these areas depends on the vegetation cover and land use practices.

The most recent national survey of the actual extent of erosion in New Zealand was carried out two decades ago as part of the NZ Land Resource Inventory (see Table 8.10 and Figure 8.9). Some regions have since been remapped as part of the current NZLRI update, but the only national level statistics still relate to the 1970s. It showed that severe to extreme erosion affected nearly 10 percent of the country, mostly in the mountains and in unstable hill country, such as the South Island high country and the East Coast of the North Island (Eyles, 1983). Although half of New Zealand was affected by surface erosion, and around one-third by slips and other mass movement, much of this was slight. From that survey and subsequent erosion incidents, it is known that North Island areas with serious land instability and erosion include northern Hawke's Bay, East Cape, Northland, the Volcanic Plateau, King Country, Rangitikei, inland Taranaki, and the Wairarapa. South Island areas include Marlborough and coastal Otago.

Surface erosion is significant in Northland and on the Volcanic Plateau. It is also a problem in large areas of the eastern South Island, particularly in North Otago and South Canterbury where soil is picked up by warm dusty northwest winds during droughts and springtime seed bed preparation. A single episode can remove up to 100 tonnes of soil per hectare, or 5 percent of the total (W. Armstrong, 1993). In the South Island high country, surface erosion is caused by the combined effect of frost and wind on denuded soils (O'Connor and Harris, 1991). This has played a significant role in the desertification of around 200,000 hectares of former tussock land which is now bare or covered in hawkweed (Belton, 1991). Surveys have found that in various high country districts anything from 7 percent to 44 percent of the ground is devegetated (Clough and Hicks, 1992).

Recently, Landcare Research scientists estimated the rates of surface erosion in several parts of the South Island by measuring the amount of radioactive caesium ($^{137}Cs$) in the topsoil. This radioactive material was generated between 1953 and 1976 by global atmospheric atomic weapon testing. It was deposited by rainfall and quickly adhered to surface soil particles. Now, by measuring the distribution of these caesium-bound soil particles, erosion and sedimentation rates can be estimated for the past 40 years. In both South Canterbury cropland and unfarmed Central Otago arid land, the average yearly erosion rates appear to exceed 10 tonnes per hectare (Basher *et al.* 1995; Hewitt, 1996).

In the Central Otago study, significant surface erosion was estimated to affect about a quarter of the landscape near Earnscleugh. In the eroded parts of this area, the topsoil had declined from an original thickness of at least 9.8 centimetres before the arrival of rabbits and sheep to about 4.3 cm. About 3.4 cm of this loss had occurred in the past 40 years. The remaining topsoil on the most eroded slopes is projected to disappear entirely in the next 44 to 72 years (Hewitt, 1996).

**Box 8.5**

### *Erosion on the North Island East Coast*

The East Coast region represents only 7 percent of the land area of the North Island, but it contains 50 percent of the worst soil erosion (Miller, 1991). An early example was the Tarndale Slip, one of the largest single examples of fluvial and mass movement erosion in New Zealand. In 1915 Tarndale was a single, narrow gully. Today the slip covers an area of 50 hectares and the soil it has dumped in the gully has raised the bed of the river below by approximately 30 metres (Glasby, 1991). The erosion problems began more than a century ago when European settlers began deforesting the unstable hill country for pasture. Every heavy rain storm resulted in land slips and large amounts of sediment washing into rivers. The infilling of riverbeds by fine silt and gravel was noted from about 1910 onwards, with many river flats and low terraces gradually being overwhelmed since then. As the riverbeds rose, the incidence of flooding increased. By the late 1930s, floods and erosion were causing serious alarm among local residents. Floods in 1938 and 1948 resulted in stopbanks being constructed along the Waipaoa River.

A review of the area in the 1960s led to recommendations for a government-funded soil conservation project whose features would include better land use planning and controls, the retirement of unsuitable land from agriculture, and, most importantly, the afforestation of eroding and erosion-prone land (Taylor, 1967). The East Coast Project began a year later. Although the project met resistance from many farmers who did not want pine forests on what they saw as good grazing land, trees were planted on a number of slopes. However, the project conflicted with government policies of the 1970s and early 1980s (such as agricultural subsidies and development loans) which encouraged farmers to bring land that had reverted to indigenous vegetation back into pasture. Policy changes in the mid-1980s ended most subsidies for pasture development and forest planting. In 1987, a government review of the East Coast Project concluded that there was no role for further government support and predicted that commercial forestry interests would probably plant the eroding land.

Three months later, in March 1988, Cyclone Bola hit. Over 72 hours it deluged the region in nearly half a metre of rain, with nearly a metre falling in some locations (Trotter, 1988). The erosion which resulted followed earlier patterns but the scale was unprecedented. The hardest hit area was the 52,000 hectare Uawa catchment, nearly all of which is Class 6,7 and 8 land (Marden *et al.*, 1991). About 60 percent of this was pasture land but a quarter had been planted in exotic forest under the East Coast Project. The cyclone provided an excellent test for both types of land cover. The pasture land lost an estimated 46 million tonnes (ranging from 660 to 3,439 tonnes per hectare), while the forested land fared better, losing an estimated 12 million tonnes (217 to 2,019 tonnes per hectare). The heaviest soil losses on the forested land came from recently planted forests. Land which had been under forest for eight years or more had only a tenth the soil loss rate of pasture land.

A similar result was found in the small Pakuratahi and Tamingimingi catchments near Napier, each of which is nearly 800 hectares in area (Fransen and Brownlie, 1995). Back in 1943, when the area was hit by a severe storm, 83 percent of Pakuratahi and 91 percent of Tamingimingi were in pasture. Pakuratahi, being steeper, suffered close to 300 slips per square kilometre while Tamingimingi sustained about 230. When Bola struck 45 years later little had changed in Tamingimingi catchment, where 93 percent of the land was in pasture and the slip density was 130 per square kilometre. In Pakuratahi, though, pine forests had been planted since the 1970s and, by 1988, 73 percent of the catchment was forested, with an additional 7 percent under native scrub and only 16 percent still in pasture. Pakuratahi's slip density during Bola was just 22 per square kilometre.

In economic terms, Cyclone Bola was one of the worst natural disasters New Zealand has experienced. The cost of property damage is estimated to have been nearly $120 million, and some 1,500 affected landowners received relief payments amounting to $60 million. Smaller erosion events continued after Bola, but neither farmers nor forestry companies showed strong inclinations to begin forest planting in the eroding areas. As a result, the Government in 1992 launched the East Coast Forestry Scheme to once again subsidise the planting of exotic forests on erodible land. The scheme involves the participation of forestry companies, local authorities, and landowners, including the local Maori iwi, and aims to plant some 200,000 hectares of eroding pastoral land over a 28 year period.

Gullies and slips occur in large areas of Gisborne, Hawke's Bay, eastern Wairarapa, the Volcanic Plateau and inland Taranaki, where erosion rates in steep pasture land have been at least 2 millimetres per year since deforestation 75 years ago (Blaschke *et al.*, 1992). In fact, in the small, steep, Lake Tutira watershed (3,208 hectares), sediment cores reveal an average erosion rate of 14 mm per year in the 110 years since the catchment was cleared for pasture (Trustrum and Page, 1991). A study of slip erosion in two small Hawke's Bay catchments (1,573 hectares) found that 1.3 percent of the total area (20 hectares) was affected, nearly all of it pasture land rather than forested land (Fransen and Brownlie, 1995). It took almost 27 years for slips to be fully recolonised by pasture grasses, which is similar to the 30 year recovery time recorded elsewhere in the North Island (Hicks, 1988).

A study on three hill country properties in Taranaki found that the cumulative effects of erosion amounted to a 20–30 percent long-term reduction in productivity on moderate slopes (around 30 degrees), and a 60 percent reduction on steep slopes (greater than 33 degrees) (Gane *et al.*, 1991). The worst eroded area of New Zealand is the Gisborne-East Coast region. Since the conversion of forest to pasture, 200,000 of its 835,000 hectares have been seriously affected by slips. The most spectacular examples occurred during Cyclone Bola in 1988 (see Box 8.5).

### *Loss of carbon and organic matter*

Carbon, the 'molecule of life', is an indicator of the amount of organic matter in the soil. Organic matter maintains soil structure by binding soil particles into small clumps or aggregates. The spaces between these aggregates function as pores which enable water to drain through and roots to penetrate. Loss of organic matter causes the clumps to lose their structure and collapse into the pores, clogging the soil.

The vegetation and soils of natural forests hold 20–30 times more carbon than agricultural lands (Tate, 1993). This is because in native forests, and also tussock, organic material has built up in the soil over thousands of years through the decay of dead roots, leaves, organisms, and animal waste. When land is converted to farmland, this natural recycling system is replaced by a system which regularly removes significant amounts of plant and animal matter as food, fibre or waste. Carbon may also be lost from soil as a result of changes in grassland species caused by prolonged high inputs of nitrogen (Wedin and Tilman, 1996).

Carbon loss is worst in land heavily cultivated for crops. A high proportion of the organic material is removed at harvest. Ploughing causes further significant losses by breaking up the soil, exposing more organic matter to the air and allowing bacteria to decompose it faster. Rather than helping to bind soil particles, the carbon is expelled by the bacteria as carbon dioxide. One New Zealand study found that ploughing alone had caused a 25 percent depletion of soil carbon over 25 years (Harrison *et al.*, 1993). Large decreases in soil carbon have been reported for market gardens in South Auckland and for croplands in Waikato, Manawatu, Canterbury, and Otago (Gradwell and Arlidge, 1971; Cotching *et al.*, 1979; Ross *et al.*, 1982; Hart *et al.*, 1988; Ross *et al.*, 1989; Haynes and Francis, 1990; Shepherd, 1991; Sparling *et al.*, 1992; Tate, 1992).

Pastoral farming has less impact on soil carbon because, although removals are significant (via grass which is converted into animal carcasses, wool, milk etc.), some carbon is returned in animal faeces, decaying grass roots (much denser than crop roots), and their associated micro-organisms (Jenkinson, 1988). Carbon losses in hill and high country pastures tend to be associated with erosion rather than plant removals. On the Canterbury Plains, where the dominant farming system is mixed cropping, many farmers have a relatively well balanced rotation in which grazed grass-clover pastures are grown for two to five years, followed by two to five years of cereals and crops. As a result, the total organic matter content of the soil remains relatively unchanged through the cropping rotation (Haynes and Francis, 1991). Several studies of long-term grazed and fertilised grass-clover pastures have shown a build-up of soil carbon (Jackman, 1964).

The difference in impact of pasture and cropping on carbon levels was demonstrated in the Manawatu-Wanganui region when pasture was converted to maize fields. Continuous maize cropping caused a rapid decline in soil carbon and, in some cases, a serious deterioration of soil structure. Over a decade, about 20 tonnes of carbon per hectare were lost to the atmosphere from the top ten centimetres of soil (Shepherd, 1991). This was because the maize left insufficient decaying plant residue to replace the large amount of carbon lost in ploughing. The rate of carbon loss was more than double that reported for many North American soils that have been intensively cultivated (Shepherd, 1992).

***Compaction and loss of soil structure***

While carbon loss is an indicator of declining soil structure, compaction is a consequence of it. When soil structure is lost, and the pores fill in, the soil becomes hard and compact and forms a layer which plant roots, air, and water cannot penetrate. Plant growth declines and bare ground may result. Soil compaction is a primary land degradation problem overseas, but in New Zealand it has only recently gained recognition as a significant problem.

An estimated 2.1 million hectares of mixed pasture-cropland and permanent cropland is considered to be at risk (Ross and Wilson, 1983). Compaction is not restricted to carbon- depleted soils. Even soils with high organic content can have their structure broken down if heavy loads are applied to them when wet. Heavy machinery and treading by farm animals, particularly cattle, are common causes of this type of soil breakdown.

Compaction can occur at different levels of the soil profile, ranging from **surface capping** and **pugging**, through **slumping and hard-setting** of the ploughed layer, to **subsoil compaction** below the ploughed layer and under wheeltracks and orchard alleys.

**Surface capping** is common on fine, sandy and silty soils with low organic matter, particularly where the land is subject to continuous cropping or market gardening. Under heavy rain, soil particles which have become detached from the deteriorating soil aggregates form a muddy layer which blocks the soil pores. Upon drying, a dense surface crust forms a rigid cap which may be strong enough to prevent seedlings breaking through (Haynes, 1994).

**Pugging**, caused by stock treading, is most common on dairy farms but can occur in any wet pasture with large concentrations of animals. It occurs when the soil is so soft that the hooves of grazing animals sink into it, compressing it and blocking the soil pores. The effect tends to be self-perpetuating because partially pugged soil prevents water from draining away. As a result, the soil remains soft and wet for longer, permitting hooves to do more damage at subsequent grazings. Severe pugging in the Manawatu, coastal Otago and Southland, Northland and the Waikato, has reduced annual pasture yields in the affected paddocks by 15–30 percent (Haynes, 1994). However, provided the pugged soil remains under grass and is protected from further animal treading, it recovers its structure much faster than cropped soil compacted by cultivation machinery. Volcanic soils are less susceptible to pugging than the yellow-grey soils which occur in many parts of New Zealand. The latter have a naturally compact subsoil which is slow to drain. As a result pugging is relatively common on the yellow-grey soils, particularly where mob-stocking is carried out over winter.

**Slumping** and **hard-setting** are one stage worse than surface capping and pugging. They occur in soils that are fine, sandy or silty and have low organic matter with very unstable aggregates. After ploughing, the aggregates slump back to the same density as before and may congeal if they get wet. When the congealed soils dry they set hard into one complete dense mass without cracks which crop roots cannot penetrate and water cannot infiltrate (Haynes, 1994). Slumping and hard-setting can be seen in some soils that have been subject to regular rotary cultivation (e.g. market garden soils) and in arable soils, particularly where row crops (e.g. maize) have been grown continuously. However, hard-setting is not a problem on peats, very sandy soils, or on soils of volcanic origin, where many market gardens are located (Haynes, 1994).

**Subsoil compaction** occurs when the heavy weight of machinery causes a hardened layer to form below the depth of normal ploughing. Tractors and other wheeled vehicles and equipment, as well as plough soles, disc edges and rotary blades can all cause subsoil compaction in wet soft soils. Cropland, orchards and berry gardens are all susceptible. Subsoil compaction limits drainage and also prevents plant roots from penetrating (Haynes, 1994).

Compaction on maize farms in the Manawatu-Wanganui region has resulted in a rapid and marked loss of production and profitability. Over a ten year period, maize yields have steadily declined by 24–45 percent on poorly-drained Kairanga soils, and by 15–30 percent on well-drained Manawatu soils. It is estimated that two-thirds of the arable land in the Manawatu-Wanganui region is highly susceptible to severe soil compaction (Shepherd, 1991).

Under Canterbury mixed cropping regimes, a similar deterioration of structure occurs during the cropping phase, but soil structure improves under the pasture phase as a result of the build-up of organic material, earthworm activity etc. Structural deterioration under long-term cropping makes the soil harder to work and more susceptible to wind erosion. Concern has been expressed that current economic pressures are leading to an intensification of cropping at the expense of the pasture phase of the rotation (Haynes and Francis, 1991).

Since the renewed intensification of agriculture in the 1970s and 1980s, examples of serious compaction have been reported, though not systematically monitored, throughout New Zealand from Northland (in horticultural land near Kerikeri), the Waikato (in lowland pasture), Manawatu (in lowland pasture and maizefields), Hawke's Bay (in orchards near Hastings), Canterbury (in cropland), and South Otago and Southland (in land used for winter strip grazing).

***Nutrient depletion***

Nutrients are lost from agricultural land when plant and animal matter, which would normally decompose and return to the soil, is removed in crops and animal products. The lost nutrients ultimately end up in urban landfills, sewers, surface waters, and other countries. In natural ecosystems nutrient replacement is a gradual process. Under intensive agriculture, fertilisers are needed.

Unlike farming, forestry only requires fertilisers where natural soil fertility is low (on podzolised soils of Northland or the West Coast), where short rotation 'pulpwood' eucalypt forests are grown, or where 'whole trees', including the foliage and small branches, are removed from the site. Most planted forests in New Zealand, many in their fourth rotation, have received no artificial fertiliser input, because most of their nutrient-bearing bark and foliage is left on site.

On pasture, nutrients are lost not only through harvesting, but also when animal waste is deposited in concentrated patches, such as the "camp" area where the animals settle for the night, rather than being evenly redistributed throughout the grazed pasture. This is a significant cause of nutrient decline on the hilltops and slopes of hill country farms (Williams and Haynes, 1991; O'Connor and Harris, 1991). Erosion, leaching, and chemical processes in the soil can also remove nutrients.

To counter such losses, agriculture is very dependent on expensive imported fertilisers containing phosphorus, sulphur, potassium, and, increasingly, nitrogen (Goh and Nguyen, 1991). In the past, nitrogen fertiliser has been used on a small scale in exotic forests (Mead, 1986), but an increasing number of dairy farmers are now applying it (Roberts *et al.*, 1992). Other farms continue to obtain their soil nitrogen from nitrogen-fixing legumes, such as clover (in pasture land) and peas (in crop land).

The removal of fertiliser subsidies in 1984, coupled with a downturn in commodity prices, led to a four year decline in fertiliser use, particularly on hill country properties. Fertiliser consumption began to increase again from 1988, but did not return to peak levels until recently (see Figure 7.11, Chapter 7). Much of the increased fertiliser use has been on dairy farms rather than hill pastures. A review of nutrient inputs and losses on New Zealand's 14 million hectares of pastoral grasslands concluded that phosphorus, nitrogen and sulphur levels were probably sufficient because of high previous levels of fertiliser use and nitrogen fixation (White, 1991). Concern was expressed, however, that potassium levels appeared to be declining and acidity may have increased because of reduced lime applications.

For farms without a build-up of residual soil nutrients, the fertiliser downturn appears to have reduced pasture productivity (Hicks, 1995). A study of one of the worst areas, the South Island tussock lands, found that annual inputs of all four major nutrients were insufficient to replace the losses (O'Connor and Harris, 1991). This is consistent with mounting scientific evidence that nutrient decline is becoming a significant problem on hill country farms throughout New Zealand, particularly in the King Country, East Coast, and Hawke's Bay regions of the North Island, as well as the eastern South Island hill country (Trustrum *et al.*, 1990; Williams and Haynes, 1991; Sheath, 1992).

### *Soil acidification*

Like nutrient loss, acidification reduces the fertility of soil. Acidity is measured on the pH scale, an index reflecting the proportion of hydrogen ions formed when a substance dissolves in water. Soils with a pH of less than seven are acidic, while those above seven are said to be alkaline. Most plants thrive in slightly acid soils, but few can cope with strong acidity (i.e. where pH is below five). Ryegrass and clover, the predominant pasture species, are particularly sensitive, with an optimal pH range of 5.7 to 6.5 (During, 1984).

In some areas, the acidification process is linked to the phenomenon of aluminium toxicity. When soil pH drops in some parts of New Zealand, such as inland Marlborough, essential elements (e.g. manganese) and inessential ones (e.g. aluminium) can become highly concentrated in the soil and inhibit pasture growth (Goh, 1994).

Acidification occurs when the more alkaline elements in the topsoil (e.g. calcium, potassium and magnesium) are removed. This happens when they link up with nitrates or other easily leached molecules which are then washed out of the topsoil by rainfall. The acidic ions that are left behind become more concentrated, gradually lowering the soil's pH. Although acidification is a natural phenomenon (the kauri forests, for example, had very acid soils) it can be accelerated when the topsoil receives large amounts of nitrate (e.g. from animal urine, nitrogen fertiliser or clover growth) or sulphur fertilisers (Goh, 1994).

Present day pH levels have led some experts to suspect that New Zealand's soils are becoming more acidic, while others consider this unlikely. Hard evidence cannot settle the matter because national trends in soil acidity have not been monitored. All that can be deduced from soil maps is that most of our land has the potential to become acidified (Parfitt and MacDonald, 1992). Susceptible soils, mainly on hill country, are widespread in the Northland, Auckland, Manawatu-Wanganui, and Wellington regions of the North Island, and throughout South Island regions.

However, most nitrate leaching does not occur on the susceptible hill country soils. The best clover growth and the heaviest concentrations of animal urine and nitrogen fertiliser are in flat dairying areas rather than hill country. Furthermore, the high rate of nitrate leaching is often countered by the use of lime (calcium carbonate) to reduce soil acidity. Lime is an alkaline powder derived from limestone. Limed agricultural soil is often less acid than the original forest soil that preceded it. However, lime use, along with fertiliser use in general, fluctuates in response to economic trends. Through the late 1980s, the national tonnage of lime application was barely half that required to counter acidification (White, 1991). Lime use has increased in recent years, but so has nitrogen fertiliser use. It is not known whether current applications of lime are sufficient to reverse pasture deterioration on some of the poorer hill country soils.

### *Chemical contamination of soil*

Contamination of land by hazardous chemicals, residues, and waste products is another form of soil degradation that New Zealanders have only recently begun to deal with (Ministry for the Environment, 1992b). Land is considered to be contaminated when hazardous substances are present at concentrations that are likely to pose an immediate or long term hazard to human health or the environment (ANZECC/NHMRC, 1992).

Humans and other animals can be exposed to soil contaminants in a number of ways, including direct contact with the soil, swallowing food or water from contaminated environments, and breathing contaminated dust. Apart from the health hazards, the presence of contaminants can also limit land uses, threaten building structures and services, and reduce land value.

Many potential contaminants have been identified in oil products, pesticides, fertilisers, industrial chemicals and byproducts, and waste disposed of at landfills. The contaminants

**Table 8.11**
**Industries, typical site activities, and likely soil contaminants.**

| Industry Sector | Examples of Industrial Activities | Examples of Likely Contaminants |
|---|---|---|
| *Chemical* | *Manufacture and use of acids/alkalis, pigments, dyes, fertilisers, pesticides, adhesives, resins, plastics, oils, pharmaceuticals, paints, timber treatment* | *Acids/alkalis, metals, non-metals (e.g. compounds of boron, arsenic, sulphides, chlorides), solvents (e.g. toluene, benzene), chlorinated organics (e.g. DDT, dieldrin, chlordane, PCP); other organic compounds (e.g phenols, carbamates, organophosphates)* |
| *Petrochemical and Energy* | *Oil refineries, tank yards, fuel storage tanks, bitumen manufacture, power stations, oil refining, gasworks* | *Hydrocarbons (e.g. petrol, diesel, polyaromatics, tars), phenols, acids/alkalis, metals, asbestos, fuel and coal products, cyanide and sulphur compounds, other organic and inorganic compounds* |
| *Metal industries* | *Iron and steel production, ferro-alloy and metal casting works, metal products manufacture, electrical products (e.g. transformers; batteries), metal coatings (e.g. anodizing and galvanizing), scrap yards, metal recycling, drum reconditioning, electroplating* | *Metals (e.g. Fe, Al, Cu, Ni, Cr, Zn, Cd, Hg, Pb), asbestos, hydrocarbons, PCBs, acids/alkalis, cyanides, inorganics, solvents* |
| *Transportation* | *Service stations, engine maintenance shops, railway yards, airports* | *Fuel, hydrocarbons, asbestos, PCBs, pesticides, metals, acids, solvents* |
| *Mining, waste disposal* | *Ore extraction, landfills and waste dumps* | *Metals (e.g. Cu, Zn, Pb), inorganics, gases (e.g methane), cyanides, phenol, PCBs, acids, leachates etc.* |
| *Others* | *Ports, tanneries, military land* | *Metals, organic compounds, hydrocarbons, methane, toxic, inflammable or explosive substances* |

**Table 8.12**
**Some land uses and risk factors associated with exposure to contaminants.**

| Examples of Land Uses | Risk Factors | Examples of contaminants of concern |
|---|---|---|
| | | |
| *Agricultural soils and domestic gardens; recreation areas* | *Ingestion of contaminated soil (children); adsorption of pollutants by crops and animals; phytotoxicity* | *Arsenic, cadmium, chromium, mercury, lead, free cyanide, copper, nickle, zinc, PAHs, phenols, organochlorines* |
| *Residential, commercial and industrial areas* | *Chemical corrosion of building materials and services, fire, explosion* | *Sulphate, sulphide, sulphur, chloride, methane, phenols, mineral oils, ammonia; oily and bituminous substances, coal dust* |
| *Construction site* | *Direct contact with pollutants (workers)* | *PAH, phenols, asbestos, oily and bituminous substances* |
| *Surface and groundwater* | *Intake of water* | *Phenols, cyanide, sulphate, soluble metals* |

include **heavy metals** (e.g. cadmium, arsenic, zinc, lead, copper, chromium, mercury etc.), **organochlorines** (e.g. DDT, DDE, PCP, PCBs, dieldrin, aldrin, chlordane, lindane, dioxins etc.), **solvents** (e.g. industrial cleaning agents), **corrosives** (e.g. acids and alkalis), **hydrocarbons** (e.g. oil derivatives such as petrol, diesel, tar and creosote), **asbestos**, and **cyanides**.

Contamination is not always limited to a specific site. Contaminants may seep through the soil into groundwater, or be carried to adjacent land and waterways in rainwater or on dust particles. Vapour and gases may emanate from a contaminated site (e.g. volatile hydrocarbon vapours from a service station or methane and carbon dioxide from a landfill site) and may pose a number of hazards (e.g. potential for explosion, odour nuisance, or asphyxiation). Some soil contaminants, particularly heavy metals and some organochlorines, can accumulate in animal tissue, with concentrations increasing as they progress up the food chain. The heaviest concentrations are generally found in top predators, particularly birds of prey, large fish and marine mammals. Human health concerns most commonly focus on the risk of long term toxic effects such as cancer. They are of particular concern because of their insidious nature, in that the harmful effect may only become apparent years after the exposure has occurred. Furthermore, the magnitude of these risks is difficult to estimate accurately.

Investigations in other countries have shown that soil contamination can be caused by a range of industrial activities, including those associated with: chemical manufacturing and use; timber treatment; paint, pesticide and pharmaceutical manufacturing and use; the petrochemical, gas, coal and mining industries; the transport sector; the metal industries (e.g. smelting, manufacturing, recycling); and waste disposal (see Tables 8.11 and 8.12). Agricultural activities can also cause soil contamination (e.g. from pesticides, fertiliser residues, storage areas and dump sites).

The actual extent of land contamination is not yet known, but the number of potentially contaminated industrial sites and landfills is estimated from business and telephone directories and other 'desktop' records to be around 7,800 (Ministry for the Environment, 1992b). No formal assessment has been made of potentially contaminated agricultural and horticultural sites, but the total number could be 4,000 or more (Ministry for the Environment, 1992b).

About 1,580 (22 percent) of the potentially contaminated urban and industrial sites are estimated to pose a high risk of harming human health or the environment. Local authorities are now conducting surveys to systematically identify high risk sites using a rapid hazard assessment methodology (Ministry for the Environment 1993b). Sites surveyed to date include landfills and waste dumps, service stations, oil storage terminals, gas works, pesticide manufacturing plants, dieldrin dump sites, sawmill and timber treatment sites, and some farm and disused mining sites.

*Landfills*

Landfills receive an estimated 3 million tonnes of waste every year and are likely to continue as the main destination of solid wastes in New Zealand (see Chapter 3). They can pose a risk to human health or the environment because of the contaminants that can escape from them into air, water or soil, even after closure (Ministry for the Environment 1992b).

Gases which escape from landfills can create a risk of methane explosions or asphyxiation by carbon dioxide. In one recent case several Wellington homes had to be evacuated because of gases issuing from a landfill site which had been closed many years previously. This illustrates the fact that the adverse consequences of poor landfill management may take many years to emerge. In contrast, the operators of a number of engineered landfills are taking advantage of the methane emissions by harnessing them as a source of energy.

In the past, most landfills were inadequately managed and many were inappropriately located. Older landfills were often in sites near waterways, or situated in old gravel pits, where leachate could enter the groundwater. Now, under the Resource Management Act, all operating landfills require consents from the local authority. In setting out the environmental conditions that must be maintained at each site the consents draw on national guidelines.

Three sets of guidelines have been developed to cover: the collection of statistical data on landfill wastes; the siting, design, operation and after-care of landfills; and the identification, sources and management options for waste hazardous substances (Ministry for the Environment, 1992c, 1992d, 1994a). The New Zealand Landfill Guidelines are based on the United Kingdom model of landfills as 'waste treatment' facilities (Ministry for the Environment, 1992d). The Waste Analysis Protocol provides a systematic approach to data collection which will enable a better assessment in the future of the environmental effects of landfills and the cumulative level of risk posed by them (Ministry for the Environment 1992c).

At a number of closed landfills, local authorities are conducting leachate monitoring programmes and other investigations to assess the risks they pose and consider management options for high risk sites. For example, Auckland City Council commissioned a review of 85 closed landfills which had been used between 1910 and the late 1970s (Tonkin & Taylor Ltd 1994b). All the landfills were ranked for their potential to harm the environment and human health.

The pre-1950 landfills tended to be small road and quarry infills with limited organic waste. The post-1950 landfills were larger, and had been filled with greater proportions of decomposable matter. In the 1960s and 1970s, some of the landfills in coastal gullies and tidal wetlands had industrial waste dumped in them. Ten sites were singled out for detailed investigations which revealed that:

- leachate was seeping from all ten landfills, with the youngest sites having the highest levels of Biochemical Oxygen Demand (50 to 200 mg/l), Chemical Oxygen Demand (500 to 1,500 mg/l) and ammonium (up to 100 mg/l);
- the leachate had very low concentrations of dissolved metals, mostly zinc;
- volatile (gaseous) and semi-volatile organic compounds (e.g. xylene, phenols etc.) were present in low concentrations in the leachate of young landfills, but not in the point source discharges;
- significant concentrations of landfill gas were detected at eight of the ten sites, with methane concentrations of up to 65 percent and carbon dioxide concentrations of up to 55 percent at the younger landfills and more variable levels at the older ones; and
- landfill gas was recorded in buildings at two of the sites with methane levels above the Lower Explosive Limit (LEL) in some floor slab joints and cracks, but not within the larger building areas, suggesting that the standard vent space beneath New Zealand buildings may protect them from gas explosions, fires and asphyxiation risks near disused landfills.

Following the investigation, cost effective management and remedial options were proposed (Tonkin and Taylor Ltd, 1994c). These included the capping of landfills to reduce leachate and seepage, the passive venting of landfill gas, the active and passive venting of particular buildings, and the sealing of floor slab joints. Where leachate discharges occurred near harbours, restrictions were proposed on shellfish gathering and recreational activities. Where environmental and human health effects were minor, the continued discharge of leachate and landfill gas was considered to be a valid option, bearing in mind that the council has an obligation under the Resource Management Act to consider the areas of greatest environmental benefit when targeting its resources.

*Sawmills and timber treatment sites*

Radiata pine is the dominant timber tree in New Zealand. Being a softwood, it is prone to attack by fungi and insects after felling. Sapstain fungi can discolour the timber surface while other fungi and wood-boring insects can cause decay. Chemical treatment is one of the methods used to protect the timber, though kiln-drying is increasingly used as a non-chemical preservation technique for indoor timber.

The main chemical preparations are anti-sapstain fungicides which are applied to the timber surface immediately after milling, and a range of preservatives which can provide varying degrees of long-term protection. Preservatives in common use since the 1970s include boron (an insecticide), LOSP (an insecticide which is applied as a light organic solvent preparation) and CCA (a heavy metal formulation of copper, chromium and arsenic which acts as a dual insecticide and fungicide).

The first timber preservative used earlier this century was creosote derived from coal tar. With the invention of organochlorine pesticides in the late 1940s and 1950s sawmills made widespread use of pentachlorophenol (PCP) to combat sapstain fungi. Some also mixed PCP with diesel oil for use as a preservative. The mixture was applied under pressure to force it into the wood fibres. Another organochlorine, chlordane, was used in the glue of some manufactured wood products (e.g. plywood), especially those intended for use in tropical regions. Significant use of these organochlorines in timber treatment ceased in 1988 and they were formally deregistered for these purposes by the end of 1991.

Soil contamination has probably occurred to a variable extent at many of the nation's 600 sawmill and timber treatment sites, some of which have now ceased to operate. Contamination would generally have been caused by the cumulative effects of drips, leaks, spills and waste disposal practices during an era when less emphasis was placed on the containment of potentially hazardous chemicals. Contamination tended to occur around treatment and storage areas, and appears to be largely confined to the top 30 cm of soil except possibly in some porous soils (McLaren, 1992; Armishaw *et al.*, 1993; CMPS&F Ltd, 1995). PCP contamination down to 5 metres is known from at least one site (Royds Garden Environmental Services/CMPS&F, 1994). In some cases, water run-off took contaminants to adjacent land, or into waterways and estuaries (Wilcock *et al.*, 1989; Shaw, 1990; Ministry for the Environment, 1992b).

PCP was used by some 70 percent of New Zealand's 400 operating sawmills between 1950 and 1988 (Bingham, 1991a, 1991b). It was also used to a lesser extent in the paper industry, the cultivation of mushrooms and the control of slimes in cooling waters (Shaw, 1990). On 31 December 1991 PCP was deregistered for use as a pesticide and prohibited from importation following confirmation that it contained toxic impurities (dioxins and furans) (Bingham, 1991b).

A National Task Group was established in 1991 to investigate potential site contamination problems (Ministry for the Environment, 1992a). The Group undertook a pilot risk assessment study of the timber processing complex at Waipa, near Rotorua, where PCP had been used over four decades. Significant contamination was found in the vicinity of treatment areas and in associated building dust. The groundwater discharging into the local stream contained high levels of PCP and the contaminants were found at elevated levels in the sediments and biota of Lake Rotorua (CMPS&F Ltd, 1992).

Following the Group's report, a National Steering Committee was established to facilitate actions at national and regional levels among government agencies and industry (Ministry for the Environment, 1993a). A major task carried out by the Committee was the preparation of guidance for the assessment and management of potentially contaminated sites, including the development of clean-up criteria (Ministry for the Environment and Ministry of Health, 1993). Recent initiatives have included:

- removing contaminated dust and intercepting and treating contaminated groundwater at Waipa (Forestry Corporation of New Zealand, 1993);
- producing a code of practice for the safe use of timber preservatives and antisapstain chemicals (Occupational Safety and Health Service, 1994);
- assessing contamination at a former sawmill site in Hanmer Springs (Royds Garden Environmental Services/CMPS&F, 1994);
- investigations by timber industry owners of a number of sawmill sites; and
- a collaborative effort between the timber industry, government and technology developers which is currently undertaking treatability trials on soils contaminated with PCP and dioxins.

#### *Service stations and oil storage terminals*

Although no published studies exist on the extent of contamination at or near service stations, the sheer number of sites (about 2,600) and the opportunities for spillage and seepage make it likely that petroleum products are a major source of soil contamination. Guidelines have been developed to deal with the hazards associated with storage tanks (Occupational Safety and Health Service, 1992, 1995) and the industry has embarked on an underground storage tank replacement programme. In addition, a set of guidelines for service stations is being prepared by industry, regional councils and central government to give clear guidance on site assessment, management and clean up procedures.

One oil company commissioned an investigation of fifteen bulk storage oil terminals, some of them now closed, to assess baseline contaminant levels (Tonkin & Taylor Ltd 1995). All were built on superficial soil deposits (alluvial and estuarine sands, silts and clays) which, in some cases, were overlain by fill materials. Groundwater at these sites is 2 to 5 metres below ground level. The larger sites date from the 1930s, but have been upgraded with lined tank compounds, improved tank foundations in earthquake sensitive areas, and spill control measures. Contamination was mostly limited to areas associated with separators, drum filling, washing and storage operations, and loading and unloading racks for road tankers and rail cars. No significant off-site environmental and human health risks were identified.

*Gas works*

New Zealand has over 50 redundant town supply gas-works sites. Based on overseas experience, soils and groundwater at these sites are likely to be contaminated by polyaromatic hydrocarbons (PAHs), phenols and sometimes heavy metals. For example, in Napier, cyanide was found on neighbouring properties where contaminated waste from the gas works had been dumped many years before. Clean-up requirements are generally dominated by the cancer-causing chemicals, such as certain PAHs and some heavy metals.

No single remediation technology appears capable of coping with the full range of contaminants, so clean-up efforts to date have relied heavily on removing contaminated material to landfills and on site management procedures to minimise exposure to contaminants. The need for national guidelines was raised following site investigations at Masterton, Wellington, Gisborne, Hamilton, and Napier. The Ministry for the Environment is now developing guidelines to assist the assessment and management of these sites.

*Mining sites*

The mining industry produces large quantities of waste rock which often contain heavy metals. An estimated 92 sites, most of them no longer being mined, may be contaminated (Ministry for the Environment, 1992b). Nearly 80 percent of these are in just five regions—Otago, Southland, the West Coast, Waikato and Northland. The soil and water surrounding some abandoned and non-working mines often have elevated heavy metal levels. The barren four hectare Tui mine site near Te Aroha, for example, was used from around 1900 to 1973. Heavy metals, such as mercury, lead and zinc leach intermittently from the 100,000 tonne tailings dam above the site and have contaminated water and soil (Ministry for the Environment, 1992b; Morrell *et al.*, 1995).

Mines that are currently operating are closely controlled by requirements under the Resource Management Act, though some are still struggling to resolve earlier mistakes. For example, the huge tailings dam at the Golden Cross mine near Waihi is now known to be on land that is unstable below the surface. The dam holds 3 million tonnes of rock dust mud containing arsenic, cadmium, copper and other metals. Efforts have been made to stabilise the slope and investigations are now taking place into the possible relocation of the tailings.

At the nearby open-cast Martha Hill goldmine efforts to minimise long-term impacts include the restoration of vegetation cover to tailing piles and oxidised waste mounds. So far, 16 hectares have been restored to productive pasture (Mason *et al.*, 1995). The mine's waste water discharges are treated to keep heavy metals traces below the maximum concentration recommended at that time in the Health Department's pre-1995 standards for drinking water (Barker and Hurley, 1993).

*Pesticide manufacture*

About a dozen pesticide manufacturing sites exist in New Zealand. Little information has been published on the scale of land contamination associated with them. One exception is a disused site in the small coastal town of Mapua, on the Waimea inlet near Nelson. Various pesticides and agricultural chemicals were manufactured and formulated there from 1945 to 1988 by the Fruitgrowers Chemical Company.

Extensive soil sampling revealed widespread contamination by DDT (and breakdown products such as DDE) and more localised contamination by dieldrin (Woodward-Clyde Ltd, 1994). Although no soil samples from the neighbouring Tasman District Council landfill were analysed, the area is assumed to be contaminated because of the history of waste dumping from the chemical sites. Samples from wells show that groundwater is significantly contaminated by pesticides, sulphur, and chlorobenzene. Stormwater analysed in 1993 was contaminated by several organochlorines, organophosphorus pesticides, cadmium, copper, lead, selenium, and zinc.

The stormwater run-off from the Mapua site is considered to be the major cause of the organochlorine contamination in the nearby tidal waters. Organochlorine-contaminated sediment fans out onto the sea-bed and shoreline on both sides of the Mapua site (Fenemor and McFadden, 1996).

The concentrations of the organochlorines and heavy metals in the soils, groundwater, shoreline and seabed sediment, and the tidal water generally exceed acceptable limits. DDT levels in shellfish are many times higher than the acceptable limit, and birds such as bitterns and banded rails, which were once a common sight pecking at the shellfish on the mud flats, have disappeared.

Efforts by the Tasman District Council to coordinate a clean-up of the site were hampered by the extent and severity of the contamination, and by questions of liability because ownership of the site and landfill was in different hands. The Council inherited the landfill, and two companies, Ceres Pacific and Mintech, both owned portions of the original site. In June, 1996, the Minister for the Environment announced that the Government would contribute $1.2 million towards the estimated $2.75 million cost of the Mapua clean-up.

The clean-up operation will seal off both the soil and groundwater on the contaminated site, and prevent continued contamination of the stormwater. A diversion system will be built to redirect groundwater away from the site and the contaminants there, the site will be capped with asphalt to prevent rainwater infiltration, the existing stormwater system will be removed, and the buildings on the site will be either taken away for decontamination, or destroyed. Forty tonnes of chemicals, which had been stored in 250 drums in a locked concrete shed in a fenced off area of the Mapua site, were taken to a secure storage facility at Gracefield, near Lower Hutt, in May 1996 to be held there until the development of an acceptable way of disposing of them, or rendering them safe.

*Dieldrin dump sites*

Dieldrin is an organochlorine which was withdrawn in the 1960s. In 1961 its use as a pesticide was banned in sheep sprays and dips—along with aldrin, DDT, BHC and methoxychlor. In 1966 its use to control pasture pests such as black beetle and grass grub was also banned. Surplus stocks of the banned pesticides, estimated at 530 tons, were collected from farms around the country by the Department of Agriculture and stored in a number of depots. By March 1963, they had been placed in regional storage centres. By February 1964, approximately 165 tons had been redistributed to land development blocks in Northland, Hawkes Bay, Rotorua, North Canterbury, Canterbury and Southland to be aerial sprayed on pasture (Gibbs 1992).

Some, but not all, of the surplus pesticides were exported from New Zealand in late 1966. What happened to the remainder is still largely a mystery because, although some storage and dump sites have been located, the files and records for most of them seem to have been lost (Loe, Pearce & Associates, 1993, 1994). Where storage and disposal sites have been found, some decontamination activity has been undertaken (Taranaki Regional Council 1993). Contaminated soil and dust have been found at some former storage centres, including four Canterbury sites where the original buildings are still standing (Tonkin and Taylor Ltd, 1994a). A fifth Canterbury site is now covered by a shopping mall. Buried and rusting pesticide containers and evidence of some soil and groundwater contamination have been found at two dump sites in the Southland region (Woodward-Clyde Ltd, 1993b).

*Agricultural land*

Contamination of rural soils can arise from pesticide and fertiliser residues in fields and orchards, and from chemical spillage and leaching at “hot spots” such as pesticide and fuel storage areas, animal dip and dosing sites, and on-farm landfills. While no area is known to have contamination which is both severe and extensive, soils on some Canterbury and Southland farms have elevated levels of DDT and DDE which require ongoing management, and some farms throughout New Zealand have cadmium concentrations higher than the natural background levels, though still low by international standards (Roberts *et al.*, 1994; Furness, 1996a, 1996b).

In addition, although the number of potentially contaminated rural sites has not been formally assessed, there may be as many as 1,000 storage and dump sites containing unwanted pesticides and herbicides and a further 1,000 private and farm landfills (Ministry for the Environment, 1992b). New Zealand may also have several thousand contaminated sheep and cattle dip sites if the Australian example is any guide. A large number of Australian dip sites that were used before 1965 have high DDT and arsenic concentrations (Ministry for the Environment, 1992b).

Organochlorines

From the 1940s until the 1970s, persistent organochlorines were heavily used in New Zealand agriculture (see Box 8.6 and Table 8.13). DDT was mixed with fertiliser and applied to pasture in a bid to control grass grubs and porina caterpillars. It was also used on lawns and market gardens, parks and sports fields. Its use was restricted in 1970 and was finally banned in 1989. DDT has a half-life of 10 years in dry soils, but its main residue, DDE, is far more persistent, showing little change in soil levels over 20 years.

**Box 8.6**

### *Organochlorine contamination*

Organochlorines are chemical compounds which contain both carbon and chlorine atoms. Carbon and chlorine are versatile atoms which can combine with many others to form a wide range of molecular structures. At least 1,500 organochlorines are found in nature—more than 100 occur in wood smoke (Abelson, 1994a). Yet this is a small number compared to the 60,000 or so synthetic organochlorines that have been created in laboratories over the past 50 years.

Most organochlorines break down quickly into non-toxic residues which are dissipated in the environment. A small number, however, are highly persistent or long-lived (e.g. DDT, DDE, PCBs, PCP, HCBs, dioxins, chlordane, lindane, aldrin, dieldrin). Some of these can kill or cause illness in fish, birds or mammals (see Table 8.13). Overseas research has also linked high concentrations of organochlorines to reproductive abnormalities and immune deficiencies in a number of species, though the interpretation of such data is still controversial (Addison, 1989; Tanabe, 1994; Motluk, 1995; Sharpe, 1995). Even more controversial are claims that low organochlorine concentrations can have similar effects through prolonged exposure or through a combined 'cocktail' effect (Colburn *et al.*, 1996; Wilkinson and Dawson, 1996). The impacts of low to moderate doses on human health are still being debated as researchers investigate their effects on mammalian reproduction, hearing, thyroid function, and cancer susceptibility (Abelson, 1994a, 1994b; Stone, 1994a, 1994b, 1995; Dibb, 1995).

The persistent organochlorines were widely used in many countries between 1940 and 1980 in a variety of products such as: insecticides (e.g. DDT, aldrin, chlordane, dieldrin, lindane), fungicides (e.g. PCP) and electrical transformers and capacitators (i.e. PCBs). Some organochlorines, such as the dioxins (PCDDs) and furans (PCDFs), were created as waste byproducts in the manufacture of other organochlorines. All of these left residues in the environment. Western industrial countries stopped manufacturing many of the persistent organochlorines in the 1970s. Since then, their presence in the environment has fallen to a tenth or less of their former levels. Even so, the traces linger on. Most of us still have low but detectable amounts of DDE, a breakdown product of DDT, in our bodies. PCP and dioxin residues have been found at some New Zealand sawmill sites, and dieldrin residues have been found at former storage and dump sites. New Zealand also has a small number of farms and other sites where soils have elevated organochlorine pesticide residues.

Compared to many northern hemisphere countries, however, the New Zealand environment probably has low organochlorine levels. A recent world survey of 22 different organochlorine compounds in tree bark found generally low concentrations (less than 100 parts per billion) at the three New Zealand sites sampled, though moderate concentrations (100 to 1,000 ppb) of DDT, chlordane and dieldrin were found at one of the two South Island sites (Simonich and Hites, 1995). The Ministry for the Environment has initiated a three year programme to deal with dioxins and other organochlorines of concern, including PCBs, PCP, DDT and dieldrin. Human and environmental data will be collected to establish background levels and assess the significance of any ongoing emissions. The programme will develop National Environmental Standards and guidelines for these substances and appraise the suitability of clean up technologies.

**Table 8.13**
**Organochlorine toxicity and half-lives.**

| Organochlorine pesticide | Acute toxicity to rats (LD-50) (mg/kg) | Toxicity to fish (rainbow trout) (μg/l) | Half-life (time needed for 50% decay) On the surface | In the soil |
|---|---|---|---|---|
| *Aldrin* | 67 | 2.6 | 1-18 days | 5 years |
| *Chlordane* | 250 | 42 | 27-72 days | 5.7-10.6 years |
| *DDT* | 250-300 | 8 | 1 year | 10.5 years |
| *Dieldrin* | 40-87 | 1.2 | 2-26 days | 2.2-11.4 years |
| *Lindane* | 88-125 | 30 | 1-5 days | 0.5-2 years |

*Source: Bingham (1992)*

Relatively low levels of DDT residues are widespread in regions where grass grub and porina are significant pasture pests (Wilcock and Watts, 1993; Roberts *et al.*, 1996). In parts of Canterbury and Southland, paddocks on some farms are still unsuitable for livestock or dairy production because of the DDT residue levels. Soil samples from Canterbury have shown an average DDT residue concentration of 0.27 mg/kg, with wide variation among districts, farms and individual paddocks. The percentage of soils with concentrations above 1 mg/kg was 20 percent in Mid-Canterbury but only 2–4 percent in North, Central, and South Canterbury (Morton and Butcher, 1990).

These residues do not affect crops but may occasionally find their way into meat and dairy products when grazing animals eat soil with their grass. The amount of ingested soil increases in dry periods when grass is shorter and sparser. Residue sampling of Canterbury lambs in drought years during the 1980s found that nearly 40 percent had DDT residues above the European Union's permitted limit, though still within the New Zealand safe tolerance limits (MacIntyre *et al.*, 1989).

A national meat and dairy product monitoring programme run by the Ministry of Agriculture ensures that export products contain low levels of these residues. The 1993/94 monitoring programme tested the fat tissue of 1,206 animals for organochlorines. It found that 656 (54 percent) had low levels of DDE and 17 (1 percent) had trace levels of DDT. However, only one animal exceeded the DDE tolerance level, and none exceeded the DDT level.

The new forms of pesticides made since the mid-1980s are designed to break down quickly, but very little is known about their residue levels in New Zealand soils and their effects on soil organisms. The newer pesticides are also more water-soluble than their fat-soluble predecessors, and thus more likely to move out of the soil into groundwater or surface water courses (Clough & Hicks, 1992).

#### Heavy metals

A survey of heavy metal contamination in pastoral soils was conducted in the early 1990s (Roberts *et al.*, 1992b, 1994). A total of 312 farm sites were sampled in both the North and South Islands. Samples were also collected from 86 natural sites to assess background levels. Five heavy metals were investigated—arsenic, cadmium, copper, lead and zinc (see Table 8.14). Only one of the five, cadmium, was present at elevated levels, though the concentrations were well below the level identified as warranting further investigation (ANZECC/NHMRC, 1992).

At high concentrations, cadmium is a particularly toxic heavy metal, accumulating in the body's tissues and organs, particularly the liver and kidney. Cadmium levels recorded to date do not appear to represent a threat to soil or animal health, but their accumulation in the kidneys and livers of sheep and cattle, particularly older animals, may reach levels exceeding tolerance limits for export markets. As a simple and practical precaution, offal from animals older than 2.5 years is not exported nor sold in New Zealand.

In New Zealand, the cadmium concentration in pasture soils is associated with the use of superphosphate fertiliser. Superphosphate is made from phosphate rock much of which is imported from the island of Nauru. It has natural cadmium concentrations ranging up to 100 milligrams per kilogram (mg/kg), and averaging around 48 mg/kg (Rothbaum *et al.*, 1986; Taylor, 1994). As a consequence, all of New Zealand's agricultural land has received cadmium in direct proportion to the amount of fertiliser applied.

Cadmium has been found to accumulate less in sedimentary soils and more in ash and pumice soils (which tend to bind strongly with phosphorus and therefore have a higher requirement for phosphatic fertilisers). On this basis, much of the central North Island, including Taranaki, Waikato, Bay of Plenty and parts of Gisborne and Hawkes Bay, as well as parts of Northland and Southland would be expected to show elevated levels.

A survey of cadmium accumulation in crops was conducted in South Auckland's prime market garden belt and on mid Canterbury wheat farms (Roberts *et al.*, 1995). It found that cadmium levels were very low. For example, lettuce, potatoes and onions had less than 5 percent of the permissible level and wheat had only 7 percent. This corroborates Ministry of

Health findings that the levels of cadmium in the average New Zealand diet are well below the maximum intake recommended by world health authorities and appear to be declining (van Oort *et al.*, 1995b). For females, the cadmium intake was 24 percent of the tolerable level and, for males, it was 29 percent.

At present, the cadmium situation in New Zealand appears to be well managed and measures are in place to ensure it stays that way. Besides the Ministry of Health's food monitoring programme and the withholding of older offal from sale, the members of the fertiliser industry group are also taking steps. The fertiliser industry initially decided to progressively reduce the level of cadmium in fertiliser by a third from the year 2000, but recent technical advances have enabled the reduction programme to get underway in 1997 (Furness, 1996a, 1996b).

Another potential source of heavy metal contamination in rural soils is the use of copper and arsenic compounds to control fungi in orchards and vineyards. Orchards have not been systematically surveyed, but a study in Central Otago found that average concentrations in old orchard soils were above the draft New Zealand guideline of 100 milligrams per kilogram (mg/kg) (Ministry for the Environment and Department of Health, 1992; Morgan and Bowden, 1993). The copper levels were much higher in the orchard soils than in nearby pasture soils (106 mg/kg, compared to 20–30 mg/kg).

In many countries, the major source of heavy metal contamination in agricultural soils is sewage sludge. Sludge spreading is a recent practice in New Zealand. Department of Health guidelines were published in 1992 to control the composition of sludge for land application and prescribe the amounts and method of application. New Plymouth seems to be the only place in New Zealand where sewage sludge is applied to agricultural land, though in some other districts it has been spread, on a trial basis, under planted pine forests.

**Table 8.14**
**Average concentrations of heavy metals in New Zealand rural soils (mg/kg).**

| Sites | Arsenic | Cadmium | Copper | Lead | Zinc |
|---|---|---|---|---|---|
| *Pastoral soil* | 4.9 | 0.44 | 17.7 | 11.7 | 68 |
| *Natural soil* | 4.3 | 0.19 | 17.0 | 13.3 | 65 |
| *ANZECC guideline*[1] | 20.0–100.0 | 30.00–20.00 | 60.0 | 300.0 | 200 |
| *NZ draft guideline*[2] | 10.0 | - | 30.0–100.0 | - | - |

*Source: Roberts et al. (1995)*

1 *These levels warrant investigation but are not necessarily harmful. Where a range is given, the lower level warrants environmental investigation while the upper level warrants health investigation (ANZECC/NHMRC, 1992).*

2 *These draft guidelines show acceptable soil concentrations in agricultural soils only. The limits for residential and industrial sites are higher (Ministry for the Environment and Ministry of Health, 1992).*

### The state of the vegetation cover

The dramatic vegetation changes of the past 150 years have permanently altered New Zealand's landscape and ecology. Most of the natural land-cover and all the exotic land-cover are ecologically unstable (that is, unable to maintain their current mix of plant and animal species without human intervention). A degree of 'cultural' stability has been imposed on much of this land-cover through measures such as pest and weed control, soil conservation programmes, crop and pasture management, ecosystem protection, and species recovery programmes (O'Connor, 1973). But many areas remain neither ecologically nor culturally stable.

#### *The state of our indigenous forests*

Indigenous forests are now largely confined to remote mountainous areas or to lowland fragments. About 60 percent of the surviving indigenous forest is on land with no agricultural potential, approximately 30 percent is in hill country and rangelands with very limited potential, and less than 10 percent is in low-lying areas with good agricultural potential.

The largest remaining stretches in the North Island are in the Kaimai, Urewera and Raukumara ranges, inland Taranaki, the King Country, Mount Taranaki/Egmont, and the Ruahine, Tararua and Rimutaka Ranges. The remaining South Island forests are mainly in the Marlborough Sounds, Westland, Fiordland, the Catlins and Stewart Island.

The forests most affected by deforestation were the kauri and the lowland podocarp-hardwoods. The kauri forests were reduced from a pre-European area of around 1.5 million hectares to just 7,000 hectares of mature forest (a 99.5 percent reduction) with a further 60,000 hectares left to regenerate after logging (Froude *et al.*, 1985). The lowland podocarp-hardwood forests were reduced by about 85 percent. Most of the 15 percent that remain are on private land, and only a small proportion are protected. Kahikatea forests were especially affected. Only 2 percent of these wetland podocarps are believed to remain. They were made into scent-free butter boxes for export while their wetland habitats were drained to create more pasture and ultimately more butter.

In general, beech forests were less affected because of their remoter locations and lower timber quality. Beech trees yield less timber than softwoods and are often riddled with small holes created by the native pinhole borer beetle which lives inside them. Upland beech forests were left virtually intact, though lowland beech forests in many areas were cleared for farmland. Chipmills accelerated this clearing process in Southland and Nelson during the 1980s and early 1990s, but this has reduced considerably since the introduction of export control regulations and the passing of the Forests Amendment Act in 1993.

Virtually all of the estimated 4.9 million hectares of publicly owned indigenous forest are now administered by the Department of Conservation. Only 164,000 hectares are not administered by the Department and are available for timber production—152,000 hectares on the West Coast and 12,000 hectares in Southland. The West Coast production forests contain 102,000 hectares of mature loggable forest, 41,000 hectares of regenerating cutover forest, and 9,000 hectares of cleared forest which is being replaced with exotic Tasmanian blackwoods.

The area of private indigenous forest is estimated to be about 1.32 million hectares (Ministry of Forestry, 1988, 1994a). Half of this is on steep land which is not considered loggable for soil and water conservation reasons. A further 40 percent is regenerating from previous logging. Only 124,000 hectares (9 percent) carries mature, harvestable, trees, and even this may be an overestimate because a number of forest owners have recently entered voluntary protection arrangements funded by the Government's Forest Heritage Fund and Nga Whenua Rahui.

A further constraint on logging is the fact that, although private forest owners are still free to clear their forests for farmland or other land uses, logging for timber production is now subject to the indigenous forest provisions of the Forests Act 1949, as amended by the Forests Amendment Act 1993. These require most private timber production after 1996 to be from forests with an approved sustainable management plan or permit. Regenerating forest scrub is still being cleared for dairy production in some areas, but logging and burning are now relatively minor threats to the remaining indigenous forest.

Far greater are the impacts of the browsing mammals, possums, goats and deer, and also invasive plants, such as old man's beard. These attack the forests from within, changing their composition and reducing their biodiversity. This has caused canopy dieback, forest collapse and regeneration failure in increasingly large tracts of native forest (Rogers, 1995).

The few remaining areas of lowland forest also face an additional threat— fragmentation. Having become ecologically isolated as 'forest islands' in a sea of farmland these areas have no adjacent habitat from which to replenish lost populations or species. Their vulnerability is enhanced by the 'edge' effect which increases their exposure to invasive pests and weeds. Because the perimeter, or edge, is relatively large compared to the small habitat area within, exotic species can invade and penetrate fragmented ecosystems more easily than they can invade larger intact stands. The inexorable result is a decline in biodiversity within each forest fragment (Diamond, 1984; East and Williams, 1984; Kruess and Tscharntke, 1994).

***The state of our tussock grasslands***

The forest fires which raged between 400 and 700 years ago, allowed the tussock to spread from around 1.5 million hectares to almost eight million hectares, or 30 percent of the land surface (see Figure 8.3). While this enormous landscape change had a dramatic impact on forests, soils and biodiversity, its positive feature was that it allowed an expansion in the previously restricted populations of alpine plants and insects.

Most of this expansion occurred in the South Island high country, where tussock replaced **mixed podocarp forests**, comprised of matai, totara and kahikatea, and **open dry forests**, containing a great deal of lacebark, kowhai, kanuka and scrub. In the interior, mountain toatoa, totara and scrub species may have been the major vegetation in drier areas. In the North Island the change was most marked on the central plateau which, today, is traversed by the Desert Road and is home to the Army and a thousand or so wild horses. After repeated burn-offs, the forest cover surrounding the volcanoes and Lake Taupo was replaced by 660,000 hectares of tussock grassland.

Since European settlement, the total area of tussock land has decreased towards its original size, though the precise extent of this is partly a matter of definition (see Box 8.7). What can be stated with some certainty is that very little unmodified tussock land exists, as virtually all of it has been burnt many times, and most has been grazed as well. Nearly all the remaining tussock is in the South Island high country, stretching from Southland to Marlborough. The once widespread red tussock grasslands of Southland have all but disappeared, leaving only a few small remnants. The North Island has only about 150,000 hectares of tussock, half of it red tussock in the central plateau.

The reduction in tussock area has been accompanied by a much greater decline in tussock biomass. The attempt to create short pasture for sheep has led to short tussock replacing tall tussock in many areas, followed by a decline in short tussock growth and abundance due to soil degradation, oversowing with other grasses, and the invasion of the stress-resistant herbs, scabweed and hawkweed (see Box 8.8).

Tall tussock grasslands in an undisturbed state are naturally resistant to hawkweed invasion, but not to fire and grazing (Kerr, 1991). Hawkweed is not restricted to semi-arid areas. Some of the worst affected tussock lands are in relatively moist range lands with more than one metre of rainfall (e.g. the Clarence Valley in Marlborough). Again, this is land which in the past has been subject to repeated burning and heavy grazing pressure from sheep and rabbits (see Figure 8.10).

Although no native plants are known to have become extinct in the South Island tussock lands, many of the herbs, flowers and fine grasses normally associated with tall tussock have been displaced by short tussock and hawkweeds (Treskonova, 1991). Some species are on the brink of extinction and others are confined to very restricted locations (Working Party on Sustainable Land Management, 1994).

**Box 8.7**

***How much tussock land?***

Although tussock grasslands have clearly declined in the past 150 years, there is some confusion over how much remains today. Some writers give the impression that the surviving tussock lands are limited to the 2.45 million hectares of leased pastoral land in the South Island high country. One widely quoted estimate puts the area at 2.75 million hectares (McSweeney and Molloy, 1984). Other writers seem to suggest that tussock predominates throughout the entire high country, an area spanning some 6.3 million hectares (Working Party on Sustainable Land Management, 1994).

The main database for assessing the national area of tussock land is the New Zealand Land Resource Inventory 1975-79 (NZLRI)(Hunter and Blaschke, 1986) whose vegetation data was updated and mapped in *The Vegetative Cover of New Zealand* (Newsome, 1987). A separate assessment of the North Island tussock grasslands was recently undertaken by Rogers (1994). According to the NZLRI, tussock is the 'major' vegetation cover over some 5 million hectares, and a 'minor' part of the vegetation over some 3 million hectares (Hunter and Blaschke, 1986). The vegetation cover map tells a more detailed story. Tussock is listed as a component of at least 10 different vegetation groupings spanning a total of 10 million hectares. Actual tussock grassland makes up a third of this, while the other vegetation categories include tussock in association with other species. In many cases, the tussock has a minor or intermittent presence. The main categories and approximate areas can be grouped as follows:

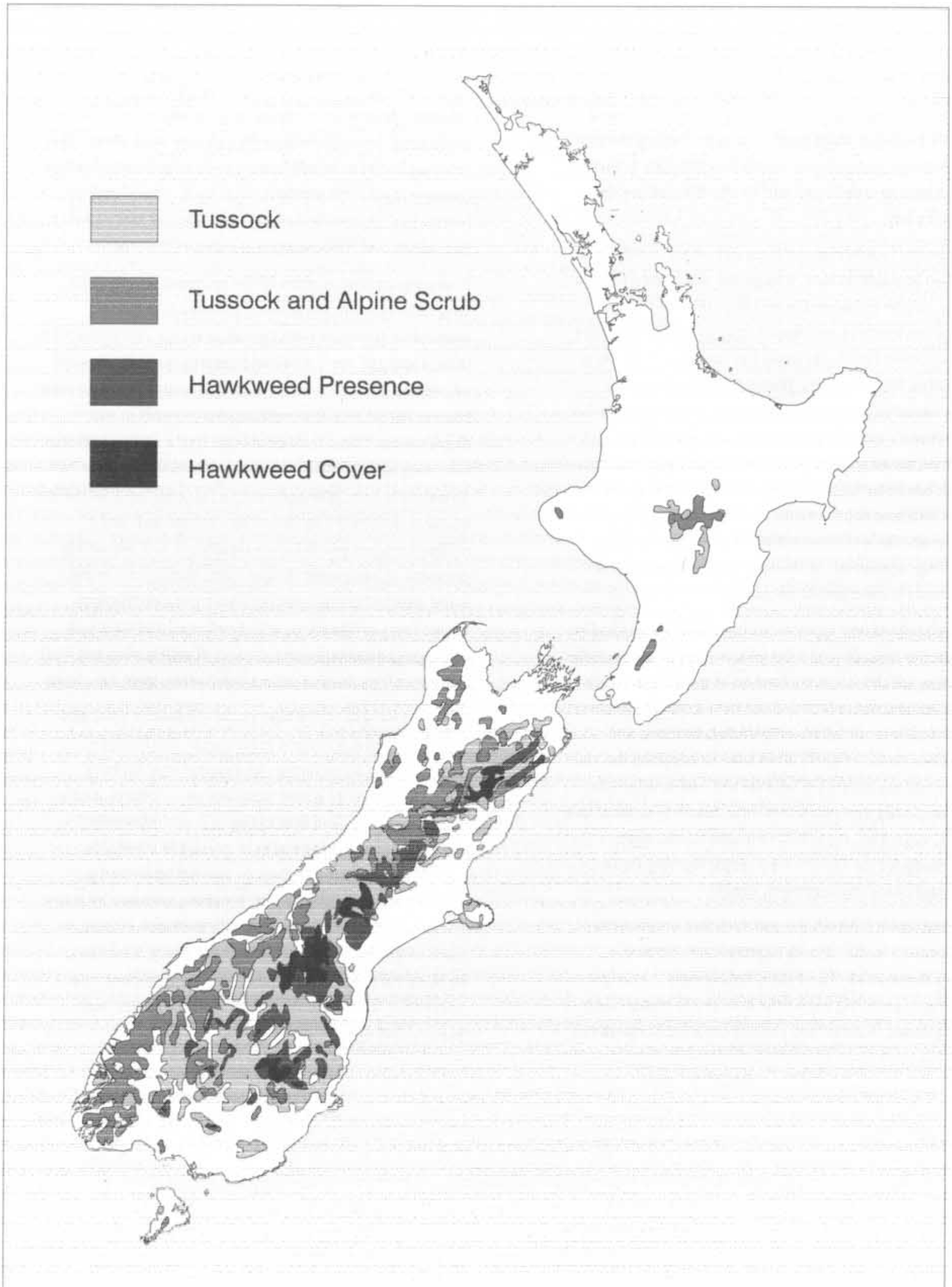
- 3.3 million hectares of 'predominant' tussock grassland in which short or tall tussocks are the largest and most abundant plant cover (though significant areas are now hawkweed-dominated or interspersed with exotic grasses);
- 1 million hectares of tussock and sub-alpine scrub;
- 900,000 hectares of 'unimproved' pasture in which short tussocks occur in mixed communities of exotic grasses and weeds;
- 110,000 hectares of mixed forest and tussock; and
- 4.7 million hectares of intermittent or scattered scrub (e.g. matagouri, sweet brier, manuka and kanuka, gorse, *Dracophyllum* and *Cassinia*) in which tussock is sometimes a component.

Nearly all of this area has been modified by burning, grazing and related land pressures. Less than 80,000 hectares, barely 2 percent of the 'predominant' tussock grasslands, are in the care of the Department of Conservation. The Department also administers nearly 650,000 hectares of mixed sub-alpine tussock and scrub and is acquiring additional small blocks of tussock through consultation with individual land-owners.

A number of tussock-dwelling animals have disappeared, such as the weka, several reptiles and several invertebrates. The spread of the exotic grass, browntop, in the area near Cass has reduced the amount of tussock and herb cover and caused a dramatic fall in the populations of many native moths (White, 1991). Although no moth species has yet disappeared, extinctions seem inevitable if the exotic grasses continue to spread at the tussock's expense.

In the North Island's central plateau, at least one native plant (*Logania depressa*) has become extinct. The red tussock itself continues to retreat under pressure from wild horses, military exercises, rabbits and a host of invasive exotic plants, including *Hieracium*, wilding lodgepole pines (*Pinus contorta*) and heather (*Calluna vulgaris*) (Newsome, 1987; Rogers, 1994). The heather was introduced from Europe and deliberately sown in the Tongariro National Park from 1912 to 1921 with the aim of 'beautifying' the tussock and creating a suitable habitat for introduced game birds. Today it is a serious nuisance, its spread having been aided by fire and other forms of vegetation disturbance, particularly near roads, tracks, and in the military area off the Desert Road (Moller *et al.*, 1993).

**Figure 8.10**
**The South Island tussock lands and main areas of hawkweed infestation.**




*Sources: Newsome (1986), Parliamentary Commissioner for the Environment (1991)*

**Box 8.8**

### *The razing and grazing of the native grasslands*

After quintupling in area during the period of Maori forest burning, New Zealand's tussock grasslands have been in retreat since the 1850s when European settlers arrived with their merino sheep. The new grazing and burning regime killed off the snow tussock over large areas and allowed the more palatable short tussock to spread above the 900 metre contour. Subsequent oversowing of exotic grasses and invasion by rabbits and and weeds reduced the short tussock as well.

Today, nearly four million hectares of tussock country are classified as pastoral land, though the actual area used for grazing may be considerably less than this. In the 1970s, 2.85 million hectares was leased to 475 runholders by the Office of Crown Lands. By 1990, the number had fallen to 349. Today, approximately 360 runholders lease 2.45 million hectares, with nearly half a million hectares having been 'retired'. Where soil and moisture levels have permitted, about 20 percent of the remaining pastoral tussock has been 'improved' by introduced grasses and regular fertiliser applications. The rest has experienced soil degradation and competition from ground-hugging weeds (e.g. scabweeds in the 1930s, Nasella grass and hawkweeds in more recent decades).

Although rabbits and hawkweeds have been named as the cause of the tussock land's decline, scientists now consider that these species are symptoms or, at worst, secondary causes, of land degradation. They have generally become established in areas where overgrazing, burning, and insufficient fertiliser application have so depleted the soil and the tussock cover that only rabbits and hawkweeds, which originally evolved in semi-arid conditions, can thrive (Belton, 1991; Kerr, 1991; O'Connor and Harris, 1991; Commission for the Environment, 1991; Working Party on Sustainable Land Management, 1994).

Repeated rabbit infestations and declining productivity have occurred in the tussock pasture lands for over a century. Between 1877 and 1881, for example, 77 Otago sheep runs, spanning more than 600,000 hectares had to be abandoned. Further bad periods occurred in the 1890s, after stock units peaked at around 2 million, and the 1940s, when they had declined to one million. An apparent turn-around began in the 1950s as government funding and the new technology of aerial topdressing made it possible to 'improve' pasture by dropping large quantities of fertiliser, grass seed, and poisoned rabbit bait over wide areas. The resulting increase in soil fertility encouraged runholders to increase their stock numbers once more. Stock units reached an unprecedented 2.5 million by the late 1980s. But rabbits and hawkweeds were also on the rise.

It now seems that, in spite of the apparent recovery, the long term trend for the tussock grasslands is one of inexorable decline in both species diversity and production (Kerr, 1991). Of the 3.9 million hectares currently classed as pastoral tussock land, at least two million hectares have been modified by either pasture improvement or soil degradation. These include at least half a million hectares oversown with introduced grasses (Working Party on Sustainable Land Management, 1994), a further half million hectares dominated by hawkweed or bare soil, and 1 million hectares which have a significant and increasing presence of hawkweed (Belton 1991; Kerr, 1991). In the worst affected areas, covering about 200,000 hectares, desertification threatens, with hawkweed and bare soil completely dominating the ground, allowing wind and frost to produce high rates of soil erosion (Belton, 1991; Kerr, 1991).

Positive changes in the high country between 1989 and 1994 included a 9 percent reduction in stock units - 50 percent on some farms - an expansion of farmers' self-help groups (e.g. the 'landcare' programme), and a five year Rabbit Land Management Programme which reduced the percentage of bare ground in a 300,000 hectare area from more than 50 percent to around 30 percent. Such developments, however, are seen by many scientists as insufficient to sustain livestock grazing in much of the South Island tussock land (e.g. Kerr, 1991; Working Party on Sustainable Land Management, 1994). Alternative land uses now being considered are exotic forestry and nature conservation.

The central plateau's 660,000 hectares of tussock were nearly halved to 310,000 hectares between 1840 and 1940. Sheep and rabbits had much the same effect as in the South Island tussock lands. Rabbit plagues in the 1920s and 1930s, combined with burning, caused substantial deterioration. This, and also large sheep losses to feral dogs, led to the abandonment of sheep farming in much of the area between 1917 and 1939 (Rogers, 1994).

In the years since then, recurrent burning of tussock for shrub suppression, fodder improvement, and control of wilding pines, plus feral horse grazing and accidental fires caused by military activities, have led to most of the remaining red tussock being replaced by exotic grasses and weeds (e.g. hawkweed). Today, 64,000 hectares survive —10 percent of the North Island's pre-European tussock area—of which about 7,000 hectares are protected (Rogers, 1994).

### *The state of our dunelands*

Few dunelands bear much resemblance to their original state because of the impacts of stock grazing, introduced plants, sand mining for iron and silicon, and dune-control planting (Newsome, 1987). The original foredunes were home for the native sand-binding plants, pingao and spinifex, and covered a total area of perhaps 60,000 hectares (King, 1984). The backdunes were covered in native scrub and forest.

Today, some 52,000 hectares of foredunes still carry sand-binding grasses and sedges—but, in most cases, it is the exotic marram grass which dominates. Some 40,000 hectares of backdunes are dominated by exotic lupins and shrubs and, beyond these, more than 200,000 hectares of backdunes are covered in pasture grasses, pine trees, gorse and other exotic species (Hunter and Blaschke, 1986; Newsome, 1987). Of the 305,000 hectares of coastal sand dunes identified in the New Zealand Land Resource Inventory 1975–79, probably less than 10 percent are still close to their original condition.

Dune control planting occurred early this century after the natural dune vegetation had been destroyed by fire, deforestation, grazing and physical disturbance. The destabilised sand began drifting inland smothering grass on land that had been converted to pasture. Concern about the problem led to the Sand-Drift Act of 1908. To stop the sand drifts, marram grass was introduced. The marram was more prolific than the native sand-binders, but needed more nitrogen than the dunes could naturally provide, so lupins were also planted.

Lupins, like clover, peas and beans, are among the world's 170,000 species of legumes. Their roots contain bacteria which can absorb nitrogen from the air and convert it into organic forms (e.g. ammonium and nitrates). This organic nitrogen can then be absorbed from the soil by other plants. In the same way that peas are planted to provide nitrogen for other vegetable crops, and clover is planted to sustain the nation's pasture grasses, lupins were planted to sustain the marram grass. For most of this century, the stability of most New Zealand sand dunes has depended on this marram-lupin combination.

A national survey of New Zealand's sand dune and beach vegetation was carried out between 1984 and 1988 by the Botany Division of the former Department of Scientific and Industrial Research (DSIR) (Partridge, 1992; Johnson, 1992). Many of the nation's beaches were visited—608 in total (273 in the North Island, 302 in the South Island, 27 on Stewart Island and six on nearby Ruapuke Island). Despite the high number of beaches in the south, most of the southern dunelands are comparatively small in area. In fact, 80 percent of New Zealand's sand dunes are in the North Island - principally on the west coast and north of the island.

The dunelands were ranked according to four criteria: the diversity of their landforms; the extent to which native sand plants were present; the extent to which the dunes and vegetation had escaped modification; and the extent to which they were free of adventive weeds. Total rankings gave an indication of those areas with the greatest botanical value for conservation.

Unfortunately, the ranking system tended to focus more on the dunes themselves rather than the inter-dune slacks, swamps and lakes which harbour much of the dunelands' biodiversity. Furthermore, a number of dunelands were not surveyed while, for others, the rapid survey approach did not do justice to their complexity and missed many rare species (Rapson, 1996). As a result, the survey probably understates the ecological importance of many dunelands.

Of the 608 beaches, about one third were considered worthy of conservation management, and 53 (9 percent) were identified as dunelands of national importance (Johnson, 1992; Partridge, 1992). A quarter (13) of the top ranking dunelands were in Northland whose far north beaches have the largest assemblage of botanically valuable dune systems in the North Island. The Northland dune lakes shelter threatened species of plants and native fish.

The best of the Northland dunelands is Spirits Bay, an almost pristine sequence of foredune and backdunes grading behind into wetland and forest vegetation. The slack communities which occupy the moist hollows between the dunes are in relatively good condition. All the important native dune species are present and among the common weeds, marram and kikuyu are apparently absent with just a small amount of scattered lupin (Partridge, 1992).

The best of the southern dunelands are in the extreme south, at Stewart Island where nine out of 27 dunelands (33 percent) were rated as being of national importance. They include the near pristine Smoky Bay, a dramatic sweep of beach, native dune, and forest, of high biological and scenic value, and also the 13 kilometre Mason Bay which is outstanding on several counts: its size, the dramatic appearance of its dune landscapes, the diversity of habitats, the rich and largely unmodified plant life, and the presence of brown kiwis and other birdlife. However, marram now dominates Mason Bay's foredunes and grazing by sheep, white-tailed deer, red deer, and possums, affects the dune vegetation to some extent (Johnson, 1992).

In the majority of the surveyed dunelands the native pingao and spinifex are dominated by marram grass, usually in association with lupins. Another dune stabilising plant, lyme grass (*Leymus arenarius*) has also been planted in some dunes, as have radiata pine plantations. Many dune areas have been burnt and some have been invaded by large stands of bracken fern (*Pteridium esculentum*). Grazing by cattle, sheep, rabbits and hares has also reduced or removed the native vegetation. Direct human pressures have come in the form of housing development, protection works such as sea walls, sand mining, and heavy pedestrian and vehicle traffic, including dune buggies and trail bikes (Partridge, 1992; Hamilton, 1996). The wetlands and slacks between the dunes have been particularly hard hit by the combination of introduced species, pollution, and the drainage of adjacent farmland.

In recent years, two additional pressures have come to bear on the dunelands—the rapid spread of the introduced pampas grass (*Cortaderia selloana*), particularly in dunelands throughout the North Island; and the equally rapid spread of lupin blight, caused by the fungus *Colletotrichum gloeosporoides* (Partridge, 1992). Since 1987 this disease has spread to many areas, reducing lupin populations on open dunes by 90 percent (Douglas *et al.*, 1994). The consequent reduction in nitrogen threatened to kill off the marram and lyme grass and again destabilise the dunes, but it now seems that the lupin populations are recovering and are likely to resume their former abundance.

### *The state of our exotic grasslands*

Well fertilised, oversown, exotic grasses form a dense underground mat of roots that can improve soil structure by increasing the amount of organic matter or humus in it (as roots die and new ones replace them) and by creating root channels that aerate the soil and make it porous. However, exotic grasses also have higher nutrient and moisture requirements than the indigenous grasses, are less tolerant of soil acidity, and have shallower roots.

Without proper management, the exotic pasture grasses are vulnerable to soil degradation, moisture deficits, pests and weeds and soil erosion (Williams and Haynes, 1991; Wedderburn, 1991). In hill country the shallow roots of the exotic grasses are less effective than tussock or forest at retaining soil and water, though 'improved' grassland, with its dense root structure, is far less erosion-prone than unimproved exotic grassland with its sparser roots and vegetation cover.

At present, around two-thirds of New Zealand's farmland (68 percent) is on erosion-susceptible soils, and most of this is exotic pasture in the North Island (Clough and Hicks, 1993). Under current management practices, an estimated 6.1 million hectares of pasture land (53 percent of the entire North Island) is not sustainable because of erosion risk (Eyles, 1993). However, about 3.7 million hectares could be made sustainable by space-planting or close-planting of trees to provide stronger root support for the soil. For the other 2.4 million hectares, however, the only sustainable option is to convert to forest (Eyles, 1993).

Apart from soil degradation, the introduced pasture grasses are also vulnerable to pests and weeds, including native species attempting to reassert themselves. Regenerating native forest is a constant problem for exotic grassland in many areas. It is usually suppressed by grazing and repeated fertiliser applications on well-stocked improved pastures, and by periodic burning on the more sparsely stocked unimproved pastures, aided by the clearing of native seedlings when they start to grow.

Sustaining pasture grasses in many areas, therefore, means maintaining soil condition and moisture availability, and combating pests. Because inputs of fertiliser, lime, irrigation water and pesticides are costly, it is not unusual for pasture condition to deteriorate in times of economic difficulty and improve in more buoyant times. During the 1980s, farmers cut back on fertiliser and lime use to save costs. For most, this caused no immediate loss of pasture condition because enough residual nutrients had accumulated from the previous decades of regular fertiliser application. But in some hill systems, deterioration became apparent.

Although fertiliser use has picked up in recent years, much of this has been increased use of nitrogen fertilisers in dairying areas rather than the replenishment of hill soils. However, on some hill farms where fertiliser applications had been lighter anyway, and nutrient reserves lower, pasture yield has dropped by as much as half over five to ten years, and a gradual reversion to their 1940s condition is already underway (Hicks, 1995).

### *The state of our croplands*

Apart from soil problems, the main threats to crop viability in New Zealand are from pests and weeds, which are controlled by both biological and chemical methods. Lack of moisture and intermittent drought is also a threat in some areas and is controlled by irrigation. At present, the area of horticultural land is expanding, though the overall crop and horticultural area remains relatively small. Up to 14 percent of New Zealand could support crops (Eyles and Newsome, 1991). At present, less than 2 percent is actually used for this purpose, the rest being used for animal production, such as dairy farming. In recent decades, there has been an intensification of harvesting on some of the crop lands, leading to soil problems, such as compaction, nutrient decline and falling productivity in some areas.

### *The state of our exotic forests*

After slumping in the late 1980s and early 1990s, the rate of new forest planting soared to a record 98,000 hectares in 1994 (Eyre, 1995). This led to planting predictions of 100,000 hectares per annum for the rest of the decade, but more sober analysis by the Forest Research Institute suggests that the rate of new planting until the year 2000 will average around 72,000 hectares per year, falling to 57,000 hectares per year for the next decade (Glass, 1996).

The biggest environmental threats to exotic forests are wind and fire. On hills, erosion is also a risk for a period after harvesting and before new root systems have become firmly established. Other forms of soil degradation, such as nutrient loss and acidification, may limit these forests' sustainability in poor soils, such as sand dunes (Hawke and O'Connor, 1993; Smith *et al.*, 1994). In most areas, however, soil degradation is not believed to pose a serious limit to forest growth and productivity, at least during the first two or three harvest cycles (O'Loughlin, 1995). In richer soils, radiata pine can actually enhance nutrient levels (Davis and Lang, 1991; Hawke and O'Connor, 1993; Smith, 1994).

Because most exotic forests consist of a single dominant species, the impacts of a serious disease or insect invasion (e.g. Asian gypsy moth) could be devastating. On the evidence to date, however, radiata pine appears to have a low susceptibility to disease while vigilant border and pest control operations have, so far, contained Asian gypsy moth arrivals. The insect and fungal pests which are already established incur economic costs but do not threaten the plantations as such. They are controlled through integrated pest management systems combining biocontrols and chemical sprays.

Outside the plantation forests, the vigour and fecundity of pine trees makes them difficult to contain. In some areas they have become aggressive weeds. Wilding pine trees have become established in parts of the tussock country of the South Island and in the North Island's Central Plateau. They have also invaded sand dunes and indigenous forests. At present, the problem is localised but increasing, with some 17,000 hectares affected in the Canterbury Region for example (Canterbury Regional Council, 1995). Despite these impacts, however, the future for exotic forests in New Zealand looks very positive.

## SOCIETY'S RESPONSES TO PRESSURES ON OUR LAND ENVIRONMENT

The environmental impacts of land use are controlled through a combination of laws and voluntary initiatives mostly implemented by local authorities and the resource users themselves. Central Government maintains a supervisory role, with the power, where necessary, to impose national policies, environ-mental standards, or protection orders, or to provide funding for protection or sustainable management projects.

The Government also has direct management responsibility for 8.1 million hectares of state-owned conservation land and 2.5 million hectares of pastoral lease land, plus about 300,000 hectares of exotic and indigenous production forest.

The key new laws governing land management are:

- the Conservation Act 1987 which operates in conjunction with several other acts (e.g. the National Parks Act 1980, Reserves Act 1977 and the Wildlife Act 1953) and charges the Department of Conservation with directly protecting the natural environment on some 30 percent of the land area, and with advocating its protection elsewhere;
- the Resource Management Act 1991, under which local authorities have, among other things, a responsibility to:
    - ensure that land resources are sustained for future generations and that the life-supporting capacity of ecosystems and soils is protected;
    - provide for the protection of outstanding natural features and landscapes from inappropriate subdivision, use, and development;
    - provide for the protection of areas of significant vegetation and habitat; and
    - have particular regard to amenity values, intrinsic ecosystem values and the maintenance and enhancement of environmental quality.
- the indigenous forests provisions of the Forests Act 1949 (Part IIIA), as amended by the Forest Amendment Act 1993, which require that indigenous timber production be from sustainably managed forests;
- the Biosecurity Act 1993, which sets out a process for establishing legally enforceable pest management strategies at national or local levels;
- the Hazardous Substances and New Organisms Act 1996, which sets up a new agency, the Environmental Risk Management Authority (ERMA), to assess hazardous substances and new organisms, including genetically modified organisms, before they are manufactured, developed, imported or released into the New Zealand environment, and to establish safeguards for their use;
- the Agricultural Compounds Bill, which will control the use of pesticides in farming and horticulture; and
- the Crown Pastoral Land Bill, now before Parliament, which will amend the tenure and management provisions of the Land Act 1948, enabling the sale of lease-hold tussock land in exchange for better protection of areas that still have some conservation value.

In addition to these statutory measures, the responses to land problems also include a considerable amount of collaborative and advisory work by government departments, local authorities, Crown Research Institutes, environmental organisations and forestry and farming organisations. The combination of statutory and voluntary measures has produced the following responses to vegetation change, land-use pressures, and pests and weeds.

### Responses to vegetation change

During the course of New Zealand's economic development, most of the useful land has undergone dramatic vegetation change. National parks and reserves are generally confined to remote mountainous areas or islands and so are not fully representative of the nation's natural vegetation and landscape diversity.

The **Protected Natural Areas (PNA) Programme** was initiated in the early 1980s, by the Biological Resources Centre (BRC) of the Department of Scientific and Industrial Research, in order to help represent the full range of indigenous biodiversity in New Zealand, through a formal programme of ecological surveys and evaluation (Simpson, 1982; Park *et al.*, 1987). The Programme uses a framework of 268 ecological districts, which was also developed by the BRC, as a basis for identifying the best remaining representative areas for protection (RAPs).

The PNA Programme is now co-ordinated by the Department of Conservation. Surveys are increasingly carried out in collaboration with district councils, some of whom use the survey results when preparing district plans.

Since its inception in the early 1980s, over 60 ecological districts which span over 9,000,000 hectares have been surveyed and described in survey reports. In 1996/97, the PNA Programme supported ecological survey work and report writing in 20 ecological districts. More than 80 RAPs have been added to the network of protected natural areas in New Zealand, but many types of natural ecosystem are still not adequately represented.

Many remaining natural areas are in poor condition, and need to be restored in order to ensure their viability. Landcare Research, supported by the Public Good Science Fund, has recently begun a programme of research into ecological restoration, particularly in lowland and peri-urban areas where some of the greatest vegetation change has already occurred. Similar research by NIWA, on restoring riparian vegetation, has resulted in the Department of Conservation publishing guidelines for the planting and management of native vegetation on stream and river banks. It is hoped that such research may assist regional and territorial authorities to actually start reversing the process of ecosystem loss.

#### *Maintaining forests*

About 77 percent (4.8 million hectares) of New Zealand's surviving indigenous forests are in **national parks** and **reserves** managed for ecological and recreational purposes by the Department of Conservation. A further 3 percent (about 200,000 hectares) have been voluntarily protected or committed for protection by private owners who have offered them for sale to the Department of Conservation or have attached legal covenants to the titles. The covenants may last from 20 years to perpetuity. These voluntary protection arrangements are funded by:

- the **Forest Heritage Fund**, which was established by the Government in 1990. By mid-1996 it had achieved protection, and commitments to protect, some 96,000 hectares, with an annual budget of $4–5 million;
- **Nga Whenua Rahui**, which was established in 1990 for use by Maori forest landowners. By August 1996 it had achieved protection, and commitments to protect, some 76,000 hectares, with an annual budget of $2–3 million; and
- the **Queen Elizabeth II National Trust**, which was established in 1977 with funding from both government and non-government sources. By mid-1996 it had achieved protection for about 37,000 hectares of 'open space', much of it forest land, and commitments to protect a further 62,000 hectares. Funding for some of this came from the Forest Heritage Fund and so is double-counted.

Up to 10 percent (650,000 hectares) of the nation's indigenous forests may be subject to regional council rules governing forest clearance on erosion-prone slopes. These rules can be imposed under the Resource Management Act wherever a council decides that the adverse effects of an activity may threaten the life supporting capacity of soil. Local authorities are also required to sustain other ecosystem attributes (e.g. life-supporting capacity, significant habitat, and intrinsic values, which include biological diversity). Generally clearance on private land is permitted, subject to environmental safeguards which vary widely from region to region.

The remaining 10 percent of indigenous forests are not in reserves or on erodible slopes but are still subject to controls of one sort or another. These forests include 164,000 hectares of government-owned production forests in the South Island and approximately 500,000 hectares of privately-owned forests.

Though legally available for logging, about 80 percent of the privately owned forests are unsuitable for timber production at present because they are regenerating from previous felling. The controls which apply to these forests are:

- **local authority rules** under the Resource Management Act which determine whether felling or clearing is a permitted activity;
- the indigenous forests provisions of the **Forests Act 1949** which require most private indigenous timber and woodchip production to be harvested under either an approved sustainable forest management plan or a permit;
- **export controls** on indigenous logs, woodchips and sawn timber; and
- **management agreements** in which the Government, as owner, defines the conditions under which its 164,000 hectares of indigenous production forests are to be managed.

The precise area of potentially loggable forest covered by **local authority rules** is not known. The Resource Management Act generally takes a permissive attitude to land use unless identifiable adverse effects can be demonstrated. Local authorities may restrict forest-felling to prevent adverse effects on soil, water, ecosystem functioning, landscapes or significant vegetation and animal habitats. Most authorities, however, have tended to leave native forest protection to the Department of Conservation, the voluntary protection funding authorities and the Forests Act.

**Box 8.9**

### *Historical responses to land problems*

Both traditional Maori society and modern New Zealand society were slow to develop sustainable land use practices. When environmental limits brought the period of Maori expansion to an end, some time after 1550, fortified settlements were built to defend territories of now scarce resources. Rules and customs evolved to control access to, and exploitation of, treasured and rare resources. Some resources became sacred or off-limits (tapu). Others became subject to temporary bans (rahui). Most tribes developed customary forms of harvesting (kaitiakitanga) based on traditional, often secret, knowledge of the plants and animals within their territories (matauranga). These customary rules should not be confused with the modern conservation ethic of protecting species and ecosystems for their own sakes. The Maori attitude was that natural resources were there to be used (King, 1984; O'Regan, 1994).

Rules to safeguard forest resources were probably most developed where communities were highly dependent on forests, such as in the Urewera mountains (Best, 1942). In other areas, where communities were more dependent on gardens and seafood, different priorities and rules applied (Davidson, 1984). Fortunately, New Zealand was large enough for Maori communities to take their time adjusting. In some other parts of the Pacific, island populations were decimated by warfare or forced to emigrate following the destruction of their forests and large prey animals (Diamond, 1991, 1995; Flannery, 1994).

Scrub burning by Maori communities was widespread when Europeans reached New Zealand, but the burning of mature forest had mostly ceased. This changed when the sudden arrival of European technologies, plants, animals and markets from the late 1700s on triggered a second expansionist phase. More forest was cleared for potato gardens, which were always situated on newly-cleared forest margins (Cameron, 1964). Maori entrepreneurs developed a thriving agricultural trade with Australia and California (O'Connor, 1993). The process of change was accelerated after 1850 by large-scale immigration from Europe. The new settlers had a single aim: to subdue the forest and make the soil economically productive. This view was reflected by successive governments whose over-riding goal was to turn as much of New Zealand into farmland as possible. Through various land and settlement acts, immigration schemes and land grants, they assisted thousands of settlers onto land.

The environmental effects of farm development were protested by a small number of Europeans and by Maori tribes who saw their traditional resources and sacred sites being destroyed. Generally these voices were ignored. A controversial Forests Act was passed in 1874 to slow the destruction but was widely seen as an obstacle to economic growth, and was subsequently repealed. The Land Act of 1877 was more successful in securing protection for steepland forest to prevent erosion and flooding. Various acts and amendments were also passed establishing rabbit control boards, river control boards, drainage boards, and security of tenure on pastoral land. Deforestation increased in the second half of the century as the mushrooming European population established farms and settlements. Expansion continued until, by 1920, virtually all usable land was fully occupied and the area of loggable native forest had been so reduced that timber shortages were predicted 30 years hence. Erosion and declining crops and pasture had become severe in some areas, particularly in some North Island hill country and some South Island tussock country.

Unable to increase production by simply felling more trees and expanding the area of occupied land, agriculture moved from an 'expansionist' era into an 'intensification' era (Roche, 1994). Successive governments began to encourage more intensive production on the land which was already occupied. To achieve this farmers needed better crop, grass and livestock strains, improved soil fertility, and better protection from hazards, such as erosion, floods and droughts, and from pests and weeds. In the 1920s, the Government established the State Forest Service, the Department of Scientific and Industrial Research and the Fields Division of the Department of Agriculture. It also passed the first of several Town Planning Acts which aimed to limit urban sprawl into farmland by requiring councils to prepare town plans.

Science, technology, new legislation and government funds were increasingly channelled into extracting higher crop and stock yields, controlling floods and erosion, combating pests and weeds, installing irrigation systems, and establishing short rotation exotic forests on land unsuitable for farming. Government scientists and advisers began evaluating fertilisers for different kinds of soils, breeding and testing new strains of legumes and grasses, and improving crop and pasture management. Animal research focused on improving animal health and the conversion of grass to meat, milk and wool. Over several decades, surveys of soil were undertaken and a land use capability classification was developed.

From the 1920s, for the next 50 years agricultural growth was mostly achieved by increasing the numbers of livestock and the yields per hectare, rather than increasing the area. Intensification began in the more fertile plains and valleys of the North Island, then spread in the 1930s to the Northland gumfields and the lowlands of the eastern South Island. The hill country and steeplands had to wait until the late 1940s and the development of aerial topdressing, bulldozers and four-wheel-drive vehicles. Aircraft were also used to spread the newly developed organochlorine pesticides (e.g. DDT) over large areas of hilly farmland to control grassgrub and porina.

In 1941 the Soil Conservation and Rivers Control Act was passed to achieve coordinated flood and erosion control within catchments (McCaskill, 1973; Poole, 1983; Roche, 1994). The Act set up a national council and a number of local catchment control bodies (variously called Boards, Commissions, or Authorities) whose members were either elected locally or appointed by the Government, and whose funds came from rates and government subsidies allocated through the national council. The catchment authorities employed soil conservators whose role was to assess erosion on farms and develop ways of reducing it. The catchment authorities also embarked on drainage and river control schemes (channels, stopbanks etc.) with the technical assistance of the Water and Soil Division of the Ministry of Works and Development.

This modernisation and intensification of farming and exotic forestry led to spectacular increases in productivity from the 1940s to the 1960s and to a large migration of surplus labour from the mechanising farms into rural towns, and, from there, into the cities. In the 1970s, however, export returns from sheep products in particular began to decline as a consequence of falling commodity prices, rising transport costs, and declining access to traditional markets (i.e. Britain). The government of the day responded by subsidising farmers to boost stock numbers and clear more marginal land for farming, putting more pressure on soils and native vegetation.

These measures ceased in the economic and institutional restructuring of the mid-1980s. Intensification of farming was still the aim of agricultural policy, but with much greater emphasis on product quality, diversity and marketing. Market forces were seen as a more efficient means of achieving this than government assistance. Advisory services were corporatised or privatised, as were the research organisations. Subsidies were ended for most agricultural activities. Cutting rights to the government's exotic forests were sold. Income taxes were reduced, a goods and services tax introduced and protective tariffs reduced. As a result of these reforms, land-based producers are now much more exposed to local and international market forces, and are investing more in horticulture, farm forestry and dairy farming and less in traditional sheep and beef farming.

In this market-driven climate, sustainable land management is to be achieved through individuals taking responsibility for the long-term effects of land use under the watchful eyes of their community and regional and district councils. Under the Resource Management Act 1991, which replaced the previous planning and soil legislation, these local bodies are now responsible for ensuring that natural and physical resources, including ecosystems and biodiversity, are managed sustainably. Although central government financial support for farmers has largely ended, many councils operate extension advisory services and provide financial assistance for farm-based erosion control schemes. Where necessary to achieve sustainability, community rules and constraints on land use can be imposed through the councils' policies and plans drawn up under the Resource Management Act.

In cases where the local authority allows indigenous forests to be felled, the new provisions of the **Forests Act 1949** apply. The Act does not prevent forests being felled, but it does prevent their timber being sold to a sawmill or chipmill if the felling was not done under a sustainable forest management plan or permit. Sustainable forest management is defined as "the management of an area of forest land in a way that maintains the ability of the forest growing on that land to continue to provide a full range of products and amenities in perpetuity while retaining the forest's natural values."

A set of harvesting prescriptions for low impact logging is contained in the Act along with export prohibitions on indigenous logs, woodchips and timber (except for sawn beech and rimu, finished or manufactured products, personal effects, and salvaged or sustainably managed stumps, roots and tree fern trunks). The Act applies to all private land except for some 57,000 hectares (containing about 35,000 hectares of forest), mostly in Southland, which were granted to dispossessed Maori families under the South Island Landless Maoris Act 1906. The inclusion of this area into the Forests Act provisions is currently under negotiation. Also exempt from the Act are 152,000 hectares of government-owned production forest on the West Coast which are subject to a separate management agreement. The Ministry of Forestry administers the Act at a cost of $1.2 million in 1994/95.

The **export controls** contained in the Act are similar to those contained in Customs regulations which preceded the Act and are still in force. One difference, however, is that the Customs regulations do not exempt the South Island Landless Maoris Act forests, so the Customs Minister's permission is required to export native beech woodchips from these forests. From 1990 to 1995, two woodchip shipments a year have been authorised, involving the clearfelling of about 300 hectares annually. In 1996, however, the Government decided to stop further shipments and negotiate a settlement with the affected landowners and sawmillers.

The Government has signed **management agreements** covering the state-owned production forests with the Forestry Corporation, which manages 12,000 hectares in Southland, and Timberlands West Coast Ltd, which manages 152,000 hectares in various parts of the South Island's West Coast. The Timberlands agreement is based on the controversial West Coast Accord.

The **West Coast Accord** was signed in 1987 by sawmillers, three environmental organisations, and the Government, following agreement on the allocation and use of forests formerly managed by the Forest Service. The Accord parties agreed on: the areas to be set aside for protection (including the Paparoa National Park); the areas that would be available for continued clearfelling and for how long; and the areas that would be managed for "sustained yield" production, including a beech scheme. The areas designated for clearfelling and sustained yield timber production were explicitly exempted from the 1993 amendment to the Forests Act so that these Accord commitments could be met.

Two other accords affecting native forests are the Tasman Accord and the New Zealand Forest Accord. The **Tasman Accord** was signed in 1989 by Tasman Forestry Ltd, environmental groups and the Government. In it, the company agreed to end native forest clearance on its land, protect some 39,000 hectares, and assist with the recovery programme for a threatened native bird, the kokako, as well as other conservation projects.

The **New Zealand Forest Accord** was signed in 1991 between forestry and timber industry representatives and environmental organisations. The signatories agreed that plantation forests provide an alternative to the depletion of natural forests, and that the forestry industry would refrain from clearing native vegetation over "any area greater than five hectares, areas greater than one hectare which have an average canopy height of more than six metres, and areas which have been or might be recommended for protection under the Protected Natural Areas Programme or as a Site of Special Wildlife Interest."

These measures cover most areas of natural forest, though instances still occur of forest and scrub clearance by farmers and others. The main threat to all native forest, however, is the sustained assault from pests and weeds, especially the impacts of goats and possums and of smothering plants like old man's beard. Pest control in indigenous forests is largely the responsibility of land owners and, on conservation land, the Department of Conservation (see below).

***Maintaining tussock lands***

The pastoral leases under which most of the remaining tussock grasslands are managed, are issued subject to the **Land Act** 1948. The leases cover 2.45 million hectares of tussock land. Only about 2 percent of the tussock grasslands (about 72,000 hectares) are on Department of Conservation land, though the conservation lands also include approximately 650,000 hectares of mixed sub-alpine tussock and scrub as well as other areas where tussock grows in association with forest, scrub, and exotic grass species.

Since 1991 the Commissioner of Crown Lands (located in the government Ministry, Land Information New Zealand) has been negotiating land swaps with pastoral leaseholders, enabling them to become freehold private owners of farmland while transferring land with high conservation values to the Department of Conservation. This is carried out under an administrative tenure review process. The process will be refined and given a statutory framework under the **Crown Pastoral Land Bill** which will amend the Land Act. The Bill was drafted following a recommendation by the Working Party on Sustainable Land Management (1994) that the legislation be reviewed "with the objective of freeholding all the land not required by the Crown for the public interest". The recommendation follows successive initiatives over a period of 15 years to amend the Act.

The presumption is that freehold ownership will motivate the leaseholders (approximately 340) to make more sustainable use of land which has become degraded under the leasehold tenure. Diversified and imaginative land uses are envisaged, as owners move away from pastoral farming to take up viticulture, forestry, arable agriculture, horticulture and tourism. Simultaneously with the tenure review process, the Department of Conservation is charged with identifying areas of high conservation and public interest values. The Commissioner of Crown Lands then negotiates with land users for return to full Crown ownership of these areas.

At the request of the lessees, areas in need of protection for nature conservation or for public access and recreation are being identified by surveys of pastoral leases. Some areas had already been identified through previous Protected Natural Area (PNA) Programme surveys. Protection mechanisms can include covenants or transfer of land to the Department of Conservation.

In addition to these arrangements, the Resource Management Act prescribes a role for local authorities in preventing environmentally harmful vegetation change in the tussock lands. Several regional councils require land users to obtain a permit before burning vegetation, including tussock. Permits are generally approved subject to environmental conditions.

***Maintaining dunelands***

Few dunelands have formal protection, but all coastal areas are required to be managed sustainably under the Resource Management Act. The Minister of Conservation and regional councils share responsibility for managing the coastal marine area–the land and water below high tide. The Minister's roles are to issue consents for 'restricted coastal activities' (i.e. activities in sensitive locations or having significant impacts below high tide) and to produce the New Zealand Coastal Policy Statement, which sets out conservation priorities, protected areas, and prohibited activities around the coast. Among the information sources for the Coastal Policy Statement was the national duneland survey which recommended 53 dunelands for national protection and approximately 150 other dunelands for regional conservation measures (Johnson, 1992; Partridge, 1992). The Coastal Policy Statement can also set out policies for the zone above high tide between land and sea. Responsibility for carrying out the policies in this zone rests with territorial authorities.

The role of local authorities under the Act is to use their polices and plans, where appropriate, to preserve "the natural character of the coastal environment" and protect it from "inappropriate subdivision, use, and development". In doing this they must not conflict with the New Zealand Coastal Policy Statement.

A number of local authorities have adopted the New South Wales concept of involving community groups in 'coast care' (or 'beach care' or 'dune care') programmes (Hamilton, 1996). Coast care programmes have been established in Auckland, Waikato/Coromandel, Hawke's Bay, Christchurch and the Bay of Plenty. The volunteer groups, which mostly involve older residents rather than young people and summer visitors, undertake such tasks as identifying weeds and ways to control them, protecting dunes with access ways, fences and sand ladders, planting native plants on foredunes, educating schoolchildren and the general public, and lobbying for council support through annual plans.

Another voluntary initiative that has some relevance to duneland protection is the New Zealand Forest Accord, the agreement between environmentalists and the forestry industry which commits the signatories not to plant exotic forests in areas recommended for protection by the PNA Programme.

#### *Maintaining shrublands*

No national measures exist specifically for the protection of shrublands, though, like other ecosystems and habitats, these are covered by the Resource Management Act. Some shrublands are protected by virtue of being on Department of Conservation land, while others have been recommended for protection by the PNA Programme. Some shrublands have also been set aside in small private reserves, including a number supported by the Queen Elizabeth II National Trust.

The New Zealand Forest Accord also provides a measure of protection to shrublands, though many land owners are not parties to the Accord. The first public test of the Accord came with the East Coast Forestry Project (see below). New planting was temporarily stalled by a disagreement between the forestry companies that had signed the Accord and some landowners who proposed to replace kanuka and manuka shrublands with pine forest. On many of the farms where shrublands occur, the main threats are from browsing by goats, trampling by cattle and clearance for pasture by the land owner. The felling of kanuka and manuka for firewood is also widespread.

#### Responses to land-use pressures

In many areas where native vegetation has been removed, unsustainable land-use pressures are damaging soil, water, crops, pasture and adjacent native vegetation and habitat. In the past, the Government assumed much of the financial responsibility for dealing with the damage, but did little to actually change land use practices. It is now thought that government production subsidies and drought and flood relief may have encouraged unsustainable land use practices by allowing land users to reap the rewards of damaging activities without having to bear the full costs of the damage.

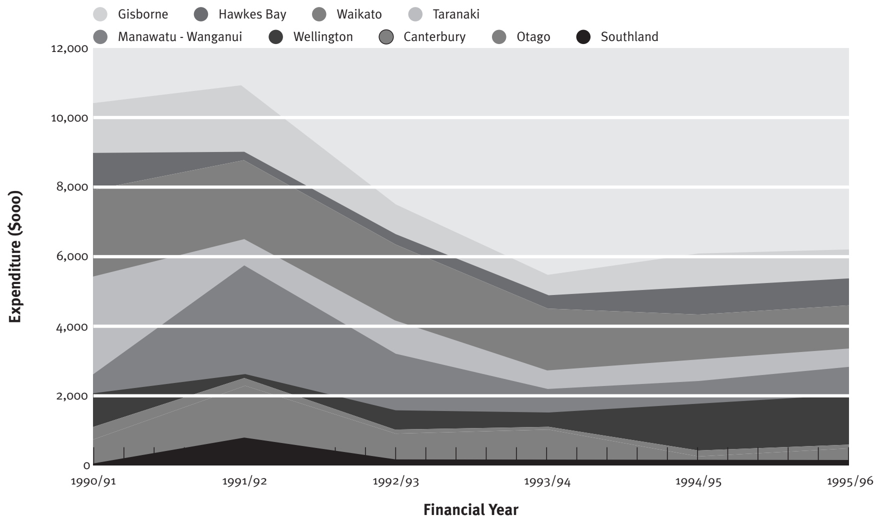
Since 1984, the broad philosophy of the Government has been to abolish production subsidies and put more responsibility on farmers and other land users to improve their land management practices. To ensure that market-driven production does not have the same environmentally damaging effects as subsidy-driven production, land use, like other forms of resource use, is subject to the Resource Management Act and the requirements of regional policy statements and regional and district plans.

The policy also presumes that land users should not be subsidised to meet environmental standards, except where action is urgently required and beyond the resources of the individual land user. As a consequence, land management subsidies to farmers and foresters are now limited to a diminishing number of regional council programmes for soil conservation and pest control, a special central government-funded programme to arrest severe erosion in the North Island's East Coast, and a recently concluded programme to combat rabbits and weeds in the South Island high country (see Figure 8.11).

Government expenditure on disaster relief for farmers has also been reduced. In the past, the ready availability of disaster relief for

**Figure 8.11**

**Expenditure on soil conservation and land sustainability programmes by nine regional councils[1]**




[1] The councils selected were those with itemised soil and land expenditure data for the complete period covered

flood or drought damage often allowed farmers to safely pursue high risk practices, such as over-stocking and devegetation of erodible land. Now, landholders are encouraged to manage their land more carefully to minimise the damage from climatic hazards. Relief payments have declined from an average of $24.6 million per year in the late 1980s to $5.6 million in 1992/93 and only $574,000 in 1994/95 (Ministry of Agriculture and Fisheries, 1995).

While local authorities are charged with developing the policies, plans and rules for sustainable land management within their regions and districts, central government, through the Ministry for the Environment, has overall responsibility for the administration of the Resource Management Act. For land use problems of national significance, the Minister for the Environment has several options to secure national objectives, such as:

- making submissions to councils and the Environment Court (as can all Ministers) during the regional and district planning process in the hope that the national view will be included in policies and plans;
- publishing guidelines or mandatory environmental standards (e.g. on contamination levels, water pollution,);
- imposing policies through National Policy Statements; and
- providing sustainable management funds to encourage authorities or land users to adopt measures that are in the national interest.

A number of government agencies also work on land management projects with scientists, local authorities, Maori tribes, farmers and foresters to foster sustainable practices and pest control. Net government expenditure on these agri-environmental programmes in 1994/95 was estimated at $227 million (see Table 8.15).

The Ministry for the Environment is responsible for coordinating these disparate activities through the Government's **Sustainable Land Management Strategy (SLMS).** Under the strategy, sustainable land management is promoted by providing direct help to land-users and by improving research, coordination, and other support. The strategy's main initiatives are:

- giving financial support to the New Zealand Landcare Trust to train a national network of landcare and community group facilitators and help set up landcare groups;
- helping prepare best management practice guidelines for land users;
- establishing a National Science Strategy Committee to advise Government and, where possible, coordinate sustainable land management research;
- developing standards and/or guidelines for sustaining water and soil quality;
- promoting voluntary and market incentives for sustainable management; and
- developing national and on-site indicators of sustainable land management.

The Ministry is also running several projects which relate to sustainable land management. These include:

- the development of a national set of environmental indicators;
- the development of a Waste Management Strategy and Waste Management Protocol to guide councils in the disposal and monitoring of solid waste; and
- the development (with the Ministry of Health) of guidelines on acceptable levels of soil contamination and of criteria and standards for disposing of persistent organochlorines.

In addition to these activities, the Ministry for the Environment also manages the **Sustainable Management Fund (SMF),** which provides money for a broad range of environmental activities, including industry-based sustainable land management initiatives. The SMF was established in July 1995. Prior to this two other programmes (catchment grants and resource management subsidies) funded regional council flood protection and soil conservation works along with other resource management activities. The annual allocation to the combined programmes declined from more than $40 million in the late 1980s to just under $10 million in 1994/95. The amount spent on flood protection and soil conservation fell from nearly $39 million to $4 million (for the completion of one remaining flood protection scheme), while the amount spent on environmental activities has stayed constant at around $5 million since the passing of the Resource Management Act in 1991. The reduction in central government funding reflects the completion of the transfer of many resource management responsibilities from central to local government. In the 1970s and 1980s, although local government had key responsibilities, substantial funding came from central government. This affected local decision making.

The Ministry of Research, Science and Technology is responsible for administering the **National Science Strategy for Sustainable Land Management** which identifies the main research priorities. This enables better coordination of research and more effective targeting of the Government's **Public Good Science Fund**, which, since July 1990, has been the main source of central government funding for research (see Table 8.16). It is administered by the Foundation for Research, Science and Technology. Government funding for research on sustainable land management is also channeled through universities, government departments and government trusts, and was $78.8 million in 1994/95 (Ministry of Research, Science and Technology, 1995).

The Ministry of Agriculture runs the **Sustainable Agriculture Facilitation Programme** which was set up after the release of a Government position paper on sustainable agriculture in 1993 (Ministry of Agriculture and Fisheries, 1993b). Through the programme, the Ministry disseminates information and cooperates with land users, other central and local government agencies and other interested parties to maintain and enhance the sustainability of New Zealand agriculture. The 1994/95 budget for the programme was around $550,000.

The Ministry of Agriculture also provides technical and administrative support to the Pesticides Board and the Animal Health Board which each have the job of assessing and regulating the harmful effects of newly registered compounds. Of their $1.8 million budget, approximately $1.6 million is recovered in fees.

The **South Island High Country Review** (known as the Martin Report) was conducted by the Working Party on Sustainable Land Management. The Working Party was established by the Ministers of Agriculture, Conservation and Environment to "identify ways in which a coordinated approach to dealing with high country land management issues could be tackled after the end of the five-year Rabbit and Land Management Programme" (Working Party on Sustainable Land Management, 1994).

The review recommended, among other things, that the Land Act be amended to incorporate sustainable management concepts and to strengthen land user incentives. It also recommended that areas of conservation importance be identified by the Department of Conservation and targeted for protection, and that areas of no conservation importance be sold to the lease holders. The Crown Pastoral Land Bill is a result of these recommendations.

**Table 8.15**
**Estimated agri-environmental expenditure, 1994-95 ($NZ million).**

| | Budget (excluding GST) | Share attributed to agriculture | Environmental protection | Agricultural protection |
|---|---|---|---|---|
| *National programmes* | *151* | *108* | *45* | *63* |
| *Regional programmes* | *158* | *71-102* | *15-29* | *56-73* |
| *Less R. M. Grants[1]* | *(9)* | *(6)* | *(2)* | *(4)* |
| ***Total expenditure[2]*** | ***300*** | ***173-204*** | ***57-72*** | ***116-132*** |
| *Less user payments[3]* | *(73)* | *(42-56)* | *(3-7)* | *(39-49)* |
| ***Net expenditure*** | ***227*** | ***131-148*** | ***54-65*** | ***77-83*** |

*Source: Ministry of Agriculture and Fisheries (1995)*

1 *Resource Management Grants are transfers from central to local government and are included in both categories of expenditure. They have been subtracted to avoid double counting.*
2 *Numbers have been rounded and do not always match totals.*
3 *These are payments for pest control on government land ($5.4 million) plus payments to regional councils by programme users or beneficiaries ($68 million).*

**Table 8.16**
**Public funding for research on sustainable land management in 1993-94 ($NZ million).**

| Sources of funding | Directly related to sustainable land management | Indirectly related to sustainable land management[1] | Total funding |
|---|---|---|---|
| ***Central Government*** | ***61.3*** | ***41.4*** | ***102.7*** |
| *Public Good Science Fund[2]* | *39.0* | *34.8* | *73.8* |
| *Universities[3]* | *19.6* | *7.9* | *27.5* |
| *Government Trusts[4]* | *0.7* | *0.7* | *1.4* |
| *Government Departments[5]* | *2.0* | *-* | *2.0* |
| ***Regional Councils*** | ***2.0*** | ***1.5*** | ***3.5*** |
| ***Total*** | ***63.3*** | ***42.9*** | ***106.2*** |

*Source: Ministry of Agriculture (1995)*

1 *This includes relevant primary research (e.g. on plant taxonomy or the geological factors affecting soil formation) and remedial research (e.g. on pollution control technologies).*
2 *Includes non-specific output funding of $6.5 million.*
3 *Based on the number of fulltime equivalents doing research, assuming a marginal cost per FTE of $60,000, using information from the 1991/92 Benchmark Review.*
4 *Agriculture and Marketing Research and Development Trust (AGMARDT) and the Lotteries Board.*
5 *Departments with operational research funding for sustainable land management, in declining order, included the Ministry of Agriculture, the Department of Conservation, the Ministry of Forestry, and the Department of Survey and Land Information.*

The Ministry of Forestry has a special unit devoted to the **sustainable management of native forests,** with a budget of some $1.2 million in 1994/95. The Ministry also coordinates the **East Coast Forestry Project** which subsidises the planting of forests over some 200,000 hectares of erodible hill pasture in the Gisborne region. The project, which will run until the year 2020, was established in 1992 "to promote large scale commercial forestry as a means of controlling soil erosion and providing employment and regional development and to recognise environmental needs on individual properties" (Ministry of Forestry, 1994b). The 1994/95 budget for the programme was around $2.9 million (including GST).

The Department of Conservation has responsibility for preparing **Regional Conservation Management Strategies** and coordinating the development of the

**National Biodiversity Strategy** part of which are concerned with developing more biodiversity-friendly forms of farming to reduce the threats to indigenous species from fragmented habitat, wandering livestock, pastoral run-off and pests and weeds. The Department's **Protected Natural Areas Programme** and **New Zealand Coastal Policy Statement** also contribute to this process.

At the local level, where most of the responsibility for sustainable land management lies, the responses of local authorities and land users are guided by the **Regional Policy Statements** with, in some cases, coordination and guidelines from central government. These responses include the development of regional and district plans and enforcement of rules for land use, monitoring of the environment and the provision of **services and advice** concerning waste disposal, soil conservation activities and pest and weed control. In 1994/95 regional councils spent about $68 million on resource policy and planning, monitoring and enforcement, and administration of permits.

Regional council programmes providing technical advice on soil conservation and other environmental issues have taken on a renewed importance with the reduction in grants from central government. In many councils, officials assist land users to develop property management plans dealing with soil conservation and other environmental problems on the farm. In some cases, farm plans have been developed which include protection covenants on natural forest or other significant natural features on their properties. Some councils charge for this service to recover some of their costs, while others provide free advice. Several councils have ratepayer funded programmes to assist with soil conservation and sustainable land management activities. The combined cost of these extension programmes in 1994/95 came to about $9 million.

The present extent and effectiveness of the soil conservation programmes is not known but surveys of North Island hill farms between 1989 and 1992 found that although erosion control measures were in use on two-thirds of the erodible land they were only applied effectively on less than one-third (Clough and Hicks, 1992).

New Zealand has no legislation devoted specifically to contaminated sites, but government policy on this topic is being developed within the context of:

- the Resource Management Act 1991, which requires resource consents for waste emissions;
- guidelines that are being prepared for each industrial sector on the assessment and management of contaminated sites;
- a regulatory system which is being developed to record site contamination information so that landowners can choose land uses that are appropriate;
- legal and policy decisions on who has liability for contaminated sites and the funding of clean ups;
- the Hazardous Substances and New Organisms Act which sets performance standards for the future handling and use of hazardous chemicals; and
- environmental management systems developed by industry, including codes of practice, waste minimisation initiatives, and the chemical industry's Responsible Care Programme which was launched in 1991.

A three-year **Organochlorines Programme** is being run by the Ministry for the Environment to assess contamination levels and develop environmental standards and guidelines for the management of contaminated sites. Several regional councils have initiated collection programmes for unwanted chemicals to reduce the risk of accidental contamination from improper and prolonged storage. Most councils have focused on agricultural chemicals, but have accepted unwanted chemicals from other sectors as well. In 1994/95 regional councils spent approximately $900,000 on this activity, mostly funded from the Minister for the Environment's Sustainable Management Fund. The councils were also provided with money to investigate the extent of contaminated soil and water in urban areas that were formerly occupied by sawmills, timber treatment sites, oil installations or gas works. The investigations are revealing a small number of seriously contaminated sites. Responsibility for the remediation of these sites is currently under discussion.

At the community and industry level, land users have become increasingly involved in promoting sustainable land management. For example, the New Zealand **Forest Code of Practice** was developed by the Logging Industry Research Association in 1991 to provide guidance on the following elements of sustainability: commercial values, soil and water values, scenic values, cultural values, recreational values, scientific and ecological values, forest health, site productivity, off-site impacts and safety. The code has been adopted by most of the larger forest companies.

About 55 **'landcare' groups** (variously called farmcare, watercare, landcare, land management and community resource groups) have been established by farmers in East Coast North Island districts and parts of the pastoral high country of the South Island. The aim of these groups is to collectively deal with land management problems such as erosion, flooding, irrigation, pests and weed control, and also more conventional concerns relating to livestock and financial performance.

Through these groups, farmers are showing a new interest in soil and vegetation monitoring and a greater willingness to resolve the problems themselves. Regional councils provide the groups with advice and some funding (estimated at around $200,000 in 1994/95). In several parts of the country, Federated Farmers branches are actively involved with local councils in encouraging the formation of landcare groups and are promoting projects to establish farm-based indicators of sustainable land management.

The dairy industry is developing an environmental strategy to address the impacts of the industry. An industry committee is working closely with farmers, processors and marketers to be pro-active and deal with environmental issues before problems arise. The Meat Development Research Cooperation's network of focus farms includes an emphasis on sustainable management, and the Rural Futures Trust has promoted decision-support computer systems and ecologically-based condition assessment models as tools for better farm management.

### Responses to pests and weeds

The two main arenas of pest and weed control are on farms and on conservation land. The pest problems differ markedly in these two arenas. Livestock are pests on conservation land, while some native insects are pests on farmland. Introduced plants are weeds in nature reserves, and regenerating native trees are weeds on farmland. Some species, however, are pests in both arenas (e.g. possums, hawkweeds). The Department of Conservation's response to pests and weeds is described in Chapter 9.

Apart from the efforts of individual landowners, most agricultural pest control is carried out by regional councils and is funded from regional property taxes and special assessments on those benefiting from the control operations. Although some central and local government funding for pest control operations continues (primarily for the control of possums and their spread of bovine Tb), landowners are expected to contribute a greater share in the future (e.g. through levies). In 1994/95 regional councils spent almost $40 million on pest control and the Ministry of Agriculture spent just over $10 million. About $13 million of this went to the Animal Health Board which also received a further $18 million in levies from the agricultural industry (Ministry of Agriculture and Fisheries, 1995).

Where individual landowners, councils or other organisations are unable to get cooperation from others in controlling a pest, they may propose a **Pest Management Strategy** under the Biosecurity Act 1993. This Act is the main law dealing with pest control operations, though several other laws apply to pest control (i.e. Conservation Act 1987, Wild Animal Control Act 1977, Wildlife Act 1953 and Forests Act 1949). The Biosecurity Act replaces the Agricultural Pest Destruction Act 1967 and the Noxious Plants Act 1978. Under the Act, any pest management strategy must be run by a specified pest management agency, which can be a government department, a regional or district council, or a private organisation.

Once a strategy is approved (either by the Government, for national strategies, or a regional council for regional ones) the agency is empowered to enter premises, seize risk goods, declare a place restricted and direct the occupier of a place to eradicate a pest (Ministry of Agriculture and Fisheries, 1994). Central government funding for any pest management strategy depends on the extent to which the particular pest is seen as injurious to the 'public good.' A national pest management strategy has been approved for bovine tuberculosis (Tb), with the Animal Health Board as the responsible agency. This requires it to place controls on stock movement in Tb infected areas and to manage possums and the other feral mammals which transmit Tb. Possums are also the main pest targeted by the Department of Conservation on conservation land.

Rabbit control is mainly a problem in the South Island high country. The Ministry of Agriculture and the Ministry for the Environment were jointly responsible for the **Rabbit and Land Management Programme**, which ran from 1989 to 1995. The programme reduced rabbit populations over nearly 300,000 hectares of badly infested tussock land. Vegetation cover increased from less than 50 percent in 1990/91 to over 60 percent in 1993/94 (Working Party on Sustainable Land Management, 1994). Central government funding for the programme averaged $3.5 million per year over five years. This covered half the programme's costs, while roughly 25 percent each came from regional councils and participating farmers. Participating farmers had to develop property management plans covering the factors that affect soil, vegetation and livestock and the economic and social factors affecting farm sustainablility.

Despite the programme's success in reducing pest problems and increasing farmer involvement in sustainable land management, the desire for a "quick fix" biocontrol solution to the rabbit problem is still strong. In the past, the only candidate, myxomatosis, was rejected because it causes unacceptable animal suffering and may also pose a risk to indigenous species, but attention has now turned to more humane viruses, such as the haemorrhagic calicivirus and the contraceptive myxoma virus.

Scientific research on pest distribution and control methods is undertaken by a number of Crown Research Institutes and universities, with funding mostly from the Public Good Science Fund and industry sources. However, pest and disease surveillance is still partly a central government responsibility. The Ministry of Agriculture monitors domestic animal and plant populations in order to detect the presence of unwanted organisms and to maintain an accurate assessment of plant and animal health status. Its budget for this in 1994/95 was almost $9 million.

The Ministries of Agriculture and of Forestry also maintain a capability to respond to unwanted organisms which could become a serious problem if left unchecked. Emergency responses are rare, but control or eradication efforts may be required at short notice. In addition these Ministries provide border control and post-entry quarantine services to prevent harmful organisms entering through airports, vessels, passengers, cargo and mail and investigate suspected illegal imports of plant and animal material. These functions are required by the Biosecurity Act 1993. They had a budget of about $18 million in 1994/95 (Ministry of Agriculture, 1995).

## CONCLUSIONS

Land use in New Zealand has considerable impacts on native ecosystems and soil. Land-based activities, particularly agriculture and transport, also cause atmospheric and water pollution, as described in previous chapters. However, the worst and least recognised land use impact has been on native biodiversity, which has lost an immense amount of habitat to agriculture. Many native species are still declining as a result of this loss (see Chapter 9). Halting the ecological decline is one of the main challenges facing today's land managers, but one that has yet to be fully grasped.

The issues of more immediate concern to land users and local authorities are the serious problems caused by soil and water degradation. Although significant degradation of both soil and water is confined to only a few regions (e.g. Taranaki, Gisborne, Hawke's Bay and Manawatu/Wanganui), moderate impacts occur in all regions and at least one form of significant impact occurs in several regions (see Table 8.8). In some areas the problems have the potential to become worse unless remedial action is taken. Among the more serious issues are:

- the loss of soil-stabilising vegetation, not only on hill farms and in tussock country, but in upper catchment indigenous forests, along streams and riverbanks and in coastal dunelands;
- the impacts of pests and weeds in agricultural systems and in natural ecosystems;
- the risk of accelerated erosion and nutrient decline in millions of hectares of North Island hill pasture as a result of deforestation;
- the degradation of soil and tussock cover in the South Island high country through pressure from fire, livestock, pests and weeds;
- the degradation of highly productive, but relatively scarce, 'elite' soils, through urban encroachment and through intensive cropping and grazing which can cause compaction, fertility decline, accelerated acidification and chemical contamination;
- the exposure of degraded farmland to climatic hazards, such as drought and flood, which can seriously exacerbate soil degradation;
- the identification and remediation of existing contaminated sites; and
- the contamination of surface water through pasture run-off containing eroded sediment, faecal matter and nutrients, as well as the contamination of groundwater through leaching of nutrients (see Chapter 7).

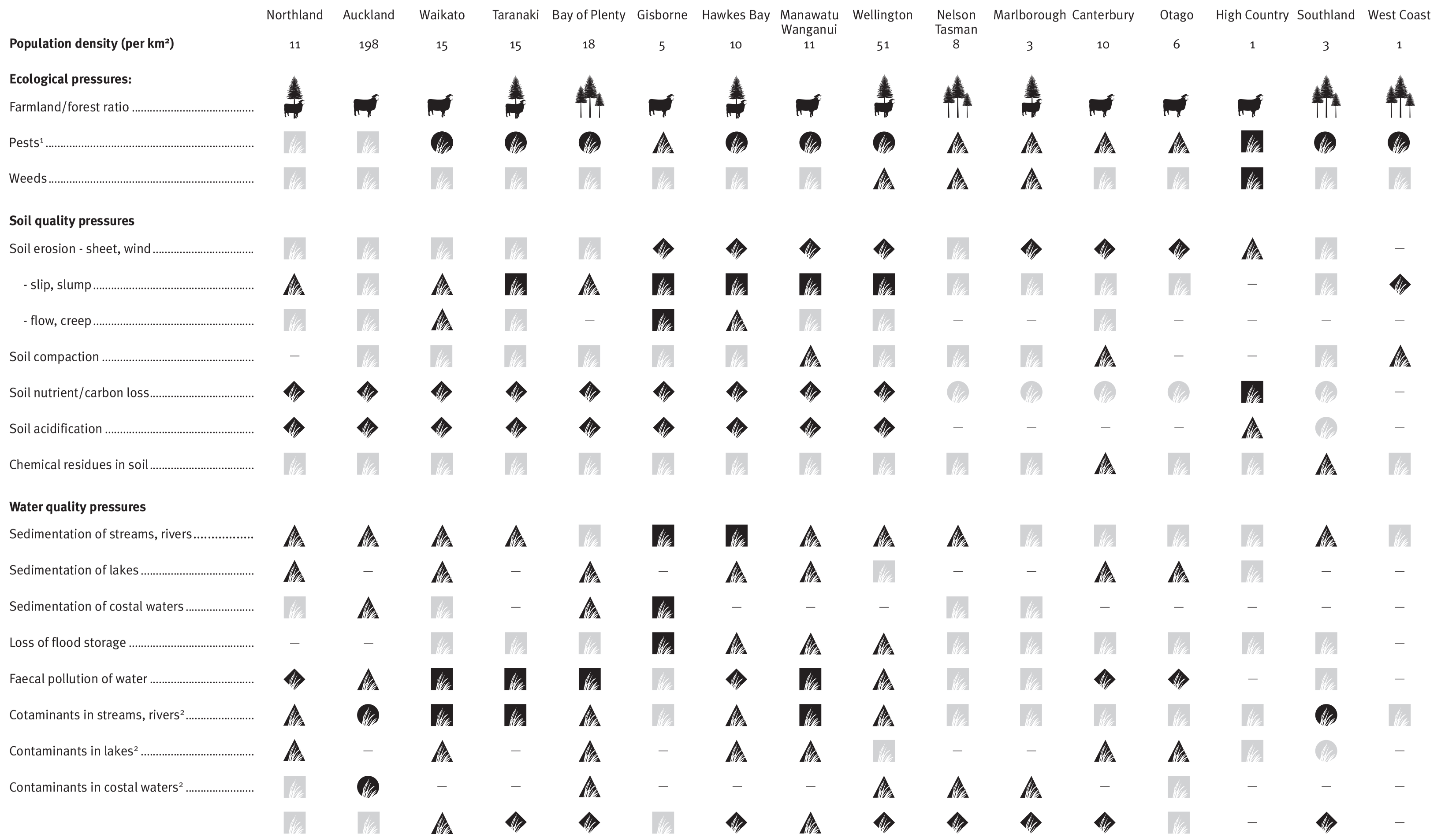
The laws, policies and plans for dealing with these issues are still new, as is the economic environment in which the new rules and processes must operate. A key to future improvements will be better information and monitoring systems to tell us both how well we are doing and which problems need more attention. If the land and the organisms living on it are to receive better treatment in the future, we will need better knowledge of their condition and the pressures affecting them.

Many efforts are now underway to achieve this through farm sustainability indicators, regional monitoring programmes, national environmental indicators, a national research strategy, national land cover databases and conservation estate maps.

Information alone, however, will not achieve sustainable land management. Ultimately, the future of our land depends on how the information is used. Although New Zealand's major environmental laws are now rooted in an ethic of environmental sustainability, short term economic motives rather than longer term environmental concerns continue to drive many land management decisions.

The negative aspects of this are visible in degraded hillsides and streams, but there have been environmentally positive outcomes too, such as the reduction in sheep numbers, the conversion and reversion of some marginal farmland to forest cover, and the more effective control of high country rabbits. Recent initiatives by forestry and agricultural organisations suggest that attitudes are changing but we have yet to see whether these will develop into a general 'greening' of the New Zealand landscape. Although the seeds of a new land ethic have been sown, it is probably too early to conclude that they have really taken root.

**Table 8.17**
**Estimated severity of land pressures and problems in New Zealand regions.**




¹ Pests include vertebrates (e.g. possums, goats, rabbits) as well as invertebrates (e.g. insects, roundworms etc.)

² Contaminants include nutrients, pesticide residues and heavy metals

## Key

- The area of native forest and scrub exceeds that of farmland
- The area of farmland is up to twice the area of native forest and scrub
- The area of farmland is more than twice that of native forest
- Potential for significant impact in some localities
- Potential for moderate impact throughout region
- Potential for significant impact throughout region
- Significant impact in some localities
- Moderate impact throughout region
- Significant impact throughout region
- No significant impact at local or regional levels

*Adapted from Ministry for the Environment (1995)*

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THE STATE OF

NEW ZEALAND'S

ENVIRONMENT

CHAPTER NINE

# THE STATE OF OUR BIODIVERSITY

## CONTENTS

## KEY POINTS

- *The world's biological diversity is declining for the first time since the catastrophe of 65 million years ago which wiped out the dinosaurs and half of Earth's other species. The reason for the current catastrophe is our species' increasing expansion of territory and use of resources at the expense of other species and their habitats. As these pressures continue to rise, extinction rates are also predicted to rise.*

- *New Zealand may have 80,000 species of native animals, fungi and plants, only about 30,000 of which have been described and named. The major groups are the insects and fungi, each with a possible 20,000 species, and the nematode worms, with more than 10,000 species.*

- *Plants and large animals account for barely 5,000 native species in total: about 2,300 vascular plants; about 1,100 mosses and liverworts; about 190 land and freshwater vertebrates (mostly birds and reptiles); approximately 1,200 marine fishes; about 60 seabirds; and about 40 marine mammals (only four of which breed in our waters).*

- *The biodiversity of our micro-organisms is poorly understood, though the known species include about 3,700 algae (a quarter of which are seaweeds while the rest are single-celled plankton and periphytons) and about 2,600 protozoans (e.g. amoeba, giardia etc.).*

- *New Zealand's biodiversity is more primitive in character than that of many other countries, having a limited representation of higher plants and animals (e.g. angiosperms and mammals), but a high representation of older plants and animals (e.g. mosses, liverworts, ferns, flatworms, snails, spiders, wingless crickets, solitary bees, leiopelmid frogs, sphenodon reptiles and ratite birds). Many species are endemic (found only in New Zealand).*

- *In only 700–800 years (about 30 generations), humans and their accompanying animals have eliminated 32 percent of the endemic land and freshwater birds (43 species and 9 subspecies), 18 percent of the endemic seabirds (4 species out of 22), 1 of the 29 freshwater fish, 3 of the 7 frogs, possibly 3 of the 64 reptiles, 1 of the 3 bats, possibly 11 of the 2,300 vascular plants, and at least 12 invertebrates, such as snails and insects. The numbers of most surviving species and subspecies have been heavily reduced.*

- *Today, nearly 1,000 animals, plants and fungi have been identified as threatened (some 800 species and 200 subspecies). Among the threatened species are: more than 200 fungi (5 percent of known species); nearly 200 vascular plants (10 percent); 85 non-vascular plants (8 percent); 150 vertebrate animals (58 percent); and at least 285 invertebrate animals (1–2 percent). One of the worst affected groups is our endemic land and freshwater birds, three-quarters of which (37 out of 50 species) are now threatened.*

- *The main threats to most species are: insufficient habitat and fragmented habitat caused by the predominance of farms, roads and settlements which now claim 63 percent of the total land area and more than 90 percent of the lowland area; human predation, which puts pressure on some species through hunting, fishing, gathering and collecting; and introduced pests and weeds which prey on native species, compete with them, or damage their habitat. Many declining species are still paying the 'extinction debt' incurred by earlier deforestation and drainage.*

- *Most of the New Zealand landscape is now ecologically hostile to many native species. Although nearly 30 percent of the land area is protected in the conservation estate, most of this is on steep and mountainous land. Lowland forests, dunelands, streams, wetlands and subalpine tussock grasslands are under-represented in our protected areas.*

- *Alien species threaten a third of our protected forests (1.8 million hectares) and put pressure on smaller reserves and individual species. Those which cause the most damage are: possums, which now number about 70 million; goats and deer, whose numbers appear to be rising; rats, stoats and feral cats; trout; and introduced weeds. New Zealand now has as many introduced conifers and flowering plants in the wild as it has native species (almost 2,000). About 200 of these are harmful to native plants.*

- *A small number of introduced crop, livestock and biocontrol species are vital to New Zealand's agriculture, horticulture and forestry industries. Specially bred strains and varieties are continually being improved or developed for New Zealand conditions. The breeding programmes need access to a wide range of exotic genetic material. However, while some New Zealand-based gene and seed collections are of world significance, many are poorly documented and stored, and several are deteriorating.*

- *Of the 1,200 or so marine fish in our Exclusive Economic Zone (EEZ), nearly 100 are rockpool species (60 percent of them endemic) and about 1,100 are sea-dwelling species (5 percent endemic). More than 100 sea-dwelling species (10 percent) are fished commercially, though this will soon increase to about 160 species (15 percent). Forty-two species (4 percent), divided into about 150 'stocks', are harvested through a quota management system (QMS) which aims to maintain the stocks at their level of maximum sustainable yield (MSY), which is roughly 25–60 percent of their original biomass.*

- *Status assessments are available for the rockpool fish, 11 of which are considered threatened, all of them endemic. Assessments are also available for half the QMS stocks (or 2 percent of our total sea-dwelling fish stocks). Most QMS stocks are thought to be still above or near the MSY level and in the 'fishing down' phase. Two species, however, orange roughy and snapper, have some stocks well below the MSY level, while several other species have some stocks recovering from previous overfishing (blue moki, elephantfish), subject to low or declining catches (gemfish, grey mullet, rig), or at risk of depletion given 1995 catch rates (smooth oreo, snapper).*

- *Fishing bycatch (accidental capture or injury of non-target species) kills, on average, several hundred New Zealand seabirds each year, more than 1,000 marine mammals, unquantified tonnes of non-commercial fish species and uncounted communities of sea-floor invertebrates. The highest seabird bycatch is in the southern bluefin tuna fishery, and the highest marine mammal bycatch is in the southern blue whiting, West Coast hoki and southern squid fisheries.*

- *Marine invertebrates depleted by gathering, over-fishing or disease are: toheroa; rock lobsters; Southland paua; and Bluff oysters. Stock recoveries may now be under way for some of these. Little is known of the status of most non-commercial marine invertebrates, but 4 black corals, 1 bryozoan, 1 seastar, 1 lampshell, 1 lobster and 3 crabs are listed as threatened.*

- *Society's responses to the pressures from human predation include: the Native Plants Protection Act 1934; the Wildlife Act 1953; the Marine Mammal Protection Act 1978; the Fisheries Act 1996; the Conservation Act 1987; and the Trade in Endangered Species Act 1989, all of which impose varying degrees of control over the harvesting of selected native species.*

- *Society's responses to pressure from habitat loss include:*
  - *the preservation of nearly 8 million hectares of publicly owned mountain areas with several thousand hectares of lowland reserves and unoccupied offshore islands, under the Conservation Act 1987, the National Parks Act 1980 and the Reserves Act 1977;*
  - *the preservation of approximately 100,000 hectares of habitat on private land through government-funded covenants and purchases, arranged through the Forest Heritage Fund, Nga Whenua Rahui, the Queen Elizabeth II National Trust and the Department of Conservation's Protected Natural Areas Programme;*
  - *the protection of 1.1 million hectares of the marine environment (less than 1 percent of our EEZ but almost 7 percent of our territorial sea), made up of: a 750,000-hectare marine reserve around the Kermadec Islands; two marine mammal sanctuaries totalling 335,000 hectares around the Auckland Islands and Banks Peninsula; and 12 other marine reserves, 2 marine parks and 1 special protected area totalling nearly 15,000 hectares of mainland coastal waters (1-2 percent of the waters within 1 kilometre of the mainland);*
  - *about 70 ecosystem restoration operations each year as part of the Department of Conservation's 500 species management programmes, including some 40 Species Recovery Programmes;*
  - *the attachment of environmental conditions to licences for the 600-plus tourism concessions and several hundred mining and prospecting licences current on conservation land; and*
  - *requirements in the Resource Management Act 1991 that decision-makers provide for protection of areas of significant indigenous vegetation, significant habitats of indigenous fauna, and wetlands.*

- *Society's responses to the pressures from alien species include:*
  - *more than 600 pest and weed control operations yearly by the Department of Conservation, roughly equally divided between animal pests and noxious weeds, and spanning more than 1 million hectares of conservation land;*
  - *pest control programmes, mainly in agricultural areas, by regional councils and the Animal Health Board under the Biosecurity Act 1993; and*
  - *testing and risk assessment of introducing new organisms, such as the calici virus, under the Hazardous Substances and New Organisms Act 1996.*

- *Biodiversity research is thinly spread, uncoordinated, and poorly resourced. Although a lot of valuable information exists in disparate databases and publications, little of it is capable of depicting trends over time. Taxonomic expertise in the identification and classification of species is actually in decline.*

- *Initiatives to improve biodiversity research and monitoring are being undertaken through the Department of Conservation's estate monitoring programme, the Ministry of Research Science and Technology's research strategy process, the Ministry for the Environment's indicators programme, and the Crown Research Institutes' databases and research programmes, notably those of Landcare Research and National Institute of Water and Atmospheric Research Ltd (NIWA). A National Biodiversity Strategy is being developed.*

## INTRODUCTION

Biodiversity (short for biological diversity) refers to ther variety of life-forms that exist in a particular place (see Box 9.1). For the first time in 65 million years, the world's biodiversity is declining (Wilson, 1992; Pimm, 1995; Heywood and Watson, 1995). Pressures from human society are the main cause and, in New Zealand, these pressures have been intense and widespread. The decline comes at a time when many people are becoming aware of the economic value of wild species (e.g. in nature tourism, new crop and livestock production, and new gene and drug discoveries) and of the 'ecological services' they provide (e.g. in pest and weed control, carbon dioxide absorption, waste and nutrient processing and fish stock nurseries). On a more ethical plane, increasing numbers of people are coming to value Earth's diverse organisms simply for what they are—as fellow beings with a right to exist.

This chapter outlines the nature and state of our biodiversity, as far as we can assess it, the historical and current pressures threatening it, and our responses, as a society, to the challenge of protecting and sustaining it. Before looking at the specific situation in New Zealand, it is important to place New Zealand's biodiversity problems in a global and historical context. In terms of Earth's 4.6 billion year history, biodiversity is a recent development, even though life itself is very old. The earliest known rocks, from Greenland, are almost 3.9 billion years old. Some scientists have interpreted their unusually high ratio of carbon-12 to carbon-13 as evidence that primitive life emerged not long after the first oceans had formed on the cooling Earth (Day, 1994; Balter, 1996; Hayes, 1996; Mojzsis *et al.*, 1996; Nisbet and Fowler, 1996).

The earliest undisputed fossil evidence of actual life forms—bacteria—is from 3.46 billion-year-old rocks in Australia (Schopf, 1993; Knoll, 1994). More ambiguous evidence for early life consists of fossilised mineral deposits called stromatolites which can be formed by either bacteria or geological processes. The oldest fossil stromatolites are 3.5 billion years old, but their biological origin cannot be stated with certainty (Grotzinger and Rothman, 1996; Hecht, 1996; Walter, 1996).

For perhaps two thirds of life's history, biodiversity was limited to single-celled organisms. Various species of bacteria ruled the oceans for 1 to 2 billion years before eventually giving rise to more advanced one-celled organisms called protists which, in their turn, eventually gave rise to everything else. Protists are commonly divided into 'algae' (micro-organisms that absorb their energy from sunlight, through a process called photosynthesis) and 'protozoa' (micro-organisms that absorb their energy from living or dead organic matter and are non-photosynthetic).

It was not until 1.7 billion years ago that the earliest multi-celled organisms left clear traces in the fossil record—tiny leaf-like seaweeds which were probably the first brown algae (Shixing and Huineng, 1995). Some species of green and red algae may also have became multi-celled about this time, though, so far, their earliest known fossils are only 1 billion years old (Kerr, 1995a). About 1 to 1.2 billion years ago, a line of protozoans began to follow the algal example and adopt multi-cellular forms (Vermeij, 1996). Although these tiny, soft-bodied, first animals left no fossil traces, the time of their origin can be dated from the genes of their modern descendants (Wray *et al.*, 1996).

It was hundreds of millions of years before atmospheric oxygen levels became high enough to sustain larger, more metabolically complex, organisms (Graham *et al.*, 1995). That is when animals began to show up in the fossil record. Numerous species of 2–10 cm circular blobs called Ediacarans appeared in the oceans between 540 and 570 million years ago (Grotzinger *et al.*, 1995; Kerr, 1995c). Soon after, biodiversity really began to take off. In a great burst of evolutionary innovation, known as the Cambrian Explosion, two separate kingdoms of multi-celled organisms—the fungi and the animals—proliferated into the most diverse collections of organisms on Earth (Kerr, 1993). The species within these kingdoms have continued to evolve and diversify, but their main body plans were laid down between 500 and 530 million years ago when the five main divisions (or phyla) of fungi and the 35 or so phyla of animals evolved (Benton, 1995; Bowring *et al.*, 1993; Sepkoski, 1993).

**Box 9.1**

### *What is biodiversity?*

Biodiversity is the variety of life. It includes "diversity within species, between species and of ecosystems and the processes that maintain them." (United Nations, 1992; Department of Conservation, 1994a). Biodiversity is most often measured as *species diversity* (the number of different species in a given area), but can also be measured as *genetic diversity* (the variety of genes within a population), or *ecological diversity* (the number of different ecosystems or ecological processes in an area). Most biodiversity research focuses on species, either as the fundamental unit of study, or as the unit which enables other aspects of biodiversity to be studied (Wilson, 1992). As closed gene pools, species are the key taxonomic units in studies of genetic diversity, and as sets of specially adapted organisms, they are the key functional units in ecology.

A **species** is commonly defined as a group of organisms belonging to the same evolutionary lineage and capable of interbreeding under natural conditions. However, this definition does not cover all species (Gibbons, 1996b; Wilson, 1992). Some are just at the point in their evolutionary divergence where they still have the physical capacity to interbreed but never do in nature because of behavioural differences or geographical barriers (e.g. lions and tigers; donkeys and horses, sheep and goats). Others reproduce asexually and so never interbreed (e.g. most bacteria, and some protozoans, plants, animals, and fungi). Asexual species clone themselves with each new generation so their only source of genetic variation is through accumulated mutations over long spans of time. Without the interbreeding criterion, it is difficult to know when asexual lineages can be considered separate species. Despite these difficulties, the species concept embraces most living things and remains the key unit of study in biology (Wilson, 1992).

**Genetic diversity** refers to differences in the nucleic acid molecules (DNA and RNA) within a population. Every organism contains a species-specific set of DNA molecules (or chromosomes). Each chromosome is made up of tens of thousands of smaller units, called genes, which, together, determine the organism's structure and function by controlling the chemistry and growth of every body part. Most genes come in several different versions (called alleles). Allele differences among individuals can cause minor variations in certain traits (e.g. height, colouring, temperament etc.). New alleles occasionally arise by random mutation. Some cause inherited diseases or handicaps, most are harmless, and some are beneficial.

The greater the variety of alleles in a population, the more genetically diverse it is said to be, and the greater its survival prospects. A high level of genetic diversity maximises the species'ability to adapt to new environmental pressures. Recent research suggests that genetic diversity declines once populations fall below 5,000 individuals and harmful alleles become more widespread as a result of inbreeding (Lande, 1995).

An **ecosystem** is an assemblage of species that interact with each other and their physical environment in a particular location. These interactions are called **ecological processes**. Most ecosystems can be characterised in broad terms by their dominant species or their main environmental features (e.g. beech forests, tussock grasslands, streams, lakes, wetlands, estuaries, etc.). Whether they are true systems, in the sense of being orderly and predictable with mutually inter-dependent parts and discrete boundaries, is still a debating point among scientists and philosophers, many of whom argue that most ecosystems are too disorderly and diffuse to be so neatly described (Botkin, 1990; Davis, 1984; Degan *et al.,* 1987; Golley, 1994; Goodman, 1975; Jackson, 1994; Kay and Schneider, 1994; Moffat, 1996; Sagoff, 1985; Shrader-Frechette and McCoy, 1993; Simberloff, 1980; Worster, 1990).

However, whether seen as systems or as mere clusters of species, there is little doubt that ecosystems contain diverse ecological processes, many of which are vital for the survival of at least some species. In some cases, these vital ecological processes even include periodic disturbance (Pickett and White, 1985). For example, recent research in the United States has shown that some species in stream and grassland ecosystems, namely those that are specially adapted to colonise disturbed sites (e.g. short grasses, mayflies) and those that prey on the colonisers (e.g. grazing animals, fish), would become extinct without episodic floods and fires (Leach and Givnish, 1996; Tilman, 1996; Wootton *et al.,* 1996). From such research it is clear that measures to conserve biodiversity must encompass not only species and genes, but also ecological processes and landscape management. Although this chapter focuses primarily on the most tangible and measurable level of biodiversity—the species—the importance of maintaining biodiversity at the ecological level is stressed throughout. For more information on the major water and land ecosystems, see Chapters 7 and 8.

The explosion of animal phyla produced sponges (phylum Porifera), jellyfish, sea anemones and corals (phylum Cnidaria), sea stars and sea urchins (phylum Echnodermata), shellfish, snails and squid (phylum Mollusca), millipedes, armour-plated trilobites and the ancestors of crabs, insects and spiders (phylum Arthropoda) and microscopic eel-like creatures called conodonts which introduced teeth and backbones to the world and ultimately gave rise to the vertebrates—fish, amphibians, reptiles, birds and mammals (phylum Chordata).

These are just some of the better known animal phyla. Many others consist of tiny, soft-bodied animals known only to a few thousand dedicated scientists. At least a dozen phyla are made up of worm-shaped animals, some of which are familiar and some obscure. These include: flatworms (phylum Platyhelminthes), ribbon worms (phylum Nemertea), jaw worms (phylum Gnathostomulida), horsehair worms (phylum Nematomorpha), spiny headed worms (phylum Priapulida), segmented worms, which include leeches and the common earthworms (phylum Annelida), beard worms (phylum Pogonophora), arrow worms (phylum Chaetognatha) and, the most diverse phylum of all, the roundworms or nematodes (phylum Nemata).

The nematodes are found living in soil, plants and other animals from the polar regions to the tropics. However, they have proliferated most dramatically in the deep ocean bathyl regions where muddy slopes fall away from the continental shelves. Mud-dwelling marine nematodes are believed by some to have more species than all other life-forms combined, accounting for perhaps three-quarters of the globe's biodiversity (Grassle and Maciolek, 1992; Lambshead, 1993; Pearce, 1995b). Even the more conservative estimate of 400,000 nematode species is a daunting prospect for the world's 20 or so nematode taxonomists, whose list of identified roundworms so far runs to only 25,000 species (Hawksworth *et al.*, 1995).

While biodiversity was dramatically expanding in the sea, multi-celled green algae and fungi were colonising the ancient shorelines. About 460 million years ago the green algae gave rise to the first plants—liverworts which soon gave rise to mosses and hornworts (Niklas, 1994; Palmer, 1995a). Many of these early plants formed symbiotic relationships with fungi which persist to the present day. About 90 percent of plant species rely on symbiotic fungi for one or more key nutrients (Kendrick, 1992). These plant-fungi communities laid down a carpet of soil and vegetation which lured the first land animals ashore about 450 million years ago (Gordon and Olson, 1995).

The pioneer land animals were members of the Arthropod phylum, whose modern descendants include: myriapods (e.g. millipedes, centipedes), arachnids (e.g. scorpions, spiders, mites), crustaceans (e.g. slaters, crabs, barnacles, shrimps) and insects (e.g. beetles, flies, butterflies). The ancestral arthropods were probably armoured myriapods whose hard yet flexible exoskeletons and jointed legs made them ideal 'Moon buggies' to explore and survive in their new environment (Palmer, 1995b). They were closely followed by the first land vertebrates, the amphibians (e.g. salamanders and frogs). Flatworms, earthworms, leeches and nematodes also wriggled ashore, alongside slugs and snails. With 90 percent of Earth history gone, the stage was now set for biodiversity to flourish on land.

### The Diversity of Life on Earth

Today Earth's extended family stretches thinly over its surface. Between 1.4 and 1.9 million living species have been scientifically identified (Wilson, 1992; May, 1992; Hawksworth *et al.*, 1995). Anywhere between 3 and 112 million species may exist in all, most of them tiny animals, fungi and micro-organisms which have yet to be described. A rough working figure is about 14 million species (Hawksworth *et al.*, 1995; Benton, 1995). Furthermore, many species contain genetically distinct subspecies and varieties.

- The standard approach to classifying this diversity is to group all species into five broad 'kingdoms'. However, recent genetic studies have shown that Earth's family tree is more complex than this (see Box 9.2). Furthermore, the number of known species in each of the five 'kingdoms' is constantly being revised as new ones are named and described. According to the *Global*

*Biodiversity Assessment* commissioned by the United Nations Environment Program (UNEP), the latest estimate of the number of species scientifically described is 1.75 million, divided up as follows (Hawksworth *et al.*, 1995):

- 4,000 known Bacteria (single-celled organisms with no nucleus; broadly divided into two groups: the *archaebacteria* which live in extremely hot or chemically hostile environments; and the more widely distributed *eubacteria*, such as *Escherichia coli*, *Rhizobia* and cyanobacteria);
- 80,000 known Protists (mostly single-celled organisms with a cell nucleus; broadly divided into: photosynthesisers, or *algae*, some of which are multicellular; and non-photosynthesisers, or *protozoa*, such as ciliates, flagellates and amoeba);
- 270,000 known Plants (multicellular organisms which are immobile and obtain their food from the sun by photosynthesis and from the soil by absorption; broadly divided into: the *non-vascular* bryophytes, mainly mosses and liverworts; and the *vascular* tracheaphytes, such as ferns, trees, flowering shrubs and grasses);
- 72,000 known Fungi (multicellular organisms which are immobile and obtain their food by absorption from the soil or from other organisms; broadly divided into: *eumycota*, the true fungi; and *myxomycota*, or slime moulds—which are now recognised as protists); and
- 1,320,000 known Animals (multicellular organisms which are usually mobile and obtain their food by eating other organisms; broadly divided into: *invertebrates*, animals that have no backbone, such as sponges, jellyfish, worms, shellfish, arthropods, etc., which account for 34 of the 35 animal phyla; and *vertebrates*, which belong to the Chordate phylum, comprising fish, amphibians, reptiles, birds and mammals).

To these, some people add a sixth 'kingdom' consisting of about 4,000 viruses. Viruses are sometimes described as 'sub-organisms' because they are not living cells. However, these tiny protein capsules contain genetic material (DNA or RNA) and, on entering living cells, they hijack the cell's chemical machinery to reproduce themselves. Viruses appear to have originated as rogue DNA and RNA from various unrelated life-forms and may actually belong to several kingdoms.

Within each of these kingdoms, organisms are classified hierarchically into taxonomic groups (or *taxa*). The classification of our own species can show how this system works. At the top level, each kingdom (in our case, the Animal kingdom) is divided into broad groups called *phyla* (except, for some reason, the Plant kingdom whose phyla are more plainly called *divisions*). Within the Animal kingdom we belong to the Chordate phylum. Each phylum, in turn, is divided into *sub-phyla* (in our case, the Vertebrates), then *classes* and sub-classes (among the vertebrates, we belong to the Mammal class), then *orders* and sub-orders (we belong to the Primate order of mammals), and then *families* and sub-families (in our case, a Primate family called Homininae, which also includes the great apes).

**Figure 9.1 Earth's family tree and classification of life**
**(a) The five-kingdom view of life based on broad morphological characteristics**

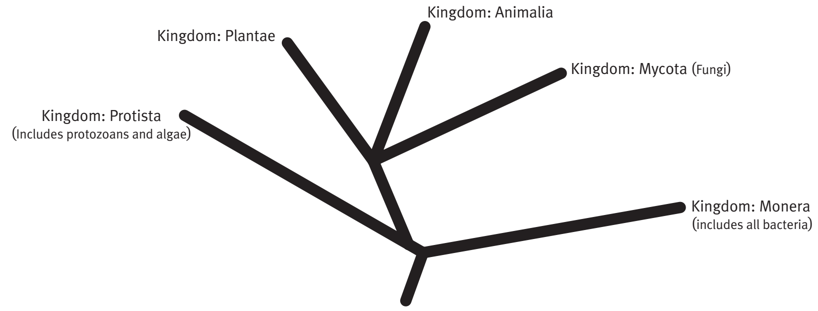
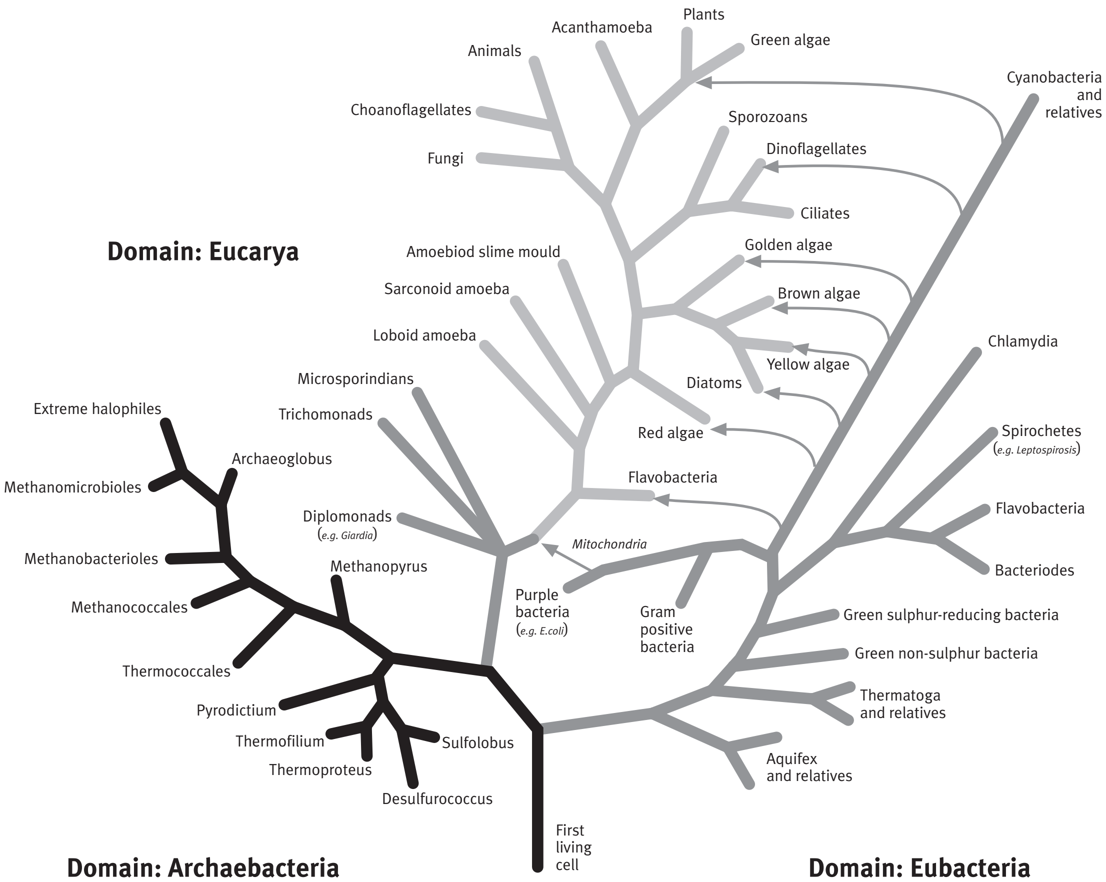



**Figure 9.1**
**(b) The three-domain, many-kingdom, view of life based on recent genetic research[1]**




[1] This diagram is a composite based on several published sources which differ on some details (e.g. Day, 1994; Doolittle *et al.*, 1996; Embley *et al.*, 1994; Morell,1996; Nisbet and Fowler, 1996; Service,1997; Wainwright *et al.*, 1993; Woese *et al.*, 1990). The definitive genetic reconstruction of Earth's family tree is still several years away.

**Box 9.2**

### *The biodiversity of micro-organisms*

The five-kingdom view of biodiversity groups Earth's millions of species into five great 'kingdoms' (Whittaker, 1959). Three of these kingdoms contain multi-celled organisms—the energy eaters (Animals), the energy absorbers (Fungi) and the energy photosynthesisers (Plants). The Animals have more species than the other kingdoms combined, followed by the Fungi, then the Plants and, finally, the two 'lower' kingdoms—the Protists (which are mostly single-celled but contain some multi-celled species) and the Bacteria (which are entirely single-celled). The main difference between the two 'lower' kingdoms is that Bacteria have simple cells in which the genetic material floats freely (prokaryote cells), while Protists have more complex cells in which the genes are housed in a protective bag or nucleus (eukaryote cells). The Protists are divided into photosynthesisers (Algae) and non-photosynthesisers (Protozoans).

Recently, genetic research has shown that the five-kingdom classification gives a somewhat distorted view of biodiversity. It minimises the diversity of the single-celled organisms while exaggerating that of the animals, fungi and plants. Although animals, fungi and plants have far more known species than the smaller life-forms, they are all relatively recent twigs on Earth's family tree (see Figure 9.1). The genetic studies show that, despite having fewer known species, the humble bacteria are the most widespread and genetically variable organisms on the planet, with the protists not far behind.

The new family tree revealed by this research has three main branches, or 'domains', each made up of many 'kingdoms' (Embley *et al.*, 1994; Woese *et al.*, 1990; Morell, 1996). The two oldest domains consist entirely of bacteria—the Archaea or Archaebacteria (primitive bacteria) and the 'true' Bacteria or Eubacteria. To date, only 4,000 bacteria species have been scientifically described, but 1 million or more species may exist (Hawksworth *et al*., 1995). The third domain, called the Eucarya or Eukaryota, contains all the organisms which have a cell nucleus. This includes all the protists as well as the animals, plants and fungi. The Eucarya are genetically closer to the Archaebacteria than the Eubacteria, though their cells also incorporate organelles (mitochondria and chloroplasts) of Eubacteria origin (see below).

The **Archaebacteria** live in extreme environments similar to those found on primeval Earth. Instead of oxygen they 'breathe' sulphur, methane and halogens (chlorine and fluorine) and many are 'thermaphiles' (heat-lovers), thriving in places such as volcanic vents and thermal pools. Their unusual chemistry is of interest to drug and chemical companies and may shed light on the ultimate origins of life (Day, 1994). Many scientists believe the archaebacteria are a relic group from Earth's early days, though dissenters argue that they are a specialist group which arose more recently. The latest molecular research suggests that they and the Eubacteria split into separate domains about 2 billion years ago, and that the archaebacteria subsequently gave rise to our domain, the Eucarya, about 1.5 billion years ago (Doolittle *et al.,* 1996).

The **Eubacteria** generally prefer less extreme environments than the archaebacteria, though some of the most primitive ones are also heat-lovers. Among the eubacteria are the well-known disease-causing groups (e.g. *Campylobacter, Staphylococci, Chlamydia, Rubella, Salmonella, Shigella* etc.), as well as many harmless species, such as the common, intestine-dwelling, faecal coliforms and enterococci (e.g. *Escherichia coli*). Many species are also beneficial, such as the various *Rhizobia* bacteria which enable plant roots to obtain nitrogen and the many soil-dwelling decomposers.

One of the most important and diverse groups Eubacteria encompasses is the *cyanobacteria* and their close relatives (e.g. *Prochloron*). These photosynthesising bacteria were once lumped in with the algae and called 'blue-green algae'. Although they are single-celled, some cyanobacteria form colonies while others form microscopic filaments of linked cells which occasionally show division of labour with some cells carrying on photosynthesis while others produce spores or attach to a surface. Cyanobacteria are found in almost every moist environment, in the sea, in fresh water and on land. They provide the beginning of the food chain in the ocean, being eaten by protozoans, which in turn are eaten by animals from corals to whales. They also provide the manure for Asia's rice paddies, the root fertiliser for tropical cycad plants, and they can form choking blooms in eutrophic lakes, producing toxins which mammals find unpleasant. Despite their name, many marine strains are red rather than blue-green, and one such strain (*Trichodesmium*) gives the Red Sea its name.

Fossil imprints in Australian rocks dating back 3.5 billion years have been interpreted as colonies of cyanobacteria or similar photosynthesising bacteria. This suggests that the first steps toward an oxygenated atmosphere were taken by lowly bacteria early in Earth's history. The cyanobacteria were also co-creators of the higher photosynthesising organisms— the algae and the plants. This ancestral connection occurred when various species of cyanobacteria were swallowed, but not killed, by hungry protozoans. Instead of being digested, the bacteria managed to survive inside the protozoans, continuing to reproduce and, most importantly, photosynthesise.

This formed the start of a symbiotic relationship in which the cyanobacteria provided a continuous supply of high energy carbohydrates to their protozoan hosts and, in return, enjoyed a ready supply of nutrients which had been captured by the larger host as well as a safe indoor life. The specialised descendants of these symbiotic cyanobacteria are still present in the cells of today's plants and algae as chloroplasts, the small 'organelles' which actually carry out the process of photosynthesis. Genetic studies have shown that this fusion of protozoan and cyanobacteria cells occurred separately in at least five different protistan 'kingdoms' forming at least five unrelated 'kingdoms' of algae.

**Algae** is the name collectively given to all the photosynthetic protistans. Although about 40,000 species have been described, some 200,000 may exist (Hawksworth *et al.*, 1995). Algae differ from cyanobacteria in having a nucleus and chloroplasts. Most are single-celled 'micro-algae' and some are multi-celled 'macro-algae'. Classifications vary, but six groups exist. The *Chlorophytes*, or Green Algae, are mostly single-celled but contain some multi-celled species (which eventually gave rise to the mosses and other plants). The *Chrysophytes* are all single-celled. They include the numerous yellow-brown Diatoms and the Yellow and Golden Algae. The *Phaeophyta*, or Brown Algae, are genetically part of the Chrysophyte 'kingdom' but have been traditionally put in a separate group because they are multi-celled seaweeds whereas the others are single-celled floating phytoplankton. The *Rhodophytes*, or Red Algae, include single-celled and multi-celled species and make up the red seaweeds. The *Pyrrophytes*, or Dinoflagellates, are single-celled and abundant. They are best known for the handful of species that form toxic algal blooms (see Chapter 7, Box 7.12). The *Euglenophytes* are green flagellates—single cells that swim by the action of one or more whip-like tails.

**Protozoans** are the non-photosynthesising protists. About 40,000 species are known, but some 200,000 may exist (Hawksworth *et al.*, 1995). They are all single-celled with the closest attempt at multi-cellularity being the colonies or 'fruiting bodies' formed by slime moulds. The slime moulds are sometimes classed as fungi, on the strength of this and their relatively advanced cell structure, but genetically are not closely related to the fungi at all. The protozoans range from primitive cyst forming species, which have no means of propelling themselves about, such as the parasite, *Giardia lamblia* (see Chapter 7, box 7.11), through to the complex *choanoflagellates*, whose cell structure is almost identical to that of the first animals, the sponges. In between are *amoeba*, which move by undulating their bodies, *flagellates*, which swim with whip-like tails, and *ciliates*, whose bodies are lined with small hair-like cilia which enable them to move about.

A feature which distinguishes the lower protozoans (such as *Giardia*) from all other Eucarya is their lack of an important 'organelle' called the mitochondrion. Just as chloroplasts convert the Sun's energy and carbon dioxide into high-energy food molecules, the mitochondria convert those food molecules into tiny fuel packages called ATP which can be used efficiently to power activities anywhere in the cell. The lower protozoans and the bacteria have no mitochondria, and genetic studies have revealed why. Like chloroplasts, mitochondria have evolved from an ancestral bacterial invader—in this case a non-photosynthesising purple bacteria. This seems to have happened only once, well before the cyanobacteria got in on the act, when a purple bacteria took up residence inside a *Giardia*-like protozoan. The symbiotic relationship between the mitochondrial bacteria and their protozoan hosts enabled the higher protozoans and algae to use energy more efficiently and diversify into the millions of larger species that now exist. These tangled relationships show that life's diverse organisms are indeed a single family, with more interconnections than Darwin ever imagined.

The final stage of classification is the most important because it is at this level that species are assigned their scientific names (in Latin)—first a 'surname' which indicates the *genus* they belong to (ours is *Homo*, meaning human) and then a *species* name (*sapiens*, meaning wise). Closely related species are generally given the same genus name and referred to as sibling species. Human classification is anomalous in this regard, dating from the founder of scientific taxonomy, Carl Linnaeus. In 1747, he wrote to a friend that he feared the clergy's reaction if he were to classify humans and chimpanzees together (Sagan, 1977). It is now known that, besides their physical and psychological similarities, humans and chimpanzees are 98.4 percent identical genetically. Some scientists and philosophers now argue that a reclassification is long overdue (Cavalieri and Singer, 1993; Diamond, 1991).

Sometimes, where a species contains populations that are genetically different, but not different enough to warrant a separate species name, a third *sub-species* name may be added—as for the extinct Neanderthal people of Europe and the Middle East (*Homo sapiens neandertalensis*). Sub-species present a special conservation problem. Apart from the usual threats, their existence is also threatened by interbreeding which preserves their genes but not their physical distinctiveness.

Despite the growing awareness of life's diversity, the important task of identifying and classifying the world's species (taxonomy) has been difficult in recent years as an increasing proportion of public and private research funding is channelled into applied rather than pure research. Increasingly, priority is being given to the urgent task of learning more about ecosystem management and the management of biodiversity for commercial uses, such as fisheries, bioprospecting and biotechnology.

In New Zealand it is now down to a few dozen taxonomists in museums, universities and research institutes to describe and name our tens of thousands of unknown species. An increasing proportion are retired scientists working part-time because there is no one else to do the work. In such circumstances, firm statistics on the number of species are hard to establish. However, based on work to date, some rough estimates can be made.

Bacterial biodiversity is poorly understood, yet may be greater than all the other kingdoms combined. About 3–4,000 species have been described worldwide, but this could be just the tip of a vast iceberg. The recent *Global Biodiversity Assessment* gives a working figure of 1 million bacteria, with a possible high of 3 million (Hawksworth *et al.*, 1995). Yet, even this may be an under-estimate. It is often assumed that each species of plant, animal and fungus harbours at least one specifically adapted bacterial species. If so, the total number of bacteria must be at least equal to all other species combined—about 13 million, to quote the working figure, but possibly as high as 112 million (Hawksworth *et al.*, 1995).

Of the remaining kingdoms, the Animals are undoubtedly the most diverse, with most of the honours going to the tiny, less glamourous species. Nematodes (roundworms) are the most diverse sea animals in the world, with maybe millions of species, and the arthropods (specifically, the insects) are the most diverse land animals. About 950,000 insect species have been formally identified, but the vast majority are still undescribed and the total number could be 8 million or more (Hawksworth *et al.*, 1995).

Our phylum, the Chordates, contains about 45,000 known species, the vast majority of which are vertebrates (animals with spinal columns). These are spread over five classes: about 20,000 fishes; 4,000 amphibians; 7,000 reptiles; 9,000 birds; and 4,000 mammals. Mammalian biodiversity is dominated by two groups of small animals—about 1,700 rodent species (rats, mice, hamsters, squirrels, etc.) and nearly 1,000 species of bats.

Fungi belong to the next most diverse kingdom after the animals—the Mycota. They are believed to number at least 1.5 million species globally, though only about 70,000 have been described (Hawksworth *et al.*, 1995). The most visible kingdom of all, that of the Plants, is well behind the animals and fungi in diversity, but is vital to the success of these kingdoms by providing the raw material for their food.

Most plant species are angiosperms (flowering plants). The total number of identified angiosperm species is almost 240,000, with many more still awaiting discovery in the tropics and in remote areas. The non-flowering plants, such as the bryophytes (e.g. mosses and liverworts), the ferns, and the gymnosperms (e.g. cone-bearing trees) evolved much earlier than the angiosperms but have fewer surviving species. The known non-flowering plants total less than 30,000 species.

### The Adversities of Life on Earth

Evolution is a slow creator and environmental crises are swift destroyers. Five times in the past 500 million years Earth's biodiversity was devastated by catastrophes that together wiped out perhaps 90 percent of the species that ever existed. We, and all living things, are descendants of the handful that got through. The catastrophes appear to have had various causes, ranging from the impacts of asteroids to tectonic plate movements, volcanic eruptions, oceanic gas eruptions and rapid climate changes (Benton, 1993, 1995; Erwin, 1993; Jablonski, 1986; Knoll *et al.*, 1996; Raup and Sepkoski, 1982; Renne *et al.*, 1995; Stanley and Yang, 1994; Ward, 1994; Wilson, 1992).

The greatest catastrophe known, the Permian–Triassic (P–T) crisis of 250 million years ago, occurred when active volcanoes covered 2.5 million square kilometres of shallow sea in what is now Siberia and when the world's deep oceans were belching up large volumes of carbon dioxide. Lava from the volcanoes formed the vast Siberian Traps. Over a million years, episodic eruptions produced huge quantities of steam and sulphurous clouds whose prolonged 'volcanic winter' may have lowered temperatures and brought acid rain to much of the planet (Renne *et al.*, 1995; Kerr, 1995b).

Evidence has also been found of a great build-up of carbon dioxide about this time in stagnant ocean depths, where sluggish currents had allowed vast amounts of decaying algae and bacteria to sink to the bottom. It is argued that this carbon dioxide-rich water eventually surged to the surface, killing sea life and emitting a toxic cloud which killed land animals and triggered rapid climate change (Knoll *et al.*, 1996; Kerr, 1995d). A small-scale version of this happened in 1986 when Lake Nyos, in Africa's Cameroons, released a toxic cloud that killed people and animals.

The last great biodiversity crisis, 65 million years ago, extinguished about half the world's species but is best known for ending the 160-million-year reign of the dinosaurs. Scientists attribute the extinctions to drastic climate changes, but have debated for a decade what might have triggered such changes (Glen, 1995; Kerr, 1994). Some argue that the extinctions occurred gradually over several hundred thousand years and might have been caused by repeated episodes of volcanic activity (Officer, 1993). Volcanic eruptions about this time did, in fact, produce one of the largest outpourings of lava ever known, forming the Deccan Traps of India.

However, most scientists now think that, big as the Deccan eruptions were, their impact was dwarfed by that of the asteroid that punched a 180-kilometre wide indent into what is now Mexico's Yucatan Peninsula (Swinbourne, 1993; Ward, 1994). The buried crater was discovered by oil company geologists. From its dimensions, the meteorite is estimated to have been 10 km across and to have hurtled into what was then a shallow sea at nearly 90,000 km per hour. The impact is believed to have produced huge tidal waves, winds of up to 1,000 km per hour, and vast clouds of dust and vapour as two great fireballs of molten rock erupted, one after the other (Alvarez *et al.*, 1995; Hecht, 1995). The fallout from this impact is still visible even in New Zealand where traces of the meteor's rare metal, iridium, are found in 65 million year old sedimentary rocks. A far-flung fragment of the asteroid itself was found in sea-floor sediments near Hawaii (Kerr, 1996).

It took 10 to 20 million years of evolution for the number of species to increase again. Among the successful evolutionary lines were the mammals and, among them, the primates, whose ape branch eventually sprouted our ancestor and close relative—the chimpanzee. The recency of our chimpanzee origin is reflected in the extraordinarily high genetic similarity between our two species (King and Wilson, 1975a, 1975b; Diamond, 1991) and in a rapidly growing sequence of fossils connecting us to chimpanzee-like ancestors who lived 3.5 to 4.5 million years ago (ago (Brunet *et al.*, 1995; Clarke and Tobias, 1995; Culotta, 1995b; Leakey *et al.*, 1995; Shreeve, 1996; White *et al.*, 1993, 1994; WoldeGabriel *et al.*, 1994; Wood, 1994).

For several million years, various species or sub-species of hominids came and went until biologically modern humans (*Homo sapiens sapiens*) emerged in Africa less than 200,000 years ago (some 5,000–7,000 generations) (Ayala, 1995; Bowcock *et al.*, 1994; Gibbons, 1994, 1995; Goldstein *et al.*, 1995; Nei, 1995; Penny *et al.*, 1995; Waddle, 1994; Wilson and Cann, 1992).

Our species began expanding out of Africa about 70,000–120,000 years ago (3,000–5,000 generations), dogging the 2 million-year-old footsteps of an earlier hominid (*Homo erectus*) which had already faded into the fossil records of China, Africa and Europe (Gibbons, 1995; Lewin, 1994; Mellars, 1996; Stringer and Gamble, 1993; Stringer and McKie, 1996) and survived only in South-east Asia (Lewin, 1996b; Swisher *et al.*, 1996).

The first emigration waves spread eastward along the equator toward India and South East Asia about 100,000 years ago (Stringer and McKie, 1996). Some groups fanned down into Melanesia and Australia (maybe 50–60,000 years ago), while others headed north-east into Asia and the Arctic circle (perhaps 60,000 years ago) and north-west into Europe (about 40,000 years ago). The Asian branches radiated in all directions, eventually sending offshoots into the Americas (about 15,000 years ago) and the islands of Micronesia and

Polynesia (beginning about 2,000 years ago). The process of expansion, migration, mixing and warfare has repeated itself since, both within and between these regions, producing a diversity of peoples, languages and cultures but a disturbing uniformity in their environmental effects (Cavalli-Sforza, 1991, Cavalli-Sforza *et al.*, 1993, 1994).

Right from the start, human invasions of new ecosystems caused extinctions and ecological changes. Among the first victims were the Neanderthal people of Europe, descendants of *Homo erectus* and cousins of our own species (Stringer and Gamble, 1993; Stringer and McKie, 1996; Gibbons, 1996a) and probably the remnant *Homo erectus* people of South-east Asia who were still in the region when the first *Homo sapiens* arrived (Lewin, 1996b; Swisher *et al.*, 1996). Thousands of birds and mammals also became extinct, not just in Europe, but in Australia, Madagascar, the Americas and the Pacific Islands (Culotta, 1995a; Diamond, 1991; Flannery, 1994; Martin and Klein, 1984; Pimm *et al.*, 1995). The Pacific extinctions were the most recent and their scale is only beginning to be understood (Diamond, 1995a; Steadman, 1995; Wragg and Weisler, 1994). As many as 2,000 of the original 3,000 Pacific birds may have disappeared following human contact (Pimm, 1995).

It was the invention of agriculture, however, between 7,000 and 12,000 years ago (300–600 generations) that enabled humans to replace whole ecosystems with just a few species of crop plants and stock animals. The revolution occurred independently in the grasslands and river valleys of Iraq, Egypt, India, China and Mesoamerica. It was made possible by the closing of the last Ice Age whose chill had dominated the global climate for the previous 100,000 years. It is only within the last two centuries (8 generations) that the invention of combustion engines and electricity generation has extended our technological power, enabling us to invade, degrade and remove virtually any ecosystem in the world.

Our towns and farms now cover 37 percent of the globe's land surface, and our activities have significantly disturbed natural habitat over 52 percent of the total land area (World Resources Institute, 1994). Extinctions have soared well beyond natural rates as we replace ecosystems with pasture, crops and settlements and convert their resources into human flesh, artefacts and waste. For the first time since mammals became the dominant land animals Earth's species are disappearing faster than evolution can replace them (Wilson, 1992; Pimm, 1995). Current extinction rates are estimated to be 20–200 times higher than the natural 'background' rates, and, on current population and economic trends, are predicted to reach anywhere between 200 and 1,500 times the natural rate within the next century, wiping out all currently threatened species (Pimm *et al.*, 1995).

Most of the known victims are creatures like us, large land animals, whose size, habitat and small natural populations, make them particularly vulnerable to predation and habitat loss. Globally, about 11 percent of mammals and birds are considered threatened and about 3 percent of reptiles and fish (World Resources Institute, 1994). The order of mammals that we belong to, the Primates, is one of the worst affected, with 66 percent of its species now threatened—including our closest living relatives, the chimpanzees, gorillas and orangutans (Ceballos and Brown, 1995). As the pressures increase, the global family appears to be heading toward another great catastrophe. This time, however, the cause is not a mindless volcano or asteroid, but the most clever species on the planet—which means that, for the first time, the scale of the catastrophe can be a matter of choice (Ward, 1994).

In 1992, world leaders made their choice by signing the Convention on Biological Diversity (or Biodiversity Convention) at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. In signing the Convention they agreed to take measures to prevent the biodiversity crisis from turning into another global catastrophe. The Convention's preamble recognises that biodiversity is important for evolution and for maintaining life-sustaining systems, as well as for its intrinsic value and its ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values (United Nations, 1992). It also notes that the "fundamental requirement for the conservation of biological diversity is the *in-situ* conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings".

Article 6 of the Convention requires each member country to develop national strategies, plans or programmes for conservation and sustainable use of biodiversity and to integrate these as much as possible into relevant sectoral or cross-sectoral plans, programmes and policies. The Convention states that scientific uncertainty should not be used as a reason for postponing conservation measures. New Zealand ratified the Convention in 1993 and, in doing so, embraced the challenge of protecting one of the world's most ravaged but distinctive outposts of biodiversity.

## SOURCES OF BIODIVERSITY DATA

Of an estimated 80,000 or more native animals, fungi and plants in New Zealand, only about 30,000 have been formally described, named and classified by taxonomists (see Table 9.1). Most of the undescribed species are fungi and invertebrate animals, particularly nematode worms and insects. Several hundred plants are also undescribed. On the other hand, it is well known globally that about 20 percent of current species names are synonyms (that is, different names for the same species). These uncertainties should be borne in mind when consulting Table 9.1 which provides a very approximate estimate of the number of species known and suspected in each major living group.

Apart from the uncertainty surrounding the number of species and their identities, considerable uncertainty also surrounds the population status and viability of many known species. Although much data exists on the ecology and behaviour of our more visible and endangered plants and animals, monitoring and research tends to be sporadic and poorly coordinated for most species and ecosystems.

Research on the taxonomy and ecology of indigenous species is carried out by many organisations, particularly universities, the major museums, and several research institutes, notably Landcare Research and the National Institute of Water and Atmospheric Research (NIWA). Most biodiversity research is funded through the Government's Public Good Science Fund and the Department of Conservation. The Department's declining budget, from its inception in 1987 until 1995, has been identified as one of the factors limiting biodiversity research (Halloy, 1995). The small increase in the latest financial year targeted pest control and species recovery programmes rather than research. Recently, however, the public funding for taxonomic work has had a million-dollar increase.

**Table 9.1**

**Indigenous and introduced species in New Zealand (excluding extinct species)[1]**

| Major taxonomic groups | | Estimated number of indigenous species[2] | Number that have been described | Percentage of described species that are endemic | Described species known to be threatened[3] | Number of introduced species in the wild |
|---|---|---|---|---|---|---|
| *SINGLE-CELLED* | Bacteria[4] | ***?*** | ***c 200–300*** | ***?*** | ***?*** | ***?*** |
| | Protozoans[4] | ***c 7,500*** | ***c 2,600*** | ***5%?*** | ***?*** | ***c 100*** |
| | *Land and freshwater* | *3,200* | *c 700* | *5%?* | *?* | *?* |
| | *Marine species* | *3,300* | *c 1,650* | *5%?* | *?* | *?* |
| | *Parasitic species* | *1,000* | *c 250* | *5%?* | *?* | *c 100* |
| | Algae[4] (see also lichen fungi below) | ***c 4,000*** | ***c 3,700*** | *?* | *?* | *?* |
| | *Micro-algae (plankton, periphytons)* | *c 3,000* | *c 2,800* | *?* | *?* | *?* |
| | *- freshwater* | *c 2,200* | *c 2,100* | *?* | *?* | *at least 6* |
| | *- marine* | *c 800* | *c 700* | *?* | *?* | *?* |
| *MULTI-CELLED SPECIES* | *Macro-algae (seaweeds)* | *c 1,000* | *c 900* | *43%* | *none* | *at least 3* |
| | Plants[4] | ***c 3,400*** | ***c 3,080*** | ***65–70%*** | ***c 300*** | ***c 1,900*** |
| | *Mosses, liverworts, hornworts* | *c 1,100* | *c 1,060* | *20–40%* | *c 85* | *13* |
| | *Vascular plants* | *c 2,300* | *c 2,022* | *81%* | *c 200* | *1,896* |
| | *Ferns and allies* | *c 200* | *189* | *46%* | *at least 15* | *26* |
| | *Gymnosperms (conifers)* | *20* | *20* | *100%* | *none* | *28* |
| | *Angiosperms* | *c 2,100* | *1,813* | *84%* | *c 180* | *1,842* |
| | Fungi[4] | ***c 22,000*** | ***c 5,800*** | ***?*** | ***c 200*** | ***c 2,000?*** |
| | *Lichens (fungi which harbour algae)* | *c 1,800* | *c 1,300* | *?* | *?* | *?* |
| | *Other (mushrooms, rusts, yeast, blight, etc.)* | *c 20,000* | *c 4,500* | *?* | *?* | *?* |
| | Invertebrate Animals[4] | ***c 52,000*** | ***c 20,500*** | ***?*** | ***c 200*** | ***c 2,200*** |
| | ***Arthropods*** | ***c 27,300*** | ***c 14,400*** | *?* | *?* | ***c 1,200*** |
| | *Insects (beetles, bees, flies etc.)* | *c 20,000* | *c 10,000* | *90%* | *c 175* | *c 1,100* |
| | *Arachnids (spiders, mites etc.)* | *c 4,600* | *c 2,600* | *90%* | *5–10* | *c 60* |
| | *Pycnogonids (sea spiders)* | *c 120* | *53* | *?* | *?* | *?* |
| | *Crustacea (crabs, copepods, slaters etc)* | *c 2,000* | *1,517* | *?* | *5* | *?* |
| | *Myriapods (millipedes, centipedes etc)* | *c 600* | *c 200* | *?* | *?* | *?* |
| | ***Molluscs c*** | ***4,800*** | ***c 2,500*** | *?* | *?* | ***c 40*** |
| | *Land and freshwater snails and slugs* | *c 1,300* | *c 500* | *100%* | *15* | *c 33* |
| | *Marine species (snails, shellfish, squid etc)* | *c 3,500* | *c 2,000* | *?* | *?* | *at least 6* |
| | ***Worms (many phyla)*** | ***c 17,500*** | ***c 1,500*** | *?* | *?* | ***c 980*** |
| | *Nematodes (roundworms etc.)* | *c 11,400* | *414* | *43%* | *?* | *c 600* |
| | *Annelids - earthworms* | *220* | *178* | *100%* | *at least 3* | *c 25* |
| | *- other (marine polychaetes etc.)* | *c 4,200* | *c 430* | *30–35%* | *at least 1* | *c 230* |
| | *Platyhelminths (flatworms, cestodes etc.)* | *430* | *80* | *56%* | *at least 3* | *c 75* |
| | *Other worms (spiny-heads, tunicates etc.)* | *c 1,200* | *c 400* | *?* | *?* | *c 50* |
| | ***All Other Invertebrates[5]*** | ***c 2,600*** | ***c 2,100*** | *?* | *?* | *?* |
| | Vertebrate Animals[4] | ***c 1,500*** | ***c 1,250*** | ***21%*** | ***c100*** | ***90*** |
| | *Fish - sea-dwelling marine species* | *c 1,100* | *c 870* | *5%* | *2* | *?* |
| | *- rockpool marine species* | *c 100* | *94* | *62%* | *9* | *?* |
| | *- freshwater species* | *c 35* | *28* | *90%* | *10* | *20* |
| | *Amphibians (frogs)* | *4* | *4* | *100%* | *4* | *3* |
| | *Reptiles* | *61* | *61* | *100%* | *25* | *1* |
| | *Birds - land and freshwater* | *88* | *88* | *57%* | *37* | *34* |
| | *- seabirds* | *61* | *61* | *30%* | *18* | *0* |
| | *Mammals - land-based* | *2* | *2* | *100%* | *2* | *34* |
| | *- marine mammals* | *41[6]* | *41* | *5% (2 spp.)* | *4* | *0* |
| | TOTAL (multi-celled species only)[4] | ***c 80,000*** | ***c 30,000*** | ***?*** | ***c 800*** | ***c 6,000*** |

[1] *No inventory of biodiversity has been attempted since the National Museum's 1980 symposium on the NZ biota (Brownsey and Baker, 1983). This table draws on that work and on the opinions of several current taxonomists, but is far from definitive.*
[2] *Total species estimates are highly uncertain, except for plants and vertebrate animals.*
[3] *Full species only. If sub-species were included, the total number of known threatened taxa would be about 1,000.*
[4] *Given the imprecision of many of these figures, all totals and sub-totals have been rounded to avoid spurious accuracy.*
[5] *Includes 350 known sponges, 400 cnidarians, 400 echinoderms, 900 bryozoans, and about 50 species from minor phyla.*
[6] *Includes 34 cetaceans and 7 pinnipeds, many of which are visitors and seasonal migrants.*

Reviews of the biological sciences by the Ministry of Research, Science and Technology (1992, 1993) found that ecological research in New Zealand is thinly spread and uncoordinated while taxonomic research is in marked decline. The number of scientists doing taxonomic work has fallen radically since 1980, to the point where retired scientists have been prevailed upon by Landcare Research to identify species of freshwater algae, mushrooms and grasses, and the National Museum of New Zealand employs retired staff and Ph.D. students on a part-time basis to undertake taxonomic work on its vast collections of unidentified species.

Despite the lack of coordinated research and the relative scarcity of information on many species, a wide range of *ad hoc* information and case studies exist relating to particular species or phyla. In some cases, disparate information has been drawn together in key publications (e.g. Williams and Given, 1981; Brownsey and Baker, 1983). Biodiversity databases are located in a variety of institutions. Landcare Research, for example, maintains native plant, fungus, plant bacteria and arthropod databases. NIWA maintains a freshwater fish database which is updated twice a year, as well as commercial marine fish stock databases. Other databases on species identification, distribution or conservation status are held by universities, museums, professional associations (e.g. the Ornithological and Botanical Societies) and the Department of Conservation.

Key information sources used in the preparation of this report have included species and stock assessments by the the Ministry of Fisheries (Annala 1995a, 1995b), Department of Conservation (1992b, 1994b, 1994e), the New Zealand Botanical Society (E.K. Cameron *et al.*, 1993, 1995) and Landcare Research (Buchanan and Beever, 1995).

The Ministry of Fisheries' assessments cover about 40 fish species, representing about 2 percent of our fish biodiversity, and about half a dozen marine invertebrates. The assessments are undertaken by 13 working groups convened by the National Institute of Water and Atmospheric Research (NIWA) under contract to the Ministry of Fisheries. The working groups are led by marine scientists and also include representatives of the fishing industry, Maori tribes, recreational fishing groups and environmental groups. The panels work primarily from catch data and trawl survey data to assess each stock's reproduction rate and distribution.

The Department of Conservation's species assessments cover a broader range of species and are based on far less information. The Department has published a draft status list for marine organisms (Department of Conservation, 1994e) and a periodically updated list of threatened land and freshwater organisms, ranked according to their conservation priority (Department of Conservation, 1992b, 1994b). The Department lists as 'threatened' any species or sub-species which falls into one of the following internationally defined categories: endangered; vulnerable; rare; indeterminate; and insufficiently known.

The conservation priority of each species is reviewed by panels of experts which include Department staff and scientists from Crown Research Institutes, universities, private consultancies and environmental organisations (Department of Conservation, 1992b, 1994b). Threatened species are placed into ranked categories (A, B and C) or unranked ones (I, O and X). Category I, the single largest category, contains 324 taxa which are presumed threatened, but for which there is insufficient information to rank their priority.

The need to prioritise threatened species is largely an economic one because funds are limited. As a result, priorities in biodiversity research are often hotly debated, with arguments about which species should be targeted, whether to focus on genetic investigations or population studies, or whether to shift away entirely from species-centered research toward more ecological research.

In a recent review, which concluded that biodiversity research is under-funded and poorly coordinated, Halloy (1995) opened the priorities debate wider. He suggested that, while the main priority in New Zealand's biodiversity research should continue to be the preservation of native endemic species, there is also scope for including some introduced species. With our low population density and high social and economic stability, New Zealand could consider becoming an international 'ark' for rare breeds and endangered species which are no longer safe in their homelands. Exotic species have an ambiguous status in New Zealand. Farmed species are the backbone of our economy but feral species impose heavy pest control costs. In either case, they tend to be hostile to indigenous ecosystems and biodiversity. This Jekyll and Hyde quality means research on exotic species is needed both to manage their economic use and to control their ecological effects (see Box 9.3).

Considerable research effort is also now going into the economic uses of native species. Most of this research is privately funded and, apart from fish stock assessments, its focus is not on population or ecological status, but on chemical properties which may be of use in the manufacture of pharmaceuticals and industrial chemicals (bioprospecting). The biochemical research has focused mostly on plants and algae. Although this research is enabling more unknown species to be identified, and also provides a rationale for preserving potentially valuable species, it makes no direct contribution to assessing their status or the pressures they face. Indeed, for some species, it may increase the pressure by creating a hitherto non-existent demand for them.

Present information on New Zealand's biodiversity is scattered. Most of our indigenous fungi and invertebrate animals have not been identified, and the status of most species is not monitored. Information is best on vertebrates and vascular plants. Fungi, mosses, invertebrates, protozoans, algae and bacteria are less well known. Privately funded research focuses more on the potential uses of biodiversity than on its conservation status and ecology.

Standard methods of classifying and measuring the status of our biodiversity have not yet been devised, but considerable research effort is going into this at regional and national levels, including work by the Department of Conservation and the research institutes on ecosystem monitoring, and by the Ministry for the Environment on developing a core set of national biodiversity indicators (Ministry for the Environment, 1996a, 1996b).

**Box 9.3**

### *Sustainably managing our exotic biodiversity*

Apart from marine fish and invertebrates, nearly all of New Zealand's economically important species, including pests and weeds, are exotic (i.e. introduced from other countries). This exotic biodiversity consists of 33 mammals, 33 birds, 1 lizard, 3 frogs, 20 freshwater fish, perhaps 1,000 invertebrates, about 100 parasitic protozoans, and perhaps 6,000 plants (nearly 2,000 of which are now established in the wild). Of these, about 25 animals and 120 plants are commercially farmed or cultivated, though the vast bulk of production comes from just 5 animals (chickens, sheep, cattle, deer, pigs) and 40 plants (pasture grasses, pine and Douglas fir trees, barley and other grain crops, peas, potatoes and other vegetables, grapes, kiwifruit, apples and other fruit).

The commercially important species are each divided into breeds, and these in turn are divided into strains, varieties and lines. Although some lines have been selectively bred here and are physically unique, none is genetically novel. This is because selective breeding does not create new genes, it simply reshuffles and sifts existing ones. Reshuffling is achieved by hybridising among breeds and varieties. Sifting is carried out over several generations by selective inbreeding among the hybrids. The result is actually a reduction in genetic diversity as unwanted genes are selected out of the gene pool until, eventually, all members share identical genes for a desired trait (e.g. placid temperament, fast growth rate, drought tolerance, high yield etc.). The genetic diversity of crop and livestock species is therefore only partly represented in any one strain or variety. This makes each one important, including wild variants and ancestral stocks, because each holds a unique subset of its species' total gene pool, though, in the case of recently developed strains and varieties (such as those in New Zealand) the genetic loss would be minor as they differ little from their parent stocks.

Maintaining diverse breeds and varieties is important for commercial as well as genetic reasons. It could take years, or even decades, of special breeding programmes to recreate a lost variety from its parent stock or related breeds. The only way to ensure that they are not lost, is to maintain their genes, either in living populations, or in collections of seeds, tissues, semen and embryos. However, this is costly so only those breeds and varieties considered to be of high priority are conserved in this way. New Zealand's Plant Variety Rights Act 1987 creates an economic incentive to develop new strains and varieties by protecting the breeder's propagation rights. However, there is no equivalent measure for encouraging the conservation and storage of existing stocks.

The loss of crop diversity is a global problem, and the need to conserve and sustainably use agricultural biodiversity is recognised in the 1992 United Nations Convention on Biological Diversity. The decline has been gathering pace for the past century as genetically uniform, high yield varieties have replaced traditional local varieties (Hawksworth *et al.*, 1995). High yielding varieties are more profitable, in part because they have been bred for disease and pest resistence. Nevertheless, the low genetic variation of some widely distributed varieties makes them vulnerable to unfamiliar diseases and pests. Examples of such crop failures include: the potato famine of Ireland last century; a grape blight that wiped out valuable vines in France and the United States; a virulent disease that has wiped out banana crops in Central America; and a mould that infested hybrid maize in Zambia. To deal with such threats, the continuous development of new varieties is essential and this requires ready access to a broad range of existing genetic material (e.g. traditional varieties and wild relatives) from which to breed. Some overseas crops have been rescued from epidemics by using genes from older, forgotten varieties, or from wild relatives, to develop new varieties. The rescued crops include: potatoes; rice; sweet potatoes; wheat; maize; sugar beet; and rubber (Holden *et al.*, 1993).

Despite their differences in outward appearance (phenotype), the plant and animal breeds of a given species are similar at the genetic level. This is because even the oldest breeds have had little time to evolve any new genetic diversity. It takes a million or more years for random mutations and natural selection to produce genetically distinct species. Plant and animal domestication is just several thousand years old. Like civilisation itself, it is a recent, late development in human history.

Our oldest domesticated species is the dog, bred in Eurasia from wild canids (wolves and jackals) more than 12,000 years ago (Davis and Valla, 1978; Olsen, 1985). The oldest skeletal remains of a domestic dog were found in Israel, but a skeleton from Idaho in the United States is nearly as old, at more than 10,000 years. Wolf, jackal and dog genes remain very similar, and all of today's 500 dog breeds are genetically close. Yet, by selecting and winnowing just a few key genes over many generations, dog breeders have managed to produce a wide variety of physical and behaviourial differences—and also a raft of inherited disorders from inbreeding (Bonner, 1994).

In contrast, cats, which were domesticated in Egypt only about 4,000 years ago, show much less diversity. Most of our other domesticated animals and crops were acquired between the taming of these two species. New Zealand's agricultural biodiversity, therefore, has its evolutionary roots in the early civilisations of Europe, Asia and the Americas.

The labour-intensive business of crop farming originated in the Middle East about 10,000 years ago and was followed shortly after by animal herding. The first crops of wheat (*Triticum* spp), barley (*Hordeumi* spp), oats (*Avena* spp) and rye (*Secale* spp) were bred from grain-bearing wild grasses (cereals), and peas were domesticated from pod-bearing wild legumes (Zohary and Hopf, 1993; Solbrig and Solbrig, 1994). This revolutionary development seems to have been driven by hard times as the world's first urban populations, at Jericho, Tel Aswad and other East Mediterranean sites ran out of wild food sources (Wright, 1994; Bunney, 1994).

It took several thousand years for Middle Eastern farmers to spread out from the area that is now Turkey and around the Mediterranean into Europe (Lewin, 1996a). During this time, wild cereals were independently domesticated in several other parts of the world. Rice (*Oryza* spp) seems to have been first domesticated in China's Yangtze Valley (Normile, 1996) and by 7,000 years ago was being grown in southern Asia. By then, millet (*Setaria* spp)and sorghum (*Sorghum* spp) were being grown in Africa and maize (*Zea* spp) may have been domesticated in South America, though it did not become widespread there until much later (Hawksworth *et al.,* 1995; Mestel, 1993). When agriculture reached Europe 7,000 years ago, it also inspired the cultivation of flax for linen. Fruits and nuts (e.g. figs, dates, grapes) were domesticated in the Middle East about 4,000 years ago. By the time of the Roman Empire (1,600–2,000 years ago), almost all of today's crops and domestic animals were being farmed (Diamond, 1994; Solbrig and Solbrig, 1994). Developments since then have largely focused on creating new breeds and varieties.

The first domesticated food animals also arose in the Middle East: the pig more than 9,000 years ago; sheep and goats a little later; and western cattle (*Bos taurus*) about 7–8,000 years ago (Clutton-Brock, 1987; Diamond, 1995b; Hyams, 1972; Loftus *et al*., 1994). The wild ancestors of all these species were probably attracted to crops and scrap heaps on the outskirts of the world's first towns. Cattle became both a food source and a form of slave labour for transport and ploughing. They were later joined as beasts of burden by the tamed African wild ass, or donkey. Horses came later, from the north. They were tamed in the Russian steppe grasslands, about 6,000 years ago, by the warrior Kurgans who then rampaged east and west, taking both the horses and their Indo-European culture and languages into Europe, Iran, northern India, the Hittite Empire of the Middle East and the Tocharian settlements along the mountain trade route into western China (Anthony *et al.,* 1991; Diamond, 1991). By 4,000 years ago, Indian civilisation had tamed zebu cattle (*Bos indicus*), several species of buffalo, and the wild red jungle fowl, which, as the humble chicken, is now the most abundant livestock animal on Earth, numbering more than 10 billion—against 1.3 billion cattle, 1.2 billion sheep, and 850 million pigs.

Today, the world's eight main livestock mammals (western and zebu cattle, sheep, goats, pigs, buffalo, horses and asses) comprise about 3,000 breeds, of which nearly 400 (14 percent) are considered to be at risk of dying out (Hawksworth *et al*., 1995). Only nine of the many chicken breeds are widespread; most of the minor breeds and varieties are declining and some have disappeared. The UN Food and Agricultural Organization has recently estimated that the world has about 30,000 species of edible plant species, of which 7,000 have been grown for food (FAO, 1996). However, only 150 species are commercially important, and 90 percent of the world's food crops come from just 100 of these. Even this diversity is reduced when it is realised that more than half our plant energy intake comes from species and varieties of just three grasses: wheat, rice and maize. Despite their low species diversity, many crops have yielded hundreds or even thousands of varieties in several thousand years of cultivation. For example, the main species of rice (*Oryza sativa*) has 100,000 distinct varieties. In all, an estimated 1 million varieties of plants are now threatened (Edwards, 1996).

An inventory of 'at risk' exotic biodiversity has yet to be compiled for New Zealand. Our domestic animals include: cattle (two species), sheep, pigs, goats, deer (several species), horses, donkeys, dogs, cats, poultry (chickens, ducks, geese, turkeys), and more recent imports such as alpaca, llama, water buffalo, emu and ostrich. We have about 40 cattle breeds and 30 sheep breeds with several additional derived sheep breeds, such as Coopworth (bred from Romney and Border Leicester hybrids) and Perendale (bred from Romney and Cheviot hybrids). Pedigree lists of pure breeds are often maintained by a Breed Society. The New Zealand Pastoral Agriculture Research Institute (AgResearch) holds most of the semen for beef cattle and sheep. Dairy cattle semen is held by artificial insemination organisations. The Livestock Improvement Corporation has the largest store, though some semen is stored under contract to private breeders.

Most of New Zealand's factory farmed chickens are hybrid varieties, specially bred by international corporations. New Zealand franchise holders are regularly supplied with the latest breeding stock so no effort is made to retain superseded varieties or develop new ones. The local poultry industry is supplied by two companies, Hi-Line International (Iowa, U.S.A.) and I.S.A. (France), whose hybrid varieties, with names like Hi-Line W77, combine the genes of several standard breeds (e.g. Mediterranean Leghorn, New Hampshire, Rhode Island Red). These state-of-the-art birds are selectively bred to quickly lay eggs (up to 320 per year) or put on meat (reaching 1.8 kg in 5 weeks—five times faster than a 'normal' chicken). At present, the New Zealand industry processes about 62 million meat chickens and 2.4 million egg-layers per year.

The four main commercial pig breeds are Large white, Land race, Duroc and Hampshire. The New Zealand herds differ little from those overseas. About half come from stock supplied by two organisations, the Pig Improvement Company and the National Pig Breeding Company. These maintain small nucleus herds whose gene lines are constantly improved through regularly imported semen and selective breeding. Semen is not stored. With pigs, chickens and other livestock, small populations of pure breed and non-commercial varieties are kept by private enthusiasts, many of whom are affiliated to the Rare Breeds Association. Other exotic species that are economically important are introduced earthworms, honey bees and biocontrol insects.

Forage plants (i.e. grasses, clover and other plants for animals to graze) are New Zealand's most economically important plant genetic resource, both for pastures and lawns. Yet New Zealand has genetic samples of fewer than 7 percent of the world's grass species. The national forage collection is held as seeds at AgResearch's Margot Forde Centre in Palmerston North, which is an Australasian regional centre for temperate forage species. The Centre is recognised as having a collection of national importance by the Foundation for Science, Research, and Technology (FRST) and funding is relatively secure. Private breeding firms have their own working collections of forage plants, but do not maintain unprofitable breeding lines.

The main collections of field and vegetable crops are held by the New Zealand Institute for Crop and Food Research Ltd (Crop and Food), though several minor collections (e.g. hops) are held by the Horticulture and Food Research Institute of New Zealand Ltd (HortResearch) at the Riwaka Research Centre, Motueka. The New Zealand hops collection is free of many pests and diseases found in other countries. These collections receive government funding on the basis that they are 'Collections of Significant National Importance'. Such funding is confined to economically important varieties of wheat, barley, oats, maize, peas, onions, potato, kumara and some vegetables. HortResearch also maintains the only comprehensive fruit gene collections in New Zealand. Some of these, such as the apple and kiwifruit collections, are among the most important in the world. The kiwifruit collection is the best outside the fruit's homeland, China. The Asian peaches and nectarines collection is unique outside Asia, and the apricot collection is rich in genetically diverse material with cultivars from North America, southern and northern Europe and North Africa.

Collections of nut crops are held only by private individuals so their conservation is not underwritten by any public agency at present. The Novel Crops Programme run by Crop and Food includes a collection of native and exotic plants and animals whose desirable attributes include extracts, medicinal uses, aromatic properties and spices (Halloy 1995). HortResearch holds a collection of plants and seeds at Aokautere, near Palmerston North, selected for soil conservation and shelterbelt purposes. The collection is used to breed new plants for farmers. The Institute's collection of willow (*Salix* spp) and poplar (*Populus* spp) varieties is of world importance. The Forestry Research Institute (FRI) holds living examples, and in some cases seeds, of 120 species of trees. About 15 are of commercial interest, and a further 25 have commercial potential. The trees are mainly exotic, but some natives are included (Halloy 1995). New Zealand also has many ornamental plant collections, some of world importance, particularly for species under threat in their country of origin. The Royal New Zealand Institute of Horticulture (RNZIH) is keen to foster local networks and possibly a national network of exotic and native plant collections, including ornamentals. The Herb Federation of New Zealand (Inc) also supports a semi-formal network of collections of herb species and varieties (Halloy, 1995).

The main threats to non-commercial and unfashionable crops and livestock are the lack of facilities to keep live populations or store genetic material (i.e. seeds, semen etc.) and the lack of resources to properly document and authenticate them (Halloy, 1995). It is not known how much of the material stored in genebanks is still alive, though current management practices often appear deficient. Collections of minor crops, such as nuts, rare fruits, and ornamentals, are at risk. There is no national register to identify them and few collections are under institutional supervision. New funding would be required to ensure that all surviving cultivars are maintained. As there are many thousands of varieties stored in gene banks, and no way of knowing in advance which of these will be needed for future breeding programmes, the maintenance of such gene banks is essentially a public good.

There is an international dimension to our need for adequate crop and livestock conservation measures. As a signatory to the International Undertaking on Plant Genetic Resources (1983) New Zealand has agreed to maintain important genetic material and share it internationally (there is no parallel agreement relating to animals). The International Convention for the protection of New Varieties of Plants (abbreviated to the French acronym, UPOV) provides a legal framework which allows legal rights to ownership of plant varieties for a limited number of years. With its wide range of climatic and habitat conditions and a relatively disease-free environment, New Zealand is well-placed to even become a repository for exotic taxa whose future is insecure in their country of origin (Halloy, 1995). This may also apply to certain wild plants and animals.

However, the need to conserve desirable exotic biodiversity must be balanced against the need to control harmful species. Our 120 crop and forage plants, for example, are matched by more than 200 exotic weeds that threaten native ecosystems (Timmins and Mackenzie, 1995). In some cases, the helpful and harmful species are one and the same. Pasture grasses and pine trees are worth millions of dollars to the economy, but their spread has often been at the expense of native forests, wetlands and dunelands. Livestock, too, can cause damage by wandering into forests and wetlands and defecating near waterways. Conserving exotic biodiversity, therefore, must go hand in hand with vigilant pest and weed control and sustainable farm and forest management.

## THE NATURE OF NEW ZEALAND'S BIODIVERSITY

New Zealand has a relatively small number of indigenous flowering plants and vertebrate animals by tropical or continental standards. This is partly because our isolation from continental landmasses limited large-scale recolonisation by these groups after the global extinction catastrophe of 65 million years ago. It is also partly the result of a long period of submergence between 60 million and 30 million years ago, when up to four-fifths of the landmass sank below sea level, leaving just a few islands (Cooper and Milliner, 1993). The ice ages of the past two million years also had an effect, reducing habitat and fragmenting populations into ecological 'islands'.

These factors limited the number of major plant and animal groups in New Zealand, but they also contributed to the uniqueness of the surviving groups. Cut off from the rest of the world, evolution took an eccentric course here, leading to a high percentage of endemic, or unique, species. This high rate of endemism is what makes New Zealand's biodiversity both special and highly vulnerable.

### The Age of the Birds

When New Zealand parted company with the prehistoric super-continent, Gondwana, about 80 million years ago, it was a mammal-free forested raft of birds, reptiles (including dinosaurs), frogs and strange invertebrates, some of them 'living fossils' from the previous Jurassic age. From then until the recent arrival of humans New Zealand had the longest period of isolation of any non-polar land mass on Earth. Our endemic biodiversity reflects this. It is dominated by plant, animal and fungal groups which arose more than 100 million years ago and which tend to be overlooked because of their lack of colour and size. These include flatworms, snails, mites and spiders, primitive insects (solitary bees and wingless crickets), and many species of fungi, mosses and liverworts. The 'higher' plants and animals are relatively under-represented, but those which do occur are mostly unique.

Following the extinction of our dinosaurs, pterosaurs and plesiosaurs 65 million years ago, the land became dominated by birds—to such an extent that they may have affected the distribution and composition of the country's vegetation (Atkinson and Greenwood, 1989; Clout and Hay, 1989; Wellman, 1994). For example, moa browsing may have maintained a relatively open forest understorey. Seabirds are known to have had a profound influence on the lowland and coastal vegetation, as shown by the high number of rare and declining plant species in these habitats now that seabirds are less abundant (Norton *et al.*, in press).

Some birds evolved into unique new forms (e.g. a giant penguin, the world's largest eagle, the flightless kakapo ground-parrot, the mammal-like kiwi and the celebrated giant moa, taller than any other bird). Flightless birds filled roles that small mammals elsewhere may fill, foraging on the ground, living in burrows and hollows. Their only predators were eagles. Poisonous insects and spiders were rare, and snakes were absent. Surrounding the birds were a range of other plants and animals, some of which still retained their ancient Jurassic forms (e.g. the fern Loxoma, kauri and podocarp trees, freshwater mussels, freshwater crayfish, the strange worm-come-insect *Peripatus*, giant wetas and giant snails, lung-bearing slugs, primitive native frogs, and tuatara). In the absence of mammals, giant wingless crickets (wetas) became the ecological equivalents of mice (see Box 9.4). While the rest of the world had entered the Age of Mammals, New Zealand had taken a unique evolutionary path and entered the Age of Birds.

**Box 9.4**

### *Jurassic giants*

Giantism evolved in various groups of New Zealand animals (Daugherty *et al.,* 1993). The giant birds, such as Haast's eagle and the moas, are extinct but many invertebrate giants still hang on in the face of rat predation and habitat destruction. Most are confined to isolated locations or rat-free islands (Meads, 1990). The world's heaviest insect is among them - the giant wingless cricket, or weta, of Little Barrier Island. At lengths of more than 8 cm and weights of up to 70 g, this relative of primitive grasshoppers is as heavy as 4 or 5 mice. Known to Maori as the wetapunga or 'god of ugly things', it is the largest of our dozen giant weta species (*Deinacrida* spp.). It has a docile temperament and lives high in the tree tops. In Jurassic times, 190 million years ago, giant wetas were widespread around the world. Now New Zealand is their only holdout.

While all seven species of the smaller tree weta (*Hemideina* spp.) are quite common, the giants face an uncertain future. All but one, the alpine scree weta (*D. connectans*) of the South Island mountains, are listed as threatened. Another group of wingless crickets, the large elephant or tusked wetas, is also under extreme threat. Named for their 2 cm tusks, these wetas can grow up to 8 cm long and live in ground burrows. Three species have been discovered. One is confined to a few hectares of forest on Middle Mercury Island, near the Coromandel peninsula, one is scattered in parts of Northland and one was recently discovered in the Raukumara mountains in Bay of Plenty.

New Zealand's other large insects cannot challenge the weta or the several species of tropical beetle that reach lengths of 15 cm or more. Nevertheless, by normal insect standards, some still qualify as giants. They include: our largest beetle, the huhu or longhorn beetle (*Prionoplus reticularis*), which grows to 5 cm in length; Helm's stag beetle (*Dorcus helmsi*) which can reach up to 4 cm; various large weevils (*Anagotus* spp.); and the enormous Buller's moth (*Aoraia mairi*) whose 6 inch (15 cm) wingspan caught the eye of Sir Walter Buller while hunting huia birds in the Ruahine Ranges 120 years ago. It has not been seen since (Meads, 1990).

Myriapods (millipedes and centipedes) are a less flamboyant class of arthropods than the insects, but they also have monsters, such as the giant pill millipede (*Procyliosoma tuberculata*). Unlike its smaller relatives in Europe, which were swallowed as folk medicine, this pill would be hard to wash down with a glass of water. Females can grow up to 5 cm long and 2.5 cm wide. They feed on rotting leaves and are widespread in the North Island and northern South Island. They reach full size, however, only on rat-free islands. Then there is the giant centipede (*Cormocephalus rubriceps*) which, at 25 cm, looks like the caterpillar from Hell with its armour-plating and jointed legs. However, mothers are protective of their young, even carrying them around. They capture prey (usually insects, spiders, snails and slugs) with claw-tipped pincers which inject a lethal poison. They can even kill small lizards. Though still present in the North Island, full-sized ones are only found on rat-free islands (Meads, 1990).

Spiders belong to the third class of land arthropods, the Arachnids. Our largest, the Cave spider (*Spelungula cavernicola*), may be a 'missing link' between primitive spiders, which arose 350 million years ago, and the modern 'true' spiders. Its 3 cm body and 30 cm leg-span have startled more than one speleologist in the limestone caves of the Tasman Region where it lives. It is very rare and is the only spider protected by the Wildlife Act 1953 (Faulls, 1991). Another group of indigenous giants confined to the Tasman Region are the giant red flatworms (*Geoplana* spp.), which can reach lengths of 20 cm. They hunt by smothering their victims (mainly slugs and snails) in slimy mucus. Once abundant, they are rarely seen today.

Far more widespread are the nine species of giant land snail (*Powelliphanta* spp.) whose colourful shells can be up to 10 cm in diameter. Some of these snails have human-scale lifespans, taking up to 15 years to reach maturity and living 40 years or more. Their reproductive rates are correspondingly low. The giant snails belong to the oldest family of carnivorous land snails on earth, having originated about 200 million years ago. They prey mainly on earthworms, slugs and other snails. Although they are scattered across habitats ranging from forest to alpine grassland, they have been driven into confined areas and nearly all are listed as threatened. Related to the giant snails are the giant leaf-veined slugs (*Pseudaneitea gigantea*) which, at 15 cm, are the largest of our native slugs. These have also been driven into relic areas of forest and tussock grassland.

## THE PRESSURES ON OUR BIODIVERSITY

Left to itself, New Zealand's bird-dominated world would have continued to depart from the evolutionary mainstream. But the arrival of people changed all that. In one sense, species diversity increased after humans arrived, because of the influx of exotic plants and animals. But the invaders also wiped out several unique endemic species and endangered many others. The gains were local but the losses were global. Today, Earth's biodiversity is dozens of species poorer because of the effect of humans and their exotic plants and animals in New Zealand.

The arrival of people brought three main pressures to bear on New Zealand's endemic species: *human predation* (hunting, fishing and gathering); *habitat destruction* (deforestation, wetland drainage, fragmentation and degradation of ecosystems); and *pests* and *weeds* (alien organisms which prey on or compete with indigenous species or degrade their habitat). These pressures arrived in two historically distinct waves; the process started by the first wave (Maori) was accelerated by the second wave (European).

### The First Human Invasion

New Zealand's long period of ecological quarantine ended when Polynesian mariners, with their families, dogs and rats, settled here 700–800 years ago (Anderson, 1991; McFadgen *et al.*, 1994). The first settlers also brought half a dozen tropical plants for food, fibre and gourds. This seemingly small ecological invasion of New Zealand was the last leg in our species' colonisation of the non-polar world. As with human intrusions elsewhere, the native species felt the effect almost immediately (Anderson and McGlone, 1992; McGlone *et al.*, 1994).

Forests were repeatedly set alight over wide areas (see Chapter 8). Seals and birds were hunted, with seals initially providing the main meat supply (Davidson, 1984). The birds were also preyed on by rats, and probably dogs, which ate the eggs and chicks of ground-nesting species. First to go were the native swan, giant goshawk, coot, crow, two geese and three ducks, followed by the giant rail, the native pelican, the giant Haast's eagle—the largest eagle that has ever lived—four smaller rails, the owlet-nightjar, a snipe and at least two wrens. The largest birds of all were given the Polynesian name for chicken, *moa*, and were avidly hunted. All eleven species went into rapid decline (King, 1984; McGlone, 1989; Anderson, 1989; Anderson and McGlone, 1992).

The number of moa skeletons in known Maori food sites is estimated to be between 100,000 and 500,000—many more than the total moa population of 60,000–70,000 estimated to have been alive at any one time (Anderson, 1989; Diamond, 1991). One of the earliest archaeological sites, at Shag Mouth in the South Island, was assumed to have been occupied for a long time because it contained the bones of about 6,000 moas. New radiocarbon dates, however, indicate that it was settled sometime after A.D 1300. and was occupied for a comparatively brief time, possibly little more than 20 years (Anderson and Smith, 1996).

Pressure on the environment seems to have intensified as the human population expanded and prey species declined. By about 1400, fires were raging in many parts of the country, destroying both lowland and upland forest and replacing them with bracken and tussock grassland (Anderson and McGlone, 1992; McGlone *et al.*, 1994; McGlone *et al.*, 1995). The fires continued to devastate the forests for about two centuries, finally dying out between 1550 and 1600. As the deforestation came to an end, fortified villages began to appear, suggesting that resident tribes were having to defend their territories and dwindling resources against each other (McFadgen, 1994). Regenerating forest continued to be cleared by fire, but the destruction of mature forest had almost ended by 1600 and would not resume again until the early 1800s (Cameron, 1961, 1964).

By then, a third or more of the forest had gone and, with it, a quarter of the endemic land-based birds (some 34 species and 1 subspecies) and a fifth of the endemic seabirds (4 out of 22 species). The extinct seabirds and all but 9 of the extinct land birds have been found in Maori middens. One of the species thought to be absent from middens, the owlet-nightjar (*Megaegotheles novaesealandiae*), has recently been identified with a midden (McCulloch, 1994). The non-midden species were probably exterminated by rats, fires and the effects of deforestation.

Among the survivors, the flightless takahe (*Porphyrio mantelli*), kakapo (*Strigops habroptilus*), huia (*Heterolocha acutirostris*), southern crested grebe (*Podiceps australis*) and little spotted kiwi (*Apteryx oweni*), were reduced to localised populations, and the merganser duck (*Mergus australis*), which once occurred throughout New Zealand, was eliminated from all but the remote Auckland Islands (Anderson and McGlone, 1992).

The extinctions also included three native frogs and an unknown number of invertebrates, few of whom left fossils. Tuataras became extinct on the mainland, with at least one species vanishing altogether and the two remaining species limited to rat-free islands (Daugherty *et al.*, 1990). Some lizard species also vanished except on rat-free islands. Fur seal colonies, which once existed the length of New Zealand, were eliminated from the northern North Island by 1500 and from all but the far south by 1800 (Davidson, 1984; Smith, 1989; Anderson and McGlone, 1992). Sea lion and elephant seal remains are found throughout New Zealand in early Maori middens, but had become rare by 1500 and absent by 1800.

The elimination of seals, sea lions and large birds forced the Maori population to concentrate more heavily on a limited range of plant foods (e.g. fern root, kumara, cabbage tree root) and on fish, crustaceans and molluscs. None of these became extinct, but midden remains show that some coastal shellfish populations disappeared completely (Davidson, 1984; Anderson and McGlone, 1992). On the other hand, freshwater fish appear to have benefited from the increased attention, occasionally having their populations enhanced by the transfer of some species (e.g. eels and smelt) to waters where they were rare or depleted (Strickland, 1993). Similarly, flax snails from Northland seem to have been transferred to the Poor Knights Islands as a food delicacy (Hayward and Brook, 1981).

As meat and animal fat sources declined and competition for territory increased, a small number of Maori left the South Island and settled in the Chatham Islands. Archaeological evidence suggests that this occurred between 1550 and 1600 (McFadgen, 1994). Surrounded by sea lions, fish and seabirds, these people, the Moriori, were able to abolish warfare and establish a pacifist society which remained isolated from the rest of New Zealand for more than two centuries. During this short time, however, the sea lions disappeared and about 20 bird taxa, including half the endemic species, became locally extinct while another four species were heavily reduced in range (Anderson and McGlone, 1992). The lost endemic species included several seabirds and the Chathams duck (Holdaway, 1989; Bell and Robertson, 1994; McFadgen, 1994). Of the 21 petrels that once bred in the Chathams, only 6 remain today (McGlone *et al.*, 1994).

As with human societies elsewhere, it took some time for the Maori communities to learn from their environmental mistakes. By the time they had developed customs and practices to limit access to, and abuse of, treasured parts of the environment, they were living in a depleted landscape where competition for food resources had become a fact of life (McGlone, 1989). The same process has been recorded from Hawaii, Easter Island, Henderson and Pitcairn Islands and other parts of the Pacific, as well as Madagascar, the Mediterranean (e.g. Cyprus and Crete), mainland Europe, North and South America and Australia (Culotta, 1995a; Diamond, 1991; Dodson, 1992; Flannery, 1994; Martin and Klein, 1984; Pimm, 1995a Pimm *et al.*, 1995; Steadman, 1995; Timson, 1993).

### The Second Human Invasion

The pressures on the remaining indigenous species intensified with the arrival of the Europeans, beginning with the release of rats, pigs and goats by Captain James Cook in 1769. Cook was followed several decades later by sealers and whalers who quickly devastated the remaining seal and sea lion populations and also drove the Right whale to the brink of extinction. After the Treaty of Waitangi was signed in 1840 by the British Government and Maori chiefs, the door opened to a torrent of land- and gold-hungry immigrants, mostly from Britain and Ireland. By 1920, the new settlers had converted half the remaining forests into farms and towns and had introduced legions of plants and animals, some of which displaced or preyed upon the indigenous plants and animals. Wetlands, dunes and estuaries were also invaded and converted into pasture or urban settlements.

The destruction of native habitat continued into the 1980s and still occurs at lower levels today. Although most native forest clearance has ended, wetlands are still being drained in some areas and dunes are still being built on. In fact, New Zealand is still in the throes of the second invasion as both our native species and our society struggle to respond to the enormous pressures we have unleashed on the nation's biodiversity. The rest of this chapter is largely about the effects of the second invasion.

Since European settlement, 16 land birds (9 species, and 7 subspecies) have been driven to extinction, together with a native bat, 1 fish, at least a dozen invertebrates and possibly as many plants. The lost birds include: the New Zealand quail (probably exterminated by early collectors), the North Island thrush (probably eliminated by feral cats), the huia (see Box 9.6), the North Island laughing owl and the North Island bush wren (both probably eradicated by rats). The stitchbird and the North Island saddleback (respective victims of dogs and rats) were eliminated from the mainland and only survive on a few islands. The South Island kokako is another probable extinction victim. Although possible sightings are occasionally reported, none has been confirmed to date.

Most significantly, the new pressures generated by the colonists and their agricultural economy greatly increased the number of threatened species. Many are still coping with the fallout from habitat destruction and predation. One example is a native parrot, the kea (*Nestor notablis*). Once widespread in the South Island, its original range was first reduced by Maori deforestation, then by the conversion of the high country into sheep pasture.

Late last century, when it became known that some keas attack sheep, a bounty was paid for their destruction and continued to be paid well into this century. At 10 shillings a beak in the 1920s (equivalent to $65 today) keas provided a lucrative living for bounty hunters. Extrapolating from Ministry of Agriculture and Fisheries records, it is estimated that about 150,000 keas were killed between 1870 and 1970, bringing the population down from about 50,000 to 5,000–15,000 today (Temple, 1996).

The kea only received formal protection in 1986 after an agreement was reached between the Department of Conservation and high country farmers, in which the Department undertook to control 'rogue' birds. Keas were also shot in the early days of ski-field development but today most ski-fields are kea-proofed. Wildlife smuggling and random shootings are the main threats now (Temple, 1996). The keas' natural intelligence and adaptability allowed them to cling on until the new invaders had an eleventh hour change of heart. Unfortunately, not all species have been so favoured and many may still succumb to the second invasion.

**Box 9.5**

### *The hairy invaders*

A group of 34 introduced mammals, headed by our own species, now dominates the New Zealand environment. Of the 54 mammalian species that were originally introduced, some died out, 18 have restricted distributions, and only 14 are widespread (King, 1990). Five of these species are clearly dominant—humans, rats, sheep, cattle, and possums. Most of the land's productivity, from both farm and forest, goes into feeding and pampering this mammalian elite. As their collective biomass (aggregate weight) has grown, that of the indigenous plants and animals has shrunk to a fraction of its original size. Landcare Research is developing and collecting information for a national database on wild populations of goats, pigs, tahr, chamois, the five species of wallabies, and the seven species of deer (red, sika, fallow, whitetail, rusa, sambar, and wapiti) that have been introduced here.

Because mammals are bigger, hungrier, and more active than most other animals their effect has been immense. The grazing mammals (sheep, cattle, and rabbits) and the mammals who eat them (humans and domestic cats and dogs) have had the greatest impact. Together, they dominate the land surface, which has been largely deforested and drained to accommodate them. Even where deforestation has not occurred, browsing mammals (e.g. goats and deer) have invaded the forests, eating young plants, preventing regrowth, and competing with birds for food. The predators (e.g. stoats, ferrets, feral cats, sojourning dogs) have reduced bird and reptile populations. And the omnivores (humans, rodents, possums and pigs) have done all these things.

Among the grazing animals, **sheep**, through their numbers, have had the greatest effect on forest and tussock ecosystems, while cattle have had the greatest impact on wetland ecosystems. In some places, sheep and cattle have become feral and degraded native forest (e.g. in the Chatham Islands where their removal is now allowing vegetation and native pigeons to recover.) Domestic **horses** are a minor presence. Their main effect on biodiversity was before 1920 when they provided the main labour source for converting forest to farmland. About 2,000 feral horses, in Northland and the Kaimanawas, are culled periodically to limit their eating and trampling of native plants. **Rabbits** are a serious problem in the South Island high country where they compete with sheep for pasture. Occasional population explosions have led to over-grazing, soil degradation and the spread of hawkweed. They pose a threat to the tussock ecosystem and are also a moderate risk to crops and pasture in dry eastern areas of both islands. Elsewhere their numbers are controlled by predators (stoats, ferrets and feral cats) and by rain-drowning, which together kill 80 percent or more of each litter.

Among the browsing animals, **goats** are worse than deer because they have wider food preferences and are more agile (Parkes, 1993). They were less widespread than deer until the early 1990s when the downturn in goat farming caused many to be released in native forest and scrub. Now they are spreading, and occupy about 25 percent of Conservation Department land. **Deer** numbers were reduced in the 1970s by heavy culling operations, particularly aerial shooting and capture for deer farming. In areas of Fiordland where deer numbers have been reduced, the vegetation is recovering. **Sika deer**, however, which were formerly confined to the Kawekas and Kaimanawas, have recently appeared in unconnected forests in the Tararuas and Coromandel, apparently transferred by recreational hunters. Himalayan wild goats, or **tahr**, have lived in the South Island high country since 1904. Their population peaked at about 60,000 in the 1970s when many rare alpine herbs were almost wiped out. Helicopter shooters reduced the tahr population to about 6,000, but, since 1983, tahr numbers have climbed back up to about 12,000, spread over 700,000 hectares of high country. The ecologically tolerable population size is estimated to be about 10,000 (Cuddihy, 1994). **Chamois** pose similar problems in these areas.

Of the predators, cats, stoats and ferrets are the most destructive. The mustelids (**stoats**, **ferrets** and **weasels**) were introduced to control rabbit numbers, and have done so in many areas. They may also have played a part in removing Norway and Pacific rats (kiore) from our forests, although they have had little effect on the tree-climbing ship rat. Their biggest impact on indigenous species appears to have been on ground-nesting birds, such as black stilts in the Mackenzie Basin. Ferrets are probably the main predators of albatrosses and possibly yellow-eyed penguins on the Otago coast. Stoats are major predators of hole-nesting species, especially yellowheads, parakeets and kaka. Stoats are probably the most difficult predator to control. They are bait-shy and trap-wary, and very fertile.

**Dogs** are meat consumers, vital labourers in the pastoral economy, a social problem in some urban areas, and, occasionally, wildlife predators. Nearly 29 percent of homes surveyed by Statistics New Zealand in 1991/92 had pet dogs, whose total population came to nearly 398,000. In addition, the country's 80,000 farms had an unknown number of working dogs, perhaps totalling 240,000 (assuming, on average, one 3-dog-team per farm). In some areas unrestrained dogs have decimated ground-living bird populations, such as kiwis in Northland. Last century, packs of **feral dogs** preyed on sheep but were soon eradicated and have not become re-established. In the early centuries of human settlement, Polynesian dogs may have preyed on flightless birds and reptiles, but there is no direct evidence of this.

Unlike dogs, many **cats** (perhaps a million or more) live entirely in the wild. A further 770,000 were living as pets in 48 percent of New Zealand homes during 1991/92. The impacts of **feral cats** are similar to those of the mustelids. They prey mostly on rabbits, other mammals and introduced birds, but also kill many indigenous species. Feral cats on islands have devastated some seabird populations, and on the mainland they pose a threat to ground-nesting birds. Dotterels on Stewart Island, black stilts in the Mackenzie Basin, and yellow-eyed penguins on the Otago Peninsula, are among their worst-pressed victims.

Omnivorous mammals are particularly dangerous because they eat both plants and animals. **Pigs**, for example, can wipe out a snail population in a day, and are very adept at rooting out petrel burrows. However, except for Northland, parts of Nelson/Marlborough, and the Chatham and Auckland islands, feral pigs are generally not numerous enough to pose a serious problem. A far bigger threat comes from the **ship rat**, one of four feral rodents in New Zealand. They exist in podocarp-hardwood forests at densities of 5–10 per hectare, but are less common in beech forests because of the lack of palatable fruit. They eat eggs, chicks and lizards, and compete with birds for food. The threat from other rats has diminished this century, partly because of predation by stoats. **Mice** may pose a threat to lizards and some invertebrates. Since stoats arrived, **Pacific rats** disappeared from all areas other than Fiordland and about 50 offshore islands. The once abundant **Norway rats** retreated to towns, farms and waterways.

Public enemy number one, however, is the **possum**. Possums were introduced to make money but now cost millions of dollars a year to control. Between 1837 and 1922, several hundred possums were brought here from Australia to establish a fur industry. In the 1890s, enthusiasm was so strong that acclimatisation societies bred and released their own strains and the government also imported and released animals. They were protected until 1921 and, for the next 25 years, were harvested under a restricted licensing system. In 1947, possums were reclassified as pests because of the damage they were inflicting on native trees and shrubs. Once thought to be exclusively vegetarian, the possum is now known to be an opportunistic omnivore. In captivity it will eat meat. In the wild, it is known to eat invertebrates, snails, mice and small birds. It raids bird nests, including those of the endangered kokako, killing the parent bird and eating its chicks and eggs (Brown *et al.*, 1993).

The possum's main food, however, is vegetation. The huge population consumes about 20,000 tonnes of plant matter every night. Their impact is heightened by the fact that they are choosy eaters which maim a wide range of plants by feeding only on the most palatable bits. They mostly eat leaves but also take buds, flowers, fruits, ferns, bark and fungi. They are known to eat from 70 native tree species, 20 ferns, a few vines and epiphytes, grasses, herbs, sedges, cultivated crops and flowers. The less palatable plants they leave untouched are attacked by the less choosy species, goats and red deer. Between them, possums, red deer and goats have thinned out forest understoreys, prevented regeneration and caused the collapse of tens of thousands of hectares of forest (Rogers, 1995). Some forests are more susceptible than others. Those whose canopies feature rata, kamahi, fuchsia and Hall's totara are particularly vulnerable, as are pohutukawa trees (Rose *et al.*, 1993).

**Box 9.6**

### *The huia's royal send-off*

The huia was one of the most magnificent birds to grace the forests of the North Island. By the time Europeans arrived, it was confined to parts of the Kaimanawa, Ruahine, Tararua and Rimutaka ranges (Falla *et al*., 1979). Quiet and curious, with its glossy green-black plumage and prized white-tipped tail feathers it was an easy target. Huia couples foraged together, the male's sharp stout beak dismembering rotten logs for insects and the female's curved slender beak reaching into the wreckage for those which escaped her partner. They were often shot together. Among the killers was Sir Walter Buller, New Zealand's foremost ornithologist. In the late 1800s collectors avidly hunted the rarest New Zealand birds to sell to foreign museums. In 1874, one expedition to the Tararua Ranges brought back 600 huia skins. The local chiefs had banned huia hunting for the previous seven years to prevent their extinction, but the collectors, both European and some Maori, were motivated by money and, in some cases, by the belief that the birds were bound to become extinct anyway so the best thing to do was get good specimens to as many museums as possible.

By the 1890s the huia had become rare enough to raise the concern of the Governor of New Zealand, the Earl of Onslow. As a result, in 1892, the Government announced a national ban on the killing of huia. As late as 1895, however, Buller was still urging collectors to get complete representative series of specimens of the rarest native birds "before it is too late." (King, 1984). The final blow came during the royal visit of 1901 when a huia feather was presented to the Duke of York (later King George V). This triggered an instant demand for huia feathers and the price of a single feather soared from one pound to five pounds (Morris and Smith, 1988). Brought to the brink of extinction by introduced predators, forest destruction, and previous hunting and collecting, the huia, like many species since, was finally unable to withstand the market forces of the fashion industry. Faltering plans to preserve huia populations on what would have been our first island sanctuaries were silenced by the collectors' guns. The last accepted sighting of a huia was on 28 December 1907. After that it was pronounced extinct.

### Current pressures on biodiversity

Today about 1,000 of our known taxa are considered threatened (about 800 species and 200 subspecies). This excludes many species still unknown to science which may be threatened and also excludes known species not yet threatened but known to be declining as the pressures on them mount. These pressures are the same ones that arrived here with the first people, though their relative importance has changed over the centuries: *human predation; habitat destruction;* and *the effects of pests and weeds.*

#### *Human predation*

These days human predation is not the threat it once was, but it can still put pressure on species already threatened or declining. Examples are: the poaching and stripping of shellfish beds in some areas (e.g. around Auckland and Wellington harbours) (Weatherley, 1996); the illegal harvesting of sphagnum moss; the impacts of fishing, both on target species (e.g. orange roughy, snapper) and non-target species (e.g. sea lions, seabirds, Hector's dolphin, corals and other marine invertebrates); the potential effects of bioprospecting on valuable rare species; and the potential effect of Maori cultural harvesting on threatened species (e.g. the native pigeon, whose population is declining faster in Northland than elsewhere, having halved since 1979). This last issue has been the subject of considerable discussion and debate (Barrington, 1995; Geden and Ryan, 1995; New Zealand Conservation Authority, 1994; Moller, 1996; New Zealand Ecological Society, 1995; Taylor, 1994; Wright *et al.*, 1995).

The fishing industry, both recreational and commercial, is the only remaining form of large-scale predation on wild animal populations. Fishing affects non-target species as well as commercial species, but little is known of these effects. Commercial fishing in New Zealand is based on a quota system. Catch levels are set by the Minister on the basis of scientific information and submissions made by industry and other interest groups.

**Box 9.7**

#### *Sponging for drugs*

Sponges of the genus *Lissendoryx* are known overseas as cancer fighters. They produce a substance called Halichondrin B (HB) which kills cancerous cells in laboratory mice at doses of just a millionth of a gram. Several years ago, scientists discovered a new species of *Lissendoryx* on rocky outcrops at depths of 100–300 on the edge of the Kaikoura Canyon off the South Island's east coast. This species, nicknamed 'yellow slimy', was found to produce HB and also a new compound called Isohomo HB which is thought to have similar powers (Statistics New Zealand, 1994; Pain, 1996b). 'Yellow slimy' is one of more then 1,500 marine species that scientists have been investigating for more than a decade in the search for potentially useful drugs.

A 50 microgram extract of Isohomo HB (i.e. 50 millionths of a gram) was sent to the National Cancer Institute in Washington D.C. where it is being tested on laboratory animals before proceeding to clinical trials costing about $200 million. If successful, the discovery could put considerable pressure on our *Lissendoryx* species. It takes one tonne of these sponges to produce one gram of the extract, and about 5 grams would be needed to complete large clinical trials. Scientists estimate that there are only about 300 tonnes in existence. With such a low yield and 200 kg of the sponges already harvested, researchers have been investigating ways to protect the species while also ensuring a commercially useful supply. Laboratory production (e.g. through chemical means or genetically-modified bacteria) has been ruled out because the process is too costly and time-consuming. Although sponges are notoriously tricky to grow, the most promising solution has turned out to be aquaculture (marine farming). The National Institute for Water and Atmospheric Research (NIWA) has experimented successfully with growing *Lissendoryx* in several locations around the coast, and even has a thriving colony in Wellington Harbour, at a depth of only three metres (Statistics New Zealand, 1994; Pain, 1996b).

A new form of human predation is the collection of plants and marine organisms in the search for genes and natural chemicals that may have medicinal, cosmetic or industrial uses. Most anti-cancer and antibiotic drugs are poisons, and medical researchers are constantly seeking new ones which may be more effective or more selective in their action. Plants and marine invertebrates are in particular demand because most are stationary (either rooted in soil or attached to a rock or reef) and so tend to rely heavily on natural poisons for self-defence.

Although biomedical companies have a strong interest in biodiversity preservation, their activities can pose a risk to some species, especially as most of the chemically useful ones also happen to be rare. Bioprospecting is not known to have endangered any New Zealand species but it has caused problems in other countries through the over-harvesting of rare plants and marine organisms (Anderson, 1995; Pain, 1996b). Bioprospecting in New Zealand is funded primarily by North American companies and is carried out by scientists at various research facilities, including Crown Research Institutes, such as Landcare Research and the National Institute of Water and Atmospheric Research, and several universities. The scientists are aware of the dangers to rare species and are generally careful to harvest only small samples. Back at the lab the samples are ground to a paste which is then subjected to about 60 different chemical tests.

About 40 percent of tested species yield potentially useful compounds, and about 2 percent advance to trials in the United States. A recent example is the sponge *Lissendoryx* (see Box 9.7). Where valuable compounds are discovered and the species that produce them are too rare to harvest commercially, production can only proceed through farming or through laboratory manufacture of the compounds (e.g. in genetically modified bacteria), allowing the natural populations to remain unmolested.

Another form of human predation, which mostly affects birds and reptiles, is collecting for the international wildlife trade. Between 20 and 50 wildlife smugglers are believed to operate here, mostly as intermediaries for the trade in foreign species, for which New Zealand is alleged to be a popular alleged to be a popular conduit (Anderson, 1997; Ansley, 1995). The wildlife trade monitoring agency, TRAFFIC Oceania, says that at least 600 birds from species listed under the Convention on Trade in Endangered Species are exported from New Zealand each year, most of them parrots and cockatoos in transit from Australia (Anderson, 1997). Worldwide the illegal bird trade has contributed to the decline of about 40 parrot species (Wildlife Conservation International, 1992). The trade poses a potential threat to New Zealand's native parrots (principally the kea, but also possibly the kaka, kakariki and near-extinct kakapo) as well as our rarer reptiles, particularly the tuatara.

#### *Habitat destruction*

For most indigenous species, habitat destruction is a graver threat than human predation. Although predation targets only a few species, habitat loss indiscriminately hits all the species in an area. Recent overseas research has shown that the effect of habitat loss on biodiversity increases markedly once a critical threshold is crossed. According to American scientist, David Tilman: "The 'good news' is that if you destroyed half the Earth, you'd lose only about 10 percent of the species. But the bad news is . . . as you near 60 percent–70 percent–80 percent habitat loss, a very slight increase in destruction leads to a sharp increase in the number of species lost" (Culotta, 1994; Tilman *et al.*,1994).

The magnitude of these extinctions is masked by the fact that they do not all happen at once—some species can hang on grimly for decades, or even centuries, before finally succumbing. To date, Earth is just barely on the 'good news' side of the ledger with about 52 percent of its land ecosystems replaced or disturbed by farmland, settlements, logging, mining and roads (World Resources Institute, 1994). However, New Zealand is on the 'bad news' side of the habitat balance sheet, with our area of domesticated land now standing at 63 percent (see Chapter 8, Table 8.3) and the percentage of significantly disturbed habitat estimated at 73 percent (World Resources Institute, 1994). Habitat loss in New Zealand has occurred at three levels:

- wholesale **removal** of ecosystems for conversion to farmland, exotic forests and settlements;

- partial removal or **fragmentation** of ecosystems into 'islands' surrounded by farmland;
- **degradation** of ecosystems through loss of species and disruption of ecological processes.

In areas where large amounts of rich lowland habitat have been removed, many of our threatened species are locally extinct. In less heavily modified areas, however, many still hang on. As a result, the more mountainous regions are where the greatest number of threatened species are found (see Figure 9.2).

*Removal of ecosystems*

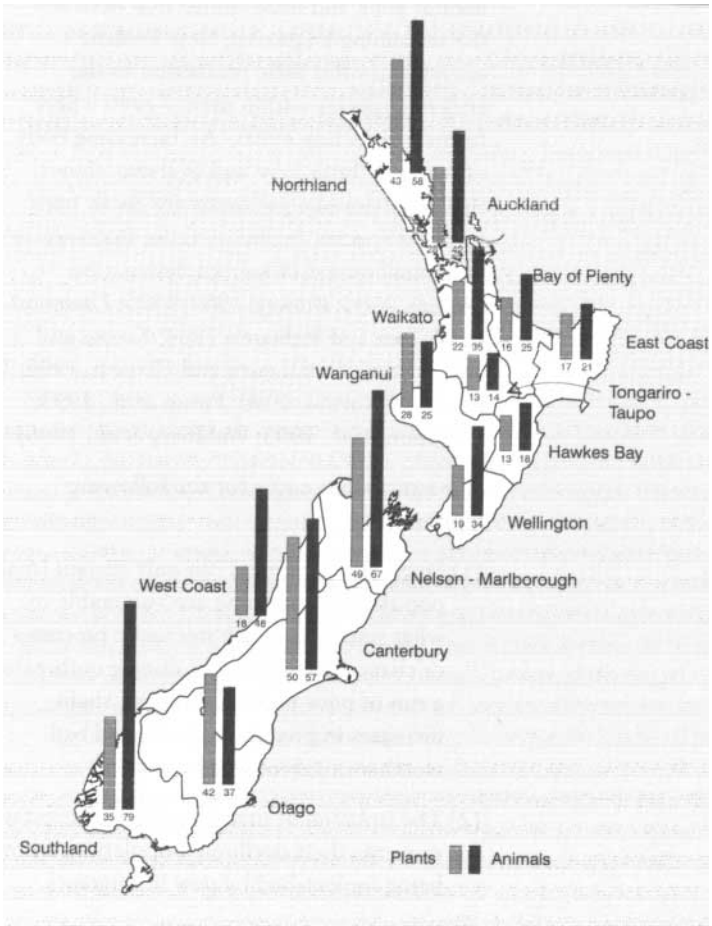
Habitat destruction has been extensive in New Zealand. Lowland forests, wetlands, dunelands and tussock grasslands have been largely converted to farmland (see Chapter 8). Many rivers, lakes and streams have been heavily modified by dams and drainage and irrigation schemes and by pollution from farms and towns (see Chapter 7). The widespread removal of riparian vegetation is a dramatic example of how, in building our agricultural economy, we have turned much of New Zealand into a biodiversity desert (see Chapter 7, Box 7.4).

A survey by the former Wildlife Service showed that in the 5 years between 1978 and 1983, the total area of wildlife habitat in Northland declined by 5.7 percent, or 1 percent per year (Anderson *et al.*, 1984). Losses varied in extent with different types of habitat. Freshwater wetlands had declined by 14.4 percent, forest and scrub by 7.5 percent, and coastal estuarine habitat by 1.8 percent.

Today, most of New Zealand's surviving, relatively undisturbed habitat is either at high altitudes in the mountains, or in small lowland forest stands, shrunken wetlands and other ecological 'islands'. Some of this habitat is on real, offshore, islands. Many island ecosystems are being restored by the removal of pests and weeds and the rescue of depleted indigenous species (Towns *et al.*, 1990). An increasing number of our most endangered species are being relocated to these islands to protect them from predation and further habitat loss (see Box 9.23).

**Figure 9.2**

**Threatened species[1] in the Department of Conservation's conservancy districts**




*Source: Department of Conservation (1994b)*

[1] *The threatened species mapped here are the plants and animals listed in Categories A, B, and C of the Department of Conservation's priority listing of threatened species. Excluded species include all fungi and micro-organisms and all threatened plants and animals listed in Categories I, X, and O.*

*Fragmentation of ecoystems*

With so much of the lowland indigenous habitat gone and little connection between the remaining fragments, New Zealand's ecosystems offer little protection to the endemic species within them—even where formal protection exists. An increasing body of research, both here and overseas, shows that fragmented ecosystems are death traps for most species, including those that survive the actual period of habitat destruction (Askins, 1995; Burkey, 1989, 1995; Diamond, 1984; East and Williams, 1984; Kreuss and Tscharntke, 1994; Leach and Givnish, 1996; Lord and Norton, 1990; Pimm *et al.*, 1993; Robinson *et al.*, 1995; Wahlberg *et al.*, 1996).

The extinctions occur for the following reasons:

(1) Fragmented habitats can only sustain small populations and these are vulnerable to what statisticians call 'stochastic processes', or chance events, such as disease outbreaks, a run of poor breeding seasons, slight increases in predation, prolonged bad weather or inbreeding.

(2) The isolation of many fragmented habitats prevents their declining populations from being replenished by new immigrants.

(3) Where fragments are small in area the species within them can never get far away from the dangerous boundary zone, which is often where the threatening predators and invasive species are most abundant.

(4) The small areas also limit resources and ecological niches so that only a limited number of species can share the habitat before crowding and competition occur.

These factors make extinction inevitable for many species, though a considerable time lag can occur before some species finally succumb. Because of their adaptability or high initial numbers, dominant species may persist in fragmented habitats for 50 to 400 years. This leads people to underestimate the full ecological costs, or 'extinction debt', incurred by habitat destruction (Tilman *et al.*, 1994).

The high percentage of threatened birds in New Zealand suggests they are still in the lag period following the massive habitat destruction of the past century. In their shrunken habitats the declining species are still paying off the 'extinction debt' arising from the development of our extensive farming system. Reversing this situation would require the re-establishment of wetlands, riparian vegetation and native forests on at least 10–20 percent of our farmland.

The fragmentation research has shown that, at least for forest birds, large areas of habitat are needed to cushion the effects of chance events, predation, species crowding and genetic isolation. The most viable fragments and island reserves seem to be those which are large or within migrating distance of other reserves (Hackwell and Dawson, 1980; Diamond, 1984; Burkey, 1995; Robinson *et al.*, 1995).

*Degradation of ecosystems*

Habitat size is not enough on its own, however. Even within relatively extensive areas of alpine forest and marine habitat, biodiversity is threatened by ecological degradation. This occurs when changes in the physical environment or in the composition of key species trigger a sequence of ecological changes that can lead to the loss of species.

Before humans, ecological degradation was caused solely by climate change and natural catastrophes. For example, 1,800 years after the Taupo eruption, some freshwater fish species are still almost absent from the 'ash zone' east of the volcano, even though vegetation and land animals have long since recovered (McDowall, 1995). Study of ancient river sediments has identified several periods of significant climate change in the past few thousand years where temperatures rose or fell by up to 2°C with some forests being devastated by natural fires during dry periods and some by wind-throw during wet stormy periods (Grant, 1994).

These days humans are the main agents of ecological degradation. Even where apparently intact habitat remains, we exert a range of insidious pressures on ecosystems, whose cumulative effects may be more damaging than the single impact of each pressure on its own. These pressures include:

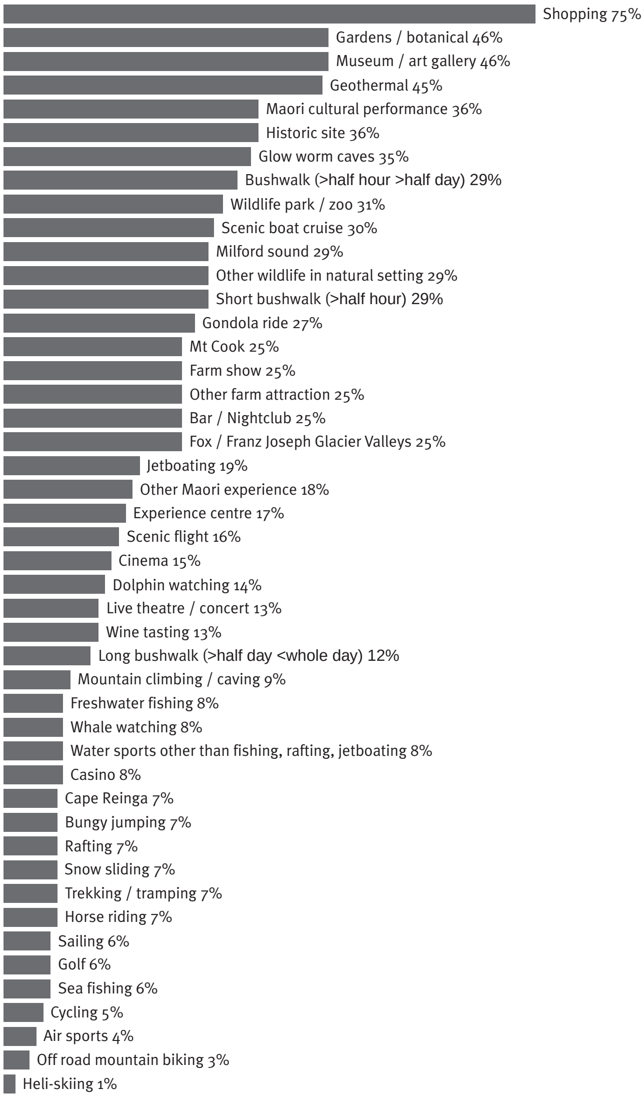
- the construction of roads and tracks, which provide access for people, pests and weeds;
- industries such as farming, forestry, mining and prospecting, and hydro dam construction and smaller river obstruction work, which can disturb or even remove forest and freshwater habitat;
- recreational activities, such as beach houses, buggies and trail bikes (which can damage duneland vegetation), tramping (which can bring alien seeds, human wastes and other forms of disturbance to heavily visited areas), sport fishing (which maintains trout in our freshwater ecosystems) and even gardening (which has introduced many of the weeds which cause problems in natural habitats);
- drainage or hydrological disruption of wetlands, rivers and lakes;
- dredging and bottom trawling (which can reduce the species on the sea floor by physically disturbing the bottom, and by causing high levels of suspended sediment);
- sedimentation and pollution of rivers, streams or coastal waters from point and non-point discharges; and
- pollution from other sources, such as air pollution, which can kill sensitive lichens.

Although they allow nature-loving humans into natural areas, roads and tracks are also a danger to natural ecosystems. They provide extensive edge zones where possums, other mammals and invasive weeds can gain entry to new habitats. Even well-intentioned human visitors can disturb sensitive micro-habitats through trampling and waste disposal.

The pressure from recreation and tourism has grown rapidly in recent years and almost amounts to a 'third human invasion' of our more popular natural parks and reserves (see Box 9.8). With a population of 3.5 million, New Zealand played host to more than 1.3 million overseas visitors in 1994–95—10 percent more than the previous year. This is well above the 3 percent growth rate in world tourism. Five years ago, the New Zealand Tourism Board was aiming to attract 3 million visitors by the year 2000. It has since backed

**Figure 9.3**

**Tourist activities in New Zealand**




*Source: New Zealand Tourism Board (1996b)*

**Box 9.8**

### *Tourism growth and the environment*

World tourism has boomed in recent decades as international travel has become easier and global income has become more unevenly distributed among the world's rich and poor. New Zealand's tourism growth has been much greater than the world average, partly because of a favourable exchange rate which made us a relatively cheap destination, and partly because of the aggressive marketing of our 'clean, green' image. The first time more than 1 million overseas visitors arrived was in 1992. By June 1996, the number had reached nearly 1.5 million. More than half these (823,178) listed 'holiday or vacation' as the reason for their visit (Statistics New Zealand, 1996). Just over 2 million visitors are expected in the year 2000 (New Zealand Tourism Board, 1996a).

Since the 1980s there has been a switch from pre-arranged package tours, in which visitor impacts were confined to major routes, to what is known as 'free and independent travel' (FIT) holidays where people drive campervans and rental cars wherever the spirit moves them (O'Neill and Kearsley, 1993). Even more recent developments include adventure tourism (bungy jumping, white water rafting), and 'eco' or 'green' tourism (Warren and Taylor, 1994). In 1993, more than half our overseas visitors went to at least one of our national parks. The most popular attractions were Milford Sound in the Fiordland National Park, the Whakapapa Skifield, Rotorua's Whakarewarewa, Taupo's Huka Falls, the Waitomo Caves and Mt Cook. Each of these gets 250–500,000 visitors per year, with 60–70 percent from overseas (Ministry of Commerce, 1994).

The rapid increase in visitors during the past decade has raised concerns about environmental effects and sustainability (Hall, 1994; Lincoln Outlook, 1995; Sage, 1995; Sowman, 1994). In 1995, the New Zealand Conservation Authority asked its regional boards to identify sites where visitor activities were thought to be having a detrimental effect (see Table 9.2). The resulting list of 60 sites is not necessarily representative, or even accurate, being based on perceptions rather than systematic monitoring, but it identifies overcrowding as a recurrent seasonal problem each summer. Overcrowding lowers the quality of visitors' experiences and intensifies pressure on facilities such as parking, space in huts, and toilets. Fouling of ground and streams, including water supplies, by human waste was seen as a nationwide problem at huts, bivouacs, camping areas, reserves and (especially) roadside areas (New Zealand Conservation Authority, 1995). Other visitor effects can include: *habitat destruction* and *wildlife disturbance* (particularly at nesting sites) by off-road vehicles, jetskis, horses, dogs and guided tours; increased risk of *fires* and *new weed introductions*; *vandalism* and *souveniring* at historic sites; *vegetation clearance* for campsite firewood; *track deterioration*; *noise;* and *visual pollution* (Department of Conservation, 1996; New Zealand Conservation Authority, 1995). Visitor impacts are greatest in fragile landscapes such as sand dunes and subalpine areas.

Although problems with visitor numbers have started to show at some tourist destinations, the effects are still relatively limited when compared with the widespread devastation caused by introduced animal pests.

At current visitor levels, the pressures can be controlled by careful planning and management. For example, several popular walking tracks (e.g. the Milford and Routeburn tracks in Fiordland) have booking systems to limit visitor pressure. Responsibility for tourism planning and impact management falls to regional councils and the Department of Conservation. The latter's Conservation Management Strategies and Plans try to balance the public's free access to protected areas (as allowed in the Conservation Act, National Parks Act and Reserves Act) against efforts to protect indigenous species, ecosystems and historic sites (as required by various laws, including the Wildlife Act). At a broader level, the Tourism Policy Group of the Ministry of Commerce is responsible for developing our national policy on tourism, while the New Zealand Tourism Board is responsible for the international marketing of New Zealand as a tourist destination.

off this target because of the potential impacts on visitor facilities, the tourism experience and the environment.

About 55 percent of overseas visitors went to at least one national park, with the average park visitor making three such trips. The two most popular activities are bush walks and scenic boat cruises. In addition to the overseas tourists, many domestic New Zealand tourists also visit national parks. In all, about 2 million people are recorded at Department of Conservation visitor centres each year. The number has increased yearly by tens of thousands. These visitors can place considerable pressure on some areas. They also place enormous pressure on the limited resources of the Department of Conservation, a quarter of whose budget is devoted to tourist servicing. More than 600 private recreation and tourism operators have concessions to operate on conservation land, some on a trial basis, and each year the Department receives more than 300 new applications for concessions.

More visitors means more roadworks, more tracks and track maintenance, and more and bigger camp sites, accommodation and service facilities. It also means more crowding, trampling, sewage and waste, and weed invasions, particularly in small reserves, near roads and along the most popular walking tracks (e.g. Rakiura on Stewart Island, Milford, Kepler, Routeburn, Heaphy, Abel Tasman, Waikaremoana and Tongariro). When one area becomes degraded, visitors tend to seek more pristine areas, thus widening the impact zone.

Visitor impacts also occur at marine reserves. New Zealand's oldest marine reserve, the Cape Rodney-Okakari Point Marine Reserve at Leigh north of Auckland, gets over 100,000 visitors a year. Recent research indicates that the trampling feet of visitors as they walk over a nearby reef platform to observe the inter-tidal marine life can alter the structure of ecological communities (Brown and Creese, in press). Similarly, heavy visitor numbers at seal rookeries can drive the seals to more distant hauling out areas, such as offshore rocks.

**Table 9.2**

**Some environmental pressures at 60 important visitor sites**

| Pressures | Sites affected | |
|---|---|---|
| ***Overcrowding*** | *27* | |
| *general* | | *(14)* |
| *campgrounds* | | *(1)* |
| *waterways (boat use)* | | *(2)* |
| *huts* | | *(3)* |
| *hot springs* | | *(1)* |
| *parking facilities* | | *(4)* |
| *fresh water supplies* | | *(1)* |
| *cooking facilities* | | *(1)* |
| ***Waste Disposal*** | *17* | |
| *toilet facilities* | | *(6)* |
| *waste disposal facilities* | | *(6)* |
| *sewage pollution* | | *(4)* |
| *contaminated fresh water* | | *(1)* |
| ***Facility Degradation*** | *11* | |
| *campground degradation* | | *(1)* |
| *access road deterioration* | | *(1)* |
| *track deterioration* | | *(7)* |
| *forest depletion for firewood* | | *(2)* |
| ***Wildlife Disturbance*** | *4* | |
| *birds* | | *(1)* |
| *wildlife (general)* | | *(3)* |
| *dogs* | | *(1)* |
| ***Environmental Degradation*** | *13* | |
| *damage to vegetation* | | *(5)* |
| *sand dune damage* | | *(1)* |
| *rock damage* | | *(1)* |
| *water scouring* | | *(2)* |
| *pugging* | | *(3)* |
| *fire risk* | | *(1)* |
| ***Recreational Vehicles*** | *5* | |
| *offroad vehicles* | | *(1)* |
| *jetboats* | | *(1)* |
| *jetskis* | | *(1)* |
| *mountain bikes* | | *(2)* |

*Source: New Zealand Conservation Authority (1995)*

Until recently, logging for timber in native forests has caused severe habitat disturbance. From mid-1996 the indigenous provisions (Part IIIA) of the Forests Act 1949 requires most timber logging in native forests to use low-impact techniques (such as helicopter extraction rather than heavy-duty ground-based equipment). Concern has been expressed, however, that even coupe felling and selective single-tree logging of podocarps, such as rimu, could affect some threatened species, such as the pigeon, bellbird and tui (Spurr *et al.*, 1992; Warburton *et al.*, 1992). Coupe and selective logging of podocarps generally target the largest old trees, which also happen to be the prime habitat for these species. Mining and prospecting in natural areas can also disturb vegetation and wildlife. Several hundred licences are current on conservation land. Although efforts are made to minimise site impacts, their cumulative effect is difficult to gauge.

The effects of hydro development range from flooding of land-based ecosystems to disturbing the flow of aquatic ecosystems. Across the country, the construction of smaller floodgates, weirs, tidegates and dams, generally associated with flood control, drainage and irrigation, have had significant cumulative effects on indigenous freshwater fish stocks causing local extinction and population fragmentation. Flow disturbances caused by heavy river floods are known to dramatically reduce the number and abundance of fish species in a river—at least in the short-term (McDowall, 1993). Flow variations can reduce habitat and feeding areas, increase water temperatures and silt up gravel spawning areas.

Fish are also affected by the physical barrier which a dam presents to their movement (Irvine and Jowett, 1987). This can have a fatal impact on upstream populations—and not necessarily the migratory ones. A case in point was reported by McDowall and Allibone (1994). They found that a species of non-migratory native fish, the common river galaxia (*Galaxia vulgaris*), has been eliminated in the waters above the Lake Mahinerangi dam in Otago. This species apparently succumbed to competition from a larger migratory galaxiid, the koaro (*Galaxia brevipinnis*), which became trapped by the dam in 1923 and was apparently thrown into ecological competition with its smaller cousins.

In marine habitats, pressures from trawling and dredging also reduce species numbers. A recent review of research on trawling impacts found that repeated dragging of heavy fishing gear across the sea floor can cause permanent changes to sea-floor biodiversity by scraping and ploughing the sea-bed, creating sediment clouds, killing sea-floor organisms (e.g. crustaceans, molluscs, sponges, corals, kina) and dumping processing waste (Jones, 1992).

The Department of Conservation commissioned a three-month study by the National Institute of Water and Atmosphere Research (NIWA) to investigate the effect of scallop dredging on marine mud-dwelling species (Thrush *et al.*, 1993). The researchers found that, in general, after only one dredging episode, the number and variety of bottom dwelling animals was reduced and remained low three months later. They concluded that repeated dredging over large areas is likely to result in reduced diversity in sea-floor communities.

In deeper water (below 1,000 m), where the animals are less adapted to sediment clouds and storm disturbance, recovery of sea floor communities probably takes decades once trawling has stopped (Jones, 1992). On seamounts, recovery of coral thickets and their associated ecosystems will probably take centuries (see Chapter 7, Box 7.3).

The commercial alternative to shellfish dredging is aquaculture. Oyster and mussel farms are well established in many bays in New Zealand and are visible as rows of floating oyster racks or rows of buoys supporting mussel long-lines. While most of the environmental objections to fish farms are based on the water space they occupy and their impact on the scenery, they can also have less visible impacts. Large amounts of faecal and other wastes accumulate on the seafloor beneath them and these can pollute water or deplete oxygen levels in the sediment (Forrest, 1994).

The few New Zealand studies to date have detected oxygen depletion but no significant water impacts. The oxygen is depleted by micro-organisms as they break down the wastes. In severe cases, this can make the sea floor uninhabitable to many animals, resulting in a 'black zone' that exudes the 'rotten egg' smell of hydrogen sulphide. Fortunately, the effect is limited to the farmed area and the few metres beyond its perimeter. Some of the ecological changes caused by fish farms are more pleasant. They provide areas for bird roosting, artificial reefs for other marine organisms, and food for opportunistic sea floor scavengers. They can also attract fish from outside the farm area, such as flounder around oyster farms and snapper around mussel farms (Forrest, 1994).

Another source of pressure on the sea floor ecosystems is the dumping of fish processing waste. For example, about 50,000 tonnes of hoki offal are dumped into the sea each year by boats fishing on the continental slope off the West Coast of the South Island, raising concerns that the decomposing waste could locally deplete oxygen levels (Livingston and Rutherford, 1988). A preliminary assessment confirmed that enough waste reaches the sea floor to alter the species composition (Grange, 1993).

***Pests and weeds***

Even when human disturbance of an ecosystem seems slight at face value, its impact often comes on top of far more serious disturbances by other species. Alien plants and animals have turned many of our protected areas into war zones. When not being smothered or overshadowed by exotic weeds, our native plants are eaten by browsing and grazing animals, such as goats, deer, tahr, cattle, sheep, wallabies, rabbits and, above all, possums. Without pest control programmes, an estimated third of our protected forests (1.8 million hectares) would suffer significant biodiversity losses from browsing animals (see Chapter 8). At present, the Department is holding the browsers at bay over about 1.3 million hectares.

Meanwhile birds, reptiles, frogs and the larger invertebrates fall prey to mammalian predators (e.g. stoats, rats and cats) and several aquatic species appear to have been displaced by trout (see Box 9.9). Among the introduced birds, Australian magpies and Asian mynas have acquired reputations as aggressive competitors with native birds, attacking them and preventing them from nesting within their territories. A recent study of the impact of mynas found that, after their removal from an area, the number of tuis and other native birds increased (Drent, 1996; Tindall, forthcoming). Introduced mallard ducks compete and sometimes breed with native grey ducks. Blackbirds, song thrushes and little owls prey on native invertebrates, including the threatened Cromwell chafer beetle.

The spread of introduced wasps in recent decades coincides with the rapid disappearance of a threatened bird, the yellowhead, from most of the northern South Island. The wasps may be compounding the intense predatory pressure from stoats (Davidson, 1992; Elliott, 1992). Wasps can kill nesting birds and are known to compete with them for insects and honeydew (Moller *et al.*, 1993). The removal of honeydew may also be excluding the threatened kaka parrot from honeydew beech forests (Beggs and Wilson, 1991; Moller *et al.*, 1993). Other wasp victims include native moths and butterflies, which are preyed on heavily. The impact on their populations is unknown but may be significant (Thomas *et al.*, 1990).

**Table 9.3**

**Key mammals which have reduced New Zealand's biodiversity**

| Species | | Population | Status |
|---|---|---|---|
| ***Humans*** | *(Homo sapiens)* | *3.6 million (1996)* | *Population growing at 1.5% per year (1990–95). Economy (GDP) growing at 2.2% per year (1990–95) Energy use growing at 2% per year (1990–95)* |
| ***Sheep*** | *(Ovis aries)* | *48.8 million (1995)* | *Peaked at 70.3 million (1982). Steadily declining.* |
| ***Cattle*** | *(Bos taurus, B. indicus)* | *9.3 million (1995)* | *At record level. (Averaged 8 million through the 1980s)* |
| ***Horses*** | *(Equus caballus)* | *Domestic: 40,000 (1981)<br>Feral: Kaimanawa ca. 1,800<br>Northland ca. 500* | *Peaked at 400,000 (1921). Feral populations can damage native plants so are periodically culled in conservation areas.* |
| ***Rabbits*** | *(Oryctolagus cuniculus)* | *Tens of millions (1995).* | *Occupy 56% (15 million hectares) of the land area. Pose a high to extreme risk to pasture over 1 million hectares of South Island high country where they are prone to dramatic population explosions.* |
| ***Goats*** | *(Capra hircus)* | *Farm: 337,000 (1995)<br>Feral: 300,000–1 million* | *Farm goats peaked at 1.3 million (1988). Feral goats were reduced by helicopter shooting in the 1970–80s, but increased during the farming downturn. They occupy 3 million hectares, two-thirds of it DOC land.* |
| ***Tahr*** | *(Hemitragus jemlahicus)* | *10,000–14,000 (1994)* | *Peaked at 60,000 (1970s). Were reduced by helicopter shooting to about 6,000 (1983).* |
| ***Deer*** | *(Cervus spp. and Dama dama)* | *Farm: 1.8 million (1995)<br>Feral: 250,000 (1993)* | *Farm deer still increasing. Wild (mostly Red) deer peaked in 1970–75, and are now controlled by hunting.* |
| ***Pigs*** | *(Sus scrofa)* | *Farm: 431,000 (1995)<br>Feral: at least 300,000* | *Farm pigs peaked at 771,000 (1964). About 100,000 feral pigs are killed annually. Problem areas are Northland, Nelson/Marlborough, the Chatham Islands and Auckland Island.* |
| ***Possums*** | *(Trichosurus vulpecula)* | *70 million (1993)* | *Occupy more than 90% of the country, still spreading, and subject to widespread control operations.* |
| ***Mustelids*** | *(Mustela spp.)<br>Stoats (M. erminea)<br>Ferrets (M. putorius)<br>Weasels (M. nivalis)* | *<br>Possibly millions<br>Possibly millions<br>Probably thousands* | *Absent from Stewart and Chatham Islands. Stoats are common in forests, including Fiordland beech forests. Ferrets are common in open country where rabbits, their main prey, are abundant. Weasels are uncommon.* |
| ***Rats*** | *(Rattus spp.)<br>Ship rats (R. rattus)<br>Norway rats (R. norvegicus)<br>Pacific rats (kiore) (R. exulans)* | *<br>Tens of millions<br>Tens of millions<br>Tens of thousands* | *Ship rats are common in forests, especially podocarp-hardwoods. Norway rats peaked before stoats arrived and are now limited to towns, farms, water margins and islands. Pacific rats are now limited to Fiordland and about 50 islands.* |
| ***Cats*** | *(Felis catus)* | *Pets: ca 770,000 (1991–92)<br>Feral: Possibly millions* | *Almost half the nation's homes have pet cats. Feral cats are widespread. Population trends unknown.* |
| ***Dogs*** | *(Canis familiaris)* | *Pets: ca 398,000 (1991–92)<br>Farm: 150–300,000 (1992)<br>Feral: Insignificant* | *Around 29% of homes have pet dogs and at least a third of the nation's farms have 1 or more teams of working dogs. Dog population trends are unknown.* |

**Box 9.9**

### *Routed by trout*

Brown trout (*Salmo trutta*) were introduced from their native Europe in 1867 and rainbow trout (*Oncorhynchus mykiss*) were brought in from North America in 1883. The sports anglers and acclimatisation societies that imported them gave little thought to the effects on native fish, 10 of which are now threatened and one of which is extinct. They thought even less about the effects on other species such as the threatened blue duck (*Hymenolaimus malacorhynchos*) and the freshwater crayfish (*Paranephrops zealandicus* and *P. planifrons*). Trout now form the basis of a thriving recreational industry involving several hundred thousand people and millions of tourist dollars a year. An estimated 45,000 tourists come here each year to catch trout, and the number is expected to grow (Mortimer, 1994). With their close relatives, European and American salmon (*Salmo* spp., and *Oncorhynchus* spp.), trout are the only introduced animals singled out for habitat protection in the Resource Management Act 1991 (Part II, Section 7 (h)).

Trout are highly aggressive, particularly brown trout, both as predators and as competitors for food and territory. Our native fish evolved without the need to defend themselves from such able enemies. Ill-equipped to resist the invaders, many were eaten, while others were robbed of their food and forced out of their territories. Several studies have shown that brown trout compete with some native species, such as various galaxiids (*Galaxias* spp.) and bullies (*Gobiomorphus* spp.), for the same foods, particularly mayfly nymphs (Hopkins, 1965; Cadwallader, 1975a, 1975b, 1975c; Edge *et al.*, 1992). Galaxiids are hardest hit because they and the trout appear to eat the same food at the same time. In contrast, eels (*Anguilla* spp.) seem to coexist with trout, despite their similar diets, because their feeding habits differ in manner, location and timing (Burnet, 1969).

Trout may also compete with blue ducks for food, perhaps influencing the ducks' current distribution and preventing their re-establishment in many areas. Experiments have shown that trout and blue ducks eat the same insect species, and that insects and blue ducks are less abundant in trout-inhabited waters (Towers, 1996). However, the two species have different feeding behaviour which makes it difficult to assess how much competition, if any, is actually occurring. Blue ducks prefer smaller insects eaten from the stream bottom while trout prefer larger ones caught in-stream or on the surface. While competition is difficult to observe directly, predation is much more straightforward. Trout kill a variety of native species. Two of these are crustaceans—the freshwater crayfish. Though not listed as threatened, crayfish have been reduced to such an extent that it is difficult to find them in areas where trout are present (McDowall, 1968). One species has been eliminated by trout from at least one North Island lake (Waingata) (Fish, 1966). The crayfish are highly vulnerable because they cannot detect trout easily. Whereas they can sense chemicals in the mucus of approaching eels, crayfish are 'chemically blind' to trout (Shave *et al.*, 1994).

Trout predation has had an even greater effect on some native fish, including at least three threatened species: the koaro (*Galaxias brevipinnis*), the dwarf inanga (*Galaxias gracilis*) and the Canterbury mudfish (*Neochanna burrowsius*). Very young galaxiids are especially vulnerable. Up to 135 may be eaten by one juvenile trout in a day (Moller *et al.*, 1993). Vast quantities of koaro were eaten when trout were introduced to our lakes (McDowall, 1987). They were so reduced in some North Island lakes that, by the 1920s, the trout themselves were declining too. Native smelt were quickly introduced to some lakes as substitute trout food, but they also preyed on the koaro, hastening their decline (Rowe, 1993). Trout impacts on native fish seem greater in lakes than in rivers and streams. This could be because upstream populations of native fish can take refuge behind waterfalls and dams, or it could be because streams are harder to survey accurately than lakes (Moller *et al.*, 1993).

Today, trout rule our waterways while blue ducks, crayfish and several native fish are confined to backwaters and marginal areas. Trout cannot be blamed entirely for this, but their presence has often been decisive. This was shown in a study which directly compared the effects of land use and trout on one galaxiid species, *Galaxias vulgaris,* whose distribution in the Taieri River is extremely fragmented. The researchers concluded that, although land use had affected the fish populations, the only factor which explained their extreme patchiness was the presence or absence of brown trout (Townsend and Crowl, 1991; Moller *et al.*, 1993).

**Box 9.10**

***The spineless invaders***

About 2,000 alien invertebrates have reached New Zealand by a variety of routes. Many came buried in the hair or guts of our domestic animals. Many came hidden in plants, containers, trouser cuffs or hats. Some were deliberately introduced. Total numbers are unknown but the invaders include more than 1,000 insects, perhaps 600 nematode worms (about half of them parasitic roundworms), about 75 platyhelminths (e.g. terretrial flatworms and parasitic tape worms), about 60 arachnids (spiders and mites) and about 40 molluscs, including about 13 land snails and 13 land slugs. No systematic assessment of their effect on biodiversity has been made, though their impact on agricultural production has been closely studied. Many appear to have had no effect. Some of the introduced earthworms, for example, have been beneficial for the soil, filling a niche left vacant by the 178 native earthworm species which retreated when their habitat was deforested. About 25 introduced earthworms may be living here, though only 17 have been identified (Yeates, 1991).

Other immigrants have been less benign. Some snails and slugs are suspected of competing with, and perhaps even preying on, native snails and slugs. A recently arrived South African spider (*Steatoda capensis*) is systematically decimating one of New Zealand's few feared wild animals—the katipo spider (*Lactrodectus katipo*). In the past 10 years the katipo, which is an endemic species, has disappeared from many North Island beaches. Although it is a superior fighter, the katipo does not breed fast enough to keep pace with its alien competitor. Nor is it so adaptable and so quick at recolonising disturbed territory. The South African spider is able to live in vegetation above the beach and quickly colonise former katipo territory after natural or human disturbance (Faulls, 1991; Daugherty *et al.*, 1993).

Insects provide examples of both good and bad aliens. A large number are agricultural pests, while a smaller number are biocontrol agents introduced deliberately to prey on or parasitise the pests (P.J. Cameron *et al.*, 1989, 1993; Harman *et al.*, 1996). Of the 321 biocontrol insects introduced since 1874, about 70 have become established, but only one, a tachinid fly (*Trigonospila brevifacies*) is known to parasitise harmless native species—in this case, moths (Atkinson and Cameron, 1993; Cameron, 1994). In general, alien invertebrates have tended not to invade native forest and so have not come into direct conflict with most native species. An example of this may be the Australian passion vine hopper (*Scolypopa australis*) which has recently been suspected of infecting cabbage trees on farms and roadsides while those in forests remain healthy (Brockie, 1995).

However, some insects do invade forests. The German and common European wasps (*Vespula germanicus* and *V. vulgaris*) became established here in 1944 and 1978 respectively and are now widespread in New Zealand forests (Moller *et al.*, 1993). In southern beech forests their biomass in infested areas can exceed the combined biomass of birds, rats, mice, stoats and ferrets, and in podocarp forests, nests as large as 14 cubic metres have been found. Apart from posing a hazard to people visiting the forests, the wasps appear to compete with native wasps and bees, prey on the larvae of native moths, butterflies and other insects, compete with birds for honeydew and insects, and may be accelerating the decline of the yellowhead and kaka (Elliott, 1992; Moller *et al.*, 1993; Thomas *et al.*, 1990). An even more recent wasp invader is the Asian paper wasp (*Polistes chinensis)* a close relative of the Australian paper wasp (*P. humilis*) which was the first foreign wasp to arrive in New Zealand. An attempt is being made to control the alien wasps with an introduced biocontrol species—fittingly enough, a tiny parasitoid wasp called *Sphecophaga vesparum burra* (Beggs *et al.*, 1992).

Because pest and weed control is such a large problem, much of New Zealand's species preservation effort is concentrated on island sanctuaries where it is easier to maintain pest-free habitats. Despite the problems of limited habitat size, some heroic rescues have been made (see Box 9.23). Unfortunately, the small size of most islands limits the number and variety of threatened species that can be sustained on them. In effect, the islands are similar to fragmented reserves on the mainland in which small isolated populations are vulnerable to chance events. The one threat that most island sanctuaries do not have, however, is alien species—and that can make the difference between a successful recovery programme and an unsuccessful one (Towns *et al.*, 1990).

On some islands, however, the threat is not from alien species, but from a transplanted endemic one. The weka or woodhen (*Gallirallus australis*) is a large flightless rail whose nearest relatives are on Lord Howe Island and New Caledonia. Wekas run quickly, swim readily, and are capable killers of rats and stoats. They are inquisitive, aggressive and omnivorous. Their fearlessness made them easy prey for Maori hunters. By the time Cook arrived, wekas had become rare in many areas and only remained abundant in isolated regions, such as the South Island's West Coast and the North Island's East Cape (Falla *et al.*, 1979; King, 1984).

Museum collectors, cats and ferrets reduced the remnant populations in less isolated areas.

They had disappeared from Taranaki by 1920, from Canterbury by 1925 and from large parts of Northland by 1940. However, some wekas had an unlikely saviour. Mutton-birders (seabird hunters) took them to several offshore islands for food supplies. The wekas prospered on the predator-free islands by preying on endemic island birds and invertebrates to the point of wiping some out. As a result, the weka now bears the unusual distinction of being listed by the Department of Conservation as both a threatened species and a pest.

More than 25,000 plant species have been introduced to New Zealand. Of these, nearly 2,000 are now established in the wild (Halloy, 1995; Timmins and Williams, 1991). In fact, exotic species of vascular plants may now outnumber natives in the wild (see Table 9.1). Every year several hundred more arrive and half a dozen or so take root in forest margins, waterways and road verges. In urban Auckland, four new species go wild each year. More than 200 of these exotics now have the potential to displace native plant ecosystems (see Table 9.4).

Pine trees and pasture grasses, the mainstays of our primary economy, are probably the most widespread introduced species, having altered ecosystems so drastically that, in some places, we have lost any vestige of native New Zealand. Other abundant intruders include willows, which can clog rivers, ginger, which has invaded forest edges, *Hieracium* (or hawkweed), which has over-run large areas of South Island high country, and various weeds which have invaded lakes and estuaries. At Pukepuke lagoon near Levin, for instance, two-thirds (120) of the 176 identified plants are introduced species (Ogden and Caithness, 1982).

**Box 9.11**

### *Stemming the plant invaders*

To combat the plant invasion, both legal and voluntary measures have been adopted. Under the Biosecurity Act 1993, the Ministry of Agriculture is drawing up a list of plants whose sale or importation will be prohibited from June 1996. In addition, the Royal Forest and Bird Protection Society, the New Zealand Institute of Noxious Plants Officers and the New Zealand Nurserymens Association have agreed on a list of plants which should not be sold by garden centres because of their harmful effects on native forests (Craw, 1994). Participating garden centres receive a 'Forest Friendly' award.

The Department of Conservation also maintains a database of introduced plant species the Department considers as weeds on the land it administers (see Table 9.4). The list of harmful plants includes **African club moss**, **periwinkle**, **wandering willie** and **Chinese ladder fern** (also known as Boston fern, ladder fern and tuber sword fern), all of which cover the forest floor, preventing seedling regrowth. It also includes **climbing asparagus** and its close relative, **smilax**, which climb into the sub-canopy layers, ringbarking trees and killing them. Shade-tolerant trees and shrubs are also listed—**cotoneaster**, **the privets**, **evergreen** (or **Italian**) **buckthorn** and the **Japanese spindle tree.** Others on the list are: **boneseed** (an aggressive invader of the coast and offshore islands); **convulvulus** or **bindweed** (a white-flowered vine which infests roadside verges and invades hedges, trees and even gardens); **lantana** (which is not only a problem around the upper North Island, but also one of the worst weeds of the entire Pacific region, invading coastlines, islands and forest edges); **pampas grass** (which replaces regenerating forest and native dune plants); and **Mexican daisy** (which is one of the most popular garden plants but invades bluffs, cliffs, stream edges, scrub, and forest margins, replacing rare small shrubs).

A further list maintained by the Department, identifies introduced plant species still to be added to the first database, or those identified by botanists as potential ecological weeds. Among the plants on this list are **Chinese lantern**, **banksia**, **Port Jackson fig**, **blue gum** and various species of **plectranthus**. A third list maintained by the Department names species which are singled out in various operational plans, but which botanists consider as not warranting inclusion on the 'weeds' database. Some of the plants on this list are **fennel**, **buttercup**, **ice plant**, **privet**, **gladiolus** and **kiwifruit**.

Vines are also prominent on the list, though most of these are a problem only north of Taupo. They include: **moth (kapok) plant**, **banana passionfruit**, **eleagnus**, **jasmine**, **mignonette** (or **madiera vine**), **blue morning glory**, **German ivy**, **Japanese honeysuckle** and **mile-a-minute**. South of Taupo the following additional species are listed: **cathedral bells**, **buddleia**, **heather**, **Cape ivy**, **Himalayan honeysuckle**, **aluminium plant**, and, in the lower South Island, **flowering currant**. A recent addition to the list is *Houttuynia cordata,* a colourful ground cover plant with attractive heart-shaped leaves which has recently been sold in some garden centres. It spreads even more vigourously than wandering willie, is self-seeding, and can grow in conditions ranging from full sunlight to dark shade. It covers the ground with a dense carpet of leaves which smother seedlings and other forms of vegetation.

**Table 9.4**

**Alien plants which are considered weeds on conservation lands in New Zealand**

| Common name | Taxonomic name | Common name | Taxonomic name |
|---|---|---|---|
| African club moss | (see selaginella) | madeira vine | Anredera cordifolia |
| African feather grass | Pennisetum macrourum | Manchurian rice grass | Zizania latifolia |
| African fountain grass | Pennisetum setaceum | marram grass | Ammophila arenaria |
| African olive | Olea europeae subsp. cuspidata | Mercer grass | Paspalum distichum |
| agapanthus | Agapanthus praecox | Mexican daisy | Erigeron karvinskianus |
| alder | Alnus glutinosa | Mexican devil | Ageratina adenophora |
| alligator weed | Alternanthera philoxeroides | mile-a-minute | Dipogon lignosus |
| American spartina | Spartina alterniflora | mist flower | Ageratina riparia |
| apple of Sodom | Solanum linnaeanum | monkey apple | Acmena smithii |
| aristea | Aristea ecklonii | monkey musk | Mimulus guttatus |
| arum lily | Zantedeschia aethiopica | montbretia | Crocosmia x crocosmiiflora |
| Australian sedge | Carex longebrachiata | Montpellier broom | Teline monspessulana |
| barberry | Berberis glaucocarpa | moth (kapok) plant | Araujia sericifera |
| barberry, Darwin's | Berberis darwinii | Mysore thorn | Caesalpinia decapetala |
| bindweed / field bindweed | (see convolvulus) | nassella tussock | Stipa trichotoma |
| blackberry | Rubus fruticosus agg. | nasturtium | Tropaeolum majus |
| blueberry / highbush blueberry | Vaccinium corymbosa | old man's beard | Clematis vitalba |
| bone seed | Chrysanthemoides monilifera | onion weed | Allium triquetrum |
| boxthorn | Lycium ferocissimum | orange cestrum | Cestrum aurantiacum |
| broom | Cytisus scoparius | orange firethorn | Pyracantha angustifolia |
| browntop | Agrostis capillaris | oxygen weed | (see erigea) |
| brush cherry | Syzygium australe | oxylobium | Oxylobium lanceolatum |
| buddleia | Buddleja davidii | palmgrass | Setaria palmifolia |
| buttercup bush | Senna septemtrionalis | pampas grass | Cortaderia selloana |
| Cape honey flower | Melianthus major | pampas, purple | Cortaderia jubata |
| Cape ivy | Senecio angulatus | parrot's feather | Myriophyllum aquaticum |
| cathedral bells | Cobaea scandens | passionfruit - banana | Passiflora mollissima |
| cheatgrass | Bromus tectorum | passionfruit - black | Passiflora edulis |
| Chilean flame creeper | Trapaeolum speciosum | passionfruit - northern banana | Passiflora mixta |
| Chilean needlegrass | Stipa neesiana | perennial ryegrass | Lolium perenne |
| Chinese ladder fern / tuber sword fern | Nephrolepis cordifolia | periwinkle | Vinca major |
| clematis | Clematis flammula | pine, cluster / maritime | Pinus pinaster |
| climbing asparagus | Asparagus scandens | pine, dally | Psoralea pinnata |
| climbing dock | Rumex sagittatus | pine, lodgepole | Pinus contorta |
| climbing spindleberry | Celastrus orbiculatus | pine, wilding | Pinus spp. |
| cocksfoot | Dactylis glomerata | privet, Chinese | Ligustrum sinense |
| coltsfoot | Tussilago farfara | privet, tree | Ligustrum lucidum |
| convolvulus / bindweed / field bindweed | Convolvulus arvensis | poplar, white | Populus alba |
| cotoneaster | Cotoneaster glaucophyllus | potato vine | Solanum jasminoides |
| crack willow | Salix fragilis | pyp grass | Ehrharta villosa |
| Douglas fir | Pseudotsuga menziesii | ragwort | Senecio jacobaea |
| egeria / oxygen weed | Egeria densa | red cestrum | Cestrum elegans |

| Common name | Taxonomic name | Common name | Taxonomic name |
|---|---|---|---|
| *elaeagnus* | *Elaeagnus x reflexa* | *rowan* | *Sorbus aucuparia* |
| *elder / elderberry* | *Sambucus nigra* | *royal fern* | *Osmunda regalis* |
| *elephant's ear* | *Alocasia brisbanensis* | *rush, bulbous* | *Juncus, bulbosus* |
| *evergreen buckthorn/ Italian buckthorn* | *Rhamnus alaternus* | *rush, heath* | *Juncus squarrosus* |
| *floating sweetgrass* | *Glyceria fluitans* | *rush, jointed* | *Juncus articulatus* |
| *German ivy* | *Senecio mikanioides* | *rush, sharp* | *Juncus acutus* |
| *giant reed* | *Arundo donax* | *rush, soft* | *Juncus effusus* |
| *ginger (kahili)* | *Hedychium gardnerianum* | *salvinia / water fern* | *Salvinia molesta* |
| *ginger (yellow)* | *Hedychium flavescens* | *selaginella* | *Selaginella kraussiana* |
| *gorse* | *Ulex europaeus* | *Senegal tea* | *Gymnocoronis spilanthoides* |
| *grey willow* | *Salix cinerea* | *smilax* | *Asparagus asparagoides* |
| *hakea, downy* | *Hakea, gibbosa* | *spartina* | *Spartina x townsendii* |
| *hakea, prickly* | *Hakea, sericea* | *spartina hybrid* | *Spartina anglica* |
| *hakea, willow-leaved* | *Hakea, salicifolia* | *spindleberry* | *Euonymus europaeus* |
| *hawkweed* | *Hieracium spp.* | *spindleberry, Japanese* | *Euonymus japonicus* |
| *hawthorn* | *Crataegus monogyna* | *St John's wort* | *Hypericum perforatum* |
| *heath, Spanish* | *Erica lusitanica* | *stinking iris* | *Iris foetidissima* |
| *heather* | *Calluna vulgaris* | *stonecrop* | *Sedum acre* |
| *honeysuckle - Himalayan* | *Leycesteria formosa* | *sweet briar* | *Rosa rubiginosa* |
| *honeysuckle - Japanese* | *Lonicera japonica* | *sweet cherry / wild cherry* | *Prunus avium* |
| *hops* | *Humulus lupulus* | *sweet pea bush* | *Polygala myrtifolia* |
| *horsetail* | *Equisetum arvense* | *sword fern* | *(see Chinese ladder fern)* |
| *hydrilla* | *Hydrilla verticillata* | *sycamore* | *Acer pseudoplatanus* |
| *inkweed* | *Phytolacca octandra* | *tall fescue* | *Festuca arundinacea* |
| *Italian buckthorn* | *(see evergreen buckthorn)* | *tall oatgrass* | *Arrhenatherum elatius* |
| *Italian lily / Italian arum* | *Arum italicum* | *thistles* | *Cirsium spp.* |
| *ivy* | *Hedera helix* | *thistle nodding* | *Carduus nutans* |
| *Japanese walnut* | *Juglans ailantifolia* | *tuber sword fern* | *(see Chinese ladder fern)* |
| *jasmine* | *Jasminium polyanthum* | *tutsan* | *Hypericum androsaemum* |
| *jasmine, yellow* | *Jasminum humile* | *veld grass* | *Ehrharta erecta* |
| *Jerusalem cherry* | *Solanum pseudocapsicum* | *viper's bugloss* | *Echium vulgare* |
| *kangaroo acacia* | *Racosperma paradoxum* | *wandering willie* | *Tradescantia fluminensis* |
| *Khasia berry* | *Cotoneaster simonsii* | *water fern* | *(see salvinia)* |
| *Kikuyu grass* | *Pennisetum clandestinum* | *water net* | *Hydrodictyon reticulatum* |
| *knotweed, giant* | *Reynoutria sachalinensis* | *watsonia* | *Watsonia bulbillifera* |
| *knotweed, Japanese* | *Reynoutria japonica* | *wattle, brush* | *Paraserianthes lophantha* |
| *lagarosiphon* | *Lagarosiphon major* | *wattle, silver* | *Racosperma dealbatum* |
| *lantana* | *Lantana camara var. aculeata* | *wattle, Sydney golden* | *Racosperma longifolium* |
| *loquat* | *Eriobotrya japonica* | *wild cherry* | *(see sweet cherry)* |
| *lotus* | *Lotus pedunculatus* | *wonga wonga vine* | *Pandorea pandorana* |
| *lupin, Russell* | *Lupinus polyphyllus* | *woolly nightshade* | *Solanum mauritianum* |
| *lupin, tree* | *Lupinus arboreus* | *yellow flag iris* | *Iris pseudacorus* |

*Source: Department of Conservation (1997)*

Only a few Northland lakes, some isolated South Island lakes, and the Chatham Islands may have no introduced aquatic plants (Howard-Williams and Davies, 1988). One lake invader is the waterweed *Lagarosiphon major*, which was introduced from southern Africa about 1950. By 1957 it had reached nuisance proportions in Lake Rotorua and by 1966 had reached Lake Taupo. By 1980 it had colonised all potential sites in Lake Taupo and had displaced native water plants over large areas of the shoreline (Howard-Williams and Davies, 1988).

Other introduced plants, such as old man's beard, pose an increasing threat to native forests. A study of 234 small to medium lowland forest reserves (500 hectares or less) found that invasive plants are more common in reserves that are close to towns, rubbish dumps, roads and farms. The alien plants are also more common in reserves which have a high number of human visitors or a large perimeter-to-area ratio (Timmins and Williams, 1991).

## THE STATE OF NEW ZEALAND'S BIODIVERSITY

About 1,000 of our known indigenous taxa (800 species and 200 sub-species) are now considered threatened. These figures relate only to the 'higher' organisms whose conservation status has been studied—plants, animals and fungi. Nearly 300 threatened plants and 500 animals have been listed by the Department of Conservation (1992b; 1994b and 1994e), while scientists at Landcare Research have compiled a list of more than 200 threatened fungi (Buchanan and Beever, 1995). Some endemic micro-organisms (bacteria, protozoans and algae) may also be threatened, though research on these groups has tended to focus on their effects on health, soil and water rather than assessing their conservation status.

The Department of Conservation has ranked 403 plant and animal taxa as having conservation priority (categories A, B and C). These include all of our endemic frogs and mammals, more than three quarters of our endemic birds, more than a third of our reptiles and freshwater fish, and most of our giant land snails and giant wetas. A further 389 threatened plants and animals are unranked (categories I, O and X). Most of these are category I species and subspecies whose rarity is known, but whose precise status is uncertain because of insufficient information. Two dozen are category X species—those which have not been seen for several years and are possibly extinct (10 plants, 12 invertebrates, 1 bird and 1 bat). A further 40 of the unranked taxa are category O species—plants and migratory birds which are threatened in New Zealand but have secure populations overseas. The Department also lists a further 19 taxa which have special importance in Maori culture and are rare or localised. These include half a dozen plant species introduced by early Maori settlers.

Given that most of our fungi and invertebrate animals are still unidentified, the true number of threatened species may be several times higher than the above figures—though the evidence to date suggests that it is larger organisms that are most at risk. Continuing pressure on habitats and vulnerable populations is likely to push the number even higher in the next century. It is also possible that, even among the known species, the level of threat is higher than currently thought. In keeping with overseas practice, the Department of Conservation (1992b and 1994b) has taken the safety threshold for plant populations to be about 500 and, for animal populations, about 1,000. Recent work in population genetics, however, suggests that the 'safe' long-term population size may be closer to 5,000 (Lande, 1995).

Despite these uncertainties, the news, for some species at least, is not all bad. In the two years between the compilation of the 1992 list and the 1994 list, the conservation status of several species improved (e.g. the Canterbury mudfish, black mudfish, yellow-eyed penguin, Mahoenui giant weta and Chatham Island pigeon). The improvements resulted from conservation programmes to control predators, protect habitats and translocate species to a safer area. Surveys also turned up both new species and 'new' populations. Four new galaxiids were found in Otago and one each on the Chatham Islands and Stewart Island. New populations of black-eyed gecko, North Island kokako, Northland tusked weta, Banks Peninsula weta, the Canterbury mudfish, and the tussock *Chionochloa spiralis* were all found. (A special area at Dog Kennel Creek has been designated to protect the best-known mudfish site.) However, these good news stories were the exception rather than the rule. The surveys showed that most threatened species were as critically threatened as before (Department of Conservation, 1994b).

**The State of Our Bacteria**

To many people bacteria are synonomous with disease, although most of the naturally-occurring bacteria in our soils and waters and on our bodies are harmless or beneficial. Globally, less than 5,000 species have been described, but scientists now think many more may exist, perhaps numbering millions, and perhaps even outnumbering all other species. Bacteria have been around for so long that most known species are almost global in their distribution.

New Zealand has less than 300 described species and most of these are also known from other parts of the world. Estimating the number of unknown species is nearly impossible, but a conservative estimate may be obtained by looking at the other species which live here. It is generally assumed that most 'higher' species harbour at least one, and sometimes several, unique species of bacteria which have evolved to live exclusively in or on them. If so, New Zealand might have at least 80,000 species of symbiotic bacteria alone. The free-living species would take this number even higher.

Nobody knows how many bacteria are threatened. In fact, the very concept of threatened bacteria seems profoundly odd because we are so used to hygiene practices and antibiotics aimed at eliminating bacteria from our bodies, food and water. But some of New Zealand's bacteria may be threatened, especially those that have evolved to live symbiotically on threatened plants, animals or fungi, and those which are endemic to threatened geothermal locations (Holmes, 1996).

Since we have at least 800 threatened plant, animal and fungi species, and several degraded hot pools and geysers, the total number of threatened bacteria could be more than 1,000 species. The geothermal bacteria are particularly interesting because their unique chemistry enables them to withstand extremely high temperatures. Many of our hot pools have come under considerable pressure in recent decades (see Chapter 7). One example of a hot pool species that could be vulnerable is a green sulphur bacteria called *Chlorobium tepidum*. This may be endemic to New Zealand and is known from only four hot springs, including a drain beneath a hotel (Holmes, 1996).

Apart from endemic symbionts and geothermal bacteria, few concerns are held for most types of bacteria. In fact, with so few species identified to date, scientists are far more interested in detecting bacteria than protecting them, both to combat harmful species and to harness useful ones. Despite the successes of modern antibiotics and public health systems, many harmful bacteria are still with us, such as food-poisoning ones like *Campylobacter, Salmonella* and *Shigella* (Public Health Commission, 1994). Other harmful bacteria include *Meningococcus* (which causes meningitis) and the deadly *Mycobacterium tuberculosis* (which causes the lung disease, Tb, and is increasing in many areas of the world, including parts of New Zealand). Nuisance blooms of *cyanobacteria* are also a problem in nutrient-rich streams, ponds, and lakes.

But not all research is preoccupied with problem bacteria. In recent years the spectacular progress in biotechnology has enabled bacterial genes to be harnessed for the production of medicines and useful industrial compounds (such as enzymes for cleaning up oil spills). Since the two bacterial domains contain greater genetic diversity than the rest of the living world, bacteria are now being seen as an unexplored goldmine (Holmes, 1996). From this perspective, rare species, such as the hot pool bacteria, are potentially valuable resources.

### The State of Our Protozoans

The number of known protozoan species in New Zealand is roughly 2,600 (see Table 9.1) but the real figure may be as high as 7,000–8,000, made up of roughly 3,500 marine species, 3,500 soil and freshwater species and 1,000 parasites. Most of the known species are marine protozoans, as these have been the best described to date (Dawson, 1992). Soil and freshwater protozoans remain poorly documented (Hayward, 1980). Their presence in soil is generally taken as a positive indicator of soil health, but their presence in water is more often taken as a sign of health risk.

About 10 percent of the known species are parasites recovered from fish, birds, reptiles, domestic and feral mammals, and humans. A large amount of research has focused on these parasitic and symbiotic species, particularly those which cause disease (e.g. *Giardia lamblia*, *Cryptosporidium*). More than a dozen protozoan parasites have been recorded in humans in New Zealand. Four of these are endemic New Zealand species which colonised humans after we had colonised the country. The other human-dwelling protozoans arrived with us from other parts of the world.

Nearly half the known parasitic protozoans are exotic species which live inside our introduced birds and mammals and were imported with them. However, many more indigenous parasites probably live in our endemic birds, reptiles and land invertebrates. No protozoans are known to be threatened in New Zealand, despite the efforts of public health experts to reduce the numbers of some of the harmful ones. In fact the health risk from waterborne and food-borne protozoans appears to have increased in recent years (see Chapter 7, Box 7.6).

### The State of Our Algae

Many unrelated groups of photosynthesising protists are called 'algae'. For convenience, they are often lumped into two broad groups according to their size—the macro-algae and the micro-algae. The *macro-algae*, or seaweeds (consisting of Brown algae and the multi-celled species of Red and Green algae) attach themselves to rocks or other hard surfaces and grow like plants. In contrast, the tiny *micro-algae*, or phytoplankton (i.e. the Dinoflagellates, Diatoms, Euglenoids, Yellow and Golden algae, and the single-celled species of Red and Green algae) either float near the surface or form thin coverings over rocks.

#### *Micro-algae (phytoplankton, periphyton)*

Micro-algae occasionally form visible blooms of phytoplankton in the sea and in polluted freshwater, and slippery green coatings of periphyton on rocks in streams. A small number of species are toxic (see Chapter 7, Box 7.11). Generally micro-algae are invisible except as coloured stains in the water, froths on the sand at high water mark, scums on ponds, or coloured mats below hot thermal pools (Cooper and Cambie, 1991). New Zealand has more micro-algae species than it has vascular plants, but few of these are endemic. The number of known species is about 2,800, three-quarters of which live in freshwater and a quarter of which live in the sea. Diatoms are the most diverse of the micro-algae kingdoms, making up 25 percent of the freshwater species and more than 60 percent of the marine species.

In the past century, some micro-algae have increased to nuisance levels in many streams, wetlands and shallow lakes (see Chapter 7). The causes are increased sunlight, where riverbanks have been cleared of native forest, and increased nutrient pollution from farm run-off and sewage discharges. One group of marine micro-algae, the dinoflagellates, has recently become more widely known because of the appearance of several toxic species (see Chapter 7, Box 7.11). It is not known whether marine micro-algae are generally becoming more or less abundant.

***Macro-algae (seaweeds)***

New Zealand has a rich diversity of seaweeds (Adams, 1994). Approximately 15 freshwater species and about a thousand marine species are found here. About 40 percent of these are endemic. Little is known about the distribution, ecology and status of most species. Many are still undescribed and many of those which have been described require major taxonomic revision (Nelson, 1994a). Although none appear to be threatened, some have specific niche requirements and are very localised in distribution (e.g. *Gelidium allanii*, *G ceramoides*) while others are vulnerable and may merit monitoring. These include:

- endemic species with very restricted distributions (e.g. *Perispoochus regalis*, *Carpococcus linearis*);
- epiphytic species attached to hosts with very restricted distributions (e.g. *Porphyra kaspar*); and
- species that are known from only one location or a very small number of collections (e.g. *Codium platyclados*, *Chnoospora minima*, *Amplisiphona pacifica*; *Palmophyllum umbracola*, *Porphyra woolhousiae*).

Seaweeds vary widely around our offshore islands. To the south, Stewart Island and the subantarctic islands have rich and diverse seaweed communities. To the north, the Kermadec Islands have some species that are closely related to those in far off warm regions of the Pacific and Indian Oceans. Some other island groups have their own endemic species (e.g. Three Kings and Chatham Islands).

**Brown algae** are the most common and largest seaweeds. Globally, they number at least 100,000 species, are almost entirely marine, and are all multi-celled. They range in size from microscopic threads to huge kelps up to 70 m long. The bull kelp (*Durvillaea antarctica*) is the world's fastest-growing organism, capable of growing 2 m in a day. It is especially noticeable in cool, shallow waters where it forms brown, ribbon-like, 'forests'. It was abundant off the South Island's east coast until recent decades. Sedimentation has been identified as a possible cause of its decline (Royal Society of New Zealand, 1993). Competition from invasive alien seaweeds, such as the brown seaweeds, *Undaria pinnatifida* and *Colpomenia durvillaei*, may also be a threat (Nelson, 1994b).

**Red algae** exist in single-celled and multi-celled forms. The latter are almost entirely marine. They form branching structures or broad, flat, plates and ruffles. Some of the more complex red algae grow up to a metre, though most are small and delicate. The red alga *Pterocladia lucida* is harvested commercially to produce high quality agar which is used in laboratories as a food source for micro-organisms grown in petri dishes. The status of red seaweeds in New Zealand is unknown.

Most **green algae** are single-celled and live in freshwater or sometimes on moist land. A number, however, are multi-celled and form small ribbon-like seaweeds and algal 'turfs' on the coastal seabed and on stream and lake beds. Their status is unknown, though many are a nuisance in freshwater, where their population blooms are associated with the eutrophication of streams and small lakes.

Our only non-algal 'seaweed' is a flowering plant, sea grass (*Zostera novazelandica*). It has apparently declined around our coasts as a result of sedimentation caused by coastal developments such as harbour and marina construction, channel dredging, spoil dumping and stormwater runoff. Efforts are being made to restore it (Turner, 1995).

### The State of Our Indigenous Plants

New Zealand's turbulent history of isolation, inundation, uplift, and ice age has left its mark on the indigenous plants (see Box 9.12). Many (80 percent) are endemic, that is they are are found nowhere else in the world. It has also allowed us to retain a rich mixture of primitive non-vascular plants (e.g. mosses) but has limited the diversity of our higher vascular plants (trees, grasses and other flowering plants). This can be seen in New Zealand's relatively low ratio of vascular to non-vascular plants. While the world in general has 9 or 10 vascular plants for every one non-vascular species, we have only 2 native vascular plants for every non-vascular one. In other words, vascular plants make up more than 90 percent of the world's land plants, but only 70 percent of New Zealand's. Having high endemism makes the conservation of New Zealand plants that much more critical: if New Zealanders do not look after their unique plants, no one else can.

In recent years, the Department of Conservation and the New Zealand Botanical Society have produced lists of the plants considered threatened (Cameron *et al.*, 1993, 1995; Department of Conservation, 1992b, 1994b). The Botanical Society's list is considered definitive by all parties, while the Department of Conservation's list has the more restricted purpose of ranking threatened species for conservation management purposes. The criteria for both lists therefore differ slightly.

Although the two threatened plants lists are in broad agreement, the Society's list is longer than the Department's because it includes a greater number of plants which are: *taxonomically indeterminate* (i.e. undescribed plants whose taxonomic status still requires clarification); and *insufficiently known* (i.e. where the identity or status of the plant is poorly understood). Unlike the Department, the Society also includes *rare* species (i.e. those with limited numbers or distributions, but which are not threatened at present) and 'local' plants (i.e. those with limited distributions that warrant monitoring).

As a result of these differences, the Department of Conservation lists a total of 302 plant taxa as threatened (including not only full species, but also threatened sub-species and varieties) while the Botanical Society lists 319 (and an additional 142 classed as 'local').

The Department's list includes 199 full species of vascular plants, representing about 10 percent of our known vascular plants, and 85 full species of non-vascular plants (8 percent). Taken together, the Department and Society lists indicate that 8–10 percent of our native plants are at risk, with the percentage rising to almost 14 percent if rare and locally restricted species are included.

The Department and the Society are mostly in agreement on another small list of plants, though they use different terminology to describe it. The list consists of a dozen species, 9 of which are 'presumed extinct' by the Botanical Society, and 10 of which are defined more optimistically by the Department of Conservation as 'species which have not been sighted for a number of years, but which may still exist' (see Table 9.6). Both organisations consider a taxon extinct when it is "no longer known to exist in the wild after repeated searches of the type localities and other known places".

One plant generally accepted to be extinct is Adams' mistletoe (*Trilepidea adamsii*). Noted for its tubular red flowers and shiny leaves, the mistletoe was known to exist in only a few areas north of Hamilton. It has not been seen since 1954 (Given, 1981; Norton, 1991; Wilson, 1992). The mistletoe's demise followed a series of increasingly fatal encounters with the main forces that have ravaged New Zealand's ecosystems during the past 700 or so years. First, deforestation by Maori and then European settlers collected the plant for its attractive flowers.

**Box 9.12**

### *The roots of our plants*

Plants evolved from multi-cellular green algae, probably in estuarine areas, about 460 million years ago (Niklas, 1994; Palmer, 1995b). Fungi were also colonising the land around this time and particular species formed associations with the new plant species, defending them against other fungi in exchange for food. Those first plants were **liverworts**, **mosses** and **hornworts.** They make up the most primitive division of the plant kingdom—the Bryophytes. Because they had no vascular tissues to store and circulate fluids within their bodies, these early land plants were unable to survive far from water. They formed low green mats on moist surfaces. Today, about 16,000 species are known worldwide, more than 1,000 of them in New Zealand.

The first **vascular** plants evolved about 410 million years ago. Called *Cooksonia*, these 10 cm long plants were vine-like, without leaves or roots, but with vascular systems that enabled them to redistribute water and nutrients inside their tissues (Palmer, 1992). They subsequently gave rise to upright plants—ferns, whose leafy fronds could catch falling water and whose rhizomes (underground stems) could absorb it from the soil. They were followed about 380 million years ago by the first trees, cone-bearing gymnosperms. Meanwhile, the mud and sediment that eventually became New Zealand had not even begun to accumulate in the sea floor. The great Permian extinction came and went, then the continent of Pangea split into smaller continents, including Gondwana. When the New Zealand landmass was finally thrust out of the sea as an appendage to the Gondwana coastline, these early plants were waiting to come aboard.

That was about 135 million years ago, and as our first kauris, podocarps, ferns and mosses were settling in, a plant revolution was brewing behind them. A new class of diverse and colourful plants was on the rise in Gondwana—the angiosperms, or flowering plants. Today, the angiosperms are the world's dominant plants, with 240,000 or more living species, compared to less than 600 gymnosperm species and about 10,000 ferns. With bright flowers, sweet nectar, aromatic scents and easily dispersed pollen and seeds, the angiosperms enlisted insects and wind as pollinating agents. From their origins, perhaps 250 million years ago, the angiosperm ancestors remained an obscure branch of the plant kingdom until about 130 million years ago when they gave rise to the first small flowering herbs and provided an evolutionary springboard for the pollinating insects (Crane *et al.*, 1995). Within the past 100 million years, these plants diversified into herbs and shrubs, hardwood trees, grasses, palms and flaxes. Some made their way to New Zealand just before it parted company with Gondwana. Others arrived later.

Among the first angiosperms to reach New Zealand was the wind-pollinated southern beech tree (*Nothofagus* species). It arrived between 80 and 110 million years ago, after New Zealand had separated from the Australian part of Gondwana, but before it had separated from the Antarctic region. For several million years, the beech forests stretched continuously from Tasmania, and through what is now New Zealand and Marie Byrd Land in Antarctica, on into South America. Even today, the beech forests of New Zealand and South America resemble each other so closely that each has the same parasitic fungi, mosses and flightless sucking bugs inhabiting their bark (Stevens *et al.*, 1995). While angiosperms were to displace gymnosperms in many parts of the world, New Zealand's gymnosperms and beech forests reached an ecological accord of sorts. The beech tended to occupy the cooler south and the high ground, while the gymnosperms took the north (i.e. the kauri forests) and the lowlands both north and south (i.e. the podoarp forests). In many intermediate zones, beech and podocarp formed mixed forests. They were later joined by other flowering trees whose seeds blew or floated down from westward and northern landmasses.

The beech trees were not the only angiosperms to migrate overland. The Magnolia, Protea, and Fuchsia families were others to arrive before the final split with Gondwana. After the split though, angiosperm immigrants arrived as pollen and seed on westerly winds and tides, or as passengers aboard windblown insects and birds. The ancestors of the pohutukawa and rata trees arrived this way some time after the great extinctions of 65 million years ago. They mingled with the podocarps and beeches and, in places, formed dominant red-flowered canopies of their own. Nikau palm arrived less than 50 million years ago as New Zealand was sinking, and the small trees *Coprosma* and *Pittosporum* got here less than 40 million years ago as the land became a string of islands. During this island phase many plants were probably lost, while those that survived began to evolve into slightly different species on each island. When New Zealand began rising again, about 25 million years ago, the land connections between these island species were restored, allowing a variety of closely related shrubs and trees to recolonise the land.

New species continued to arrive on the westerly air currents as New Zealand got bigger. They included the cabbage trees (*Cordyline* spp.) which landed here less than 25 million years ago, and the small herbs, such as daisies and rosette plants, which became established in the newly uplifted alpine areas less than 6 million years ago. Subsequent ice ages separated many populations into ice locked 'islands', once again leading to the evolution of separate, but closely related, alpine taxa. As a result, there are now more types of alpine plants than forest ones, though many of these are sub-species rather than full species. The last ice age ended about 12,000 years ago, and the plant communities that survived are a unique mix of the very old (e.g. mosses, ferns, kauri, podocarp and beech trees) and the comparatively young (e.g. cabbage trees, alpine herbs and tussock grasses). In human terms, of course, they are all ancient, having lived in stable and unique ecological communities for thousands of years before our arrival.

Introduced mammals added to the pressure on the mistletoe by helping to reduce the native bird populations which normally dispersed the mistletoe seed. Ultimately, however, it was the human factor that delivered the *coup de grâce*. Collectors and artists sought specimens of the very pretty, but increasingly rare plant, with ever greater determination, and eventually it was almost picked out of existence. New Zealand has been left a wealth of fine paintings of Adams' mistletoe, but the plant has gone. Over-collecting has been a persistent factor in the decline of several rare New Zealand plants.

Threatened plants are not limited to one or two particular habitats. About a fifth are in wetlands, where drainage and intruding species have been major pressures. Another fifth are in coastal ecosystems, where the degradation of dunelands and ecological changes caused by the decline in seabird and marine mammal colonies have been significant sources of pressure. Other significant homes of threatened plants are inland rocky habitats, scrub areas, tussock/herbfield ecosystems, and, last of all, lowland forests (see Tables 9.7 and 9.8).

Several long-lived shrubs and small trees are known only from fragmented, ageing and non-regenerating populations. They are failing to reproduce because ecological processes, such as pollination and seed dispersal, which were once carried out by native birds and other animals, no longer occur. These 'living dead' plants include such highly threatened species as the shrubby tororaro *(Muehlenbeckia astonii*) and the unusual *Helichrysum dimorphum* which, as the name suggests, can take on two very different forms: either a small shrub or a scrambling vine.

Not all threatened plants face such a bleak future, however. Occasionally a species given up for dead surprises the experts. The nodding greenhood orchid (*Pterostylis nutans*), for example, had not been seen for many years and was considered either extinct or extremely vulnerable. It has recently been discovered in at least two central North Island locations.

**Table 9.5**
**New Zealand's most threatened plants**

| Taxonomic Name | Common Name/Description | DoC (A and O species) | NZBS (Top 20) |
|---|---|---|---|
| *Acaena rorida* | *Ruahine bidibidi; (piripiri)* | *T* | *T* |
| *Amphibromus fluitans* | *Water brome* | *T** | *T** |
| *Anogramma leptophylla* | *Jersey fern* | *T** | |
| *Asplenium pauperequitum* | *Poor Knights spleenwort* | *T* | *T* |
| *Atriplex billardierei agg.* | *Crystal wort* | *T** | |
| *Australopyrum calcis subsp. calcis* | *Limestone wheatgrass* | *T* | *T* |
| *Australopyrum calcis subsp. optatum* | *Limestone wheatgrass* | *T* | |
| *Botrychium aff. lunaria* | *Moonwort* | *T* | |
| *Caleana minor* | *Small or Flying duck orchid* | *T** | *T*** |
| *Calochius herbaceus* | *Bearded swamp orchid* | *T** | |
| *Calystegia marginata* | *Australian bindweed* | *T** | |
| *Carex inopinata* | *a leafy, mat-forming sedge* | *T* | |
| *Carmichaelia kirkii s. lat.* | *Kirk's native broom* | | *T* |
| *Chiloglottis validus* | *Bird orchid* | *T** | |
| *Chordospartium muritai* | *Coastal tree broom* | *T* | |
| *Christella dentata 'N.Z.'* | *Soft fern* | *T* | |
| *Clianthus puniceus* | *Kakabeak; (kowhai gnutu-kaka)* | *T* | |
| *Coprosma 'violacea'* | *a swamp coprosma* | *T* | |
| *Cortaderia turbaria* | *Chatham Island toetoe* | *T* | *T* |
| *Corybas carsei* | *Swamp helmet orchid* | *T* | *T* |
| *Cryptostylus subulata* | *Duck orchid* | *T** | |
| *Cyclosorus interruptus* | *a thermal swamp fern* | *T** | |

| **Taxonomic Name** | **Common Name/Description** | **DoC (A and O species)** | **NZBS (Top 20)** |
|---|---|---|---|
| *Dactylanthus taylorii* | *Woodrose; (pua o te reinga)* | *T* | |
| *Davallia 'Puketi'* | *Puketi hare's foot fern* | *T* | |
| *Doodia aspera* | *Creeping rasp fern* | *T** | |
| *Gratiola nana* | *a low creeping herb* | *T** | |
| *Hebe bishopiana* | *Waitakere rock hebe* | *T* | |
| *Hebe breviracemosa* | *Kermadec koromiko* | *T* | *T* |
| *Helichrysum dimorphum* | *a small shrub or scrambling liana* | *T* | |
| *Hibiscus diversifolius* | *Thorny hibiscus* | *T** | |
| *Korthalsella salicornioides* | *Dwarf scrub mistletoe* | *T** | |
| *Lepidium banksii* | *Coastal peppercress—(a stout herb)* | *T* | *T* |
| *Lepidium sisymbrioides subsp. kawarau* | *Kawarau Gorge cress* | *T* | |
| *Lepidium sisymbrioides subsp. matau* | *Alexandra cress* | *T* | *T* |
| *Leptinella nana* | *Pygmy button daisy (Cotula)* | *T* | |
| *Lepturus repens* | *Sickle grass* | *T** | *T** |
| *Marrattia salicina* | *King fern* | *T** | |
| *Melicytis 'Egmont'* | *A low-growing divaricating shrub* | *T* | |
| *Metrosideros bartlettii* | *Bartlett's rata* | *T* | |
| *Muehlenbeckia astonii* | *Shrubby tororaro* | *T* | |
| *Myosotis 'Lytteltonensis'* | *a forget-me-not* | *T* | |
| *Olearia hectorii* | *Hector's tree daisy* | *T* | |
| *Olearia pachyphylla* | *Thick-leaved tree daisy* | *T* | |
| *Ophioglossum petiolatum* | *Adders-tongue fern* | *T** | |
| *Pennantia baylisiana* | *a small tree up to 5 m tall* | *T* | *T* |
| *Peperomia leptostachya* | *Pacific pepperonia* | *T** | *T** |
| *Phylloglossum drummondii* | *a fern ally* | *T** | |
| *Pittosporum 'Surville'* | *North Cape kohuhu* | *T* | |
| *Plantago spathulata subsp. picta* | *Papa plantain* | *T* | |
| *Plectranthus parviflorus* | *Cockspur flower* | *T** | |
| *Pomaderris apetala* | *Tainui tree* | *T** | |
| *Pomaderris polifolia* | *a low shrub* | *T** | |
| *Pterostylis micromega* | *Swamp greenhood; (tutukiwi)* | *T* | |
| *Pterostylis puberula* | *a greenhood* | *T* | *T* |
| *Pterostylis tasmanica* | *Plumed greenhood* | *T** | |
| *Ranunculus recens 'Moawhango'* | *a buttercup* | *T* | *T* |
| *Sebaea ovata* | *a yellow-flowered annual herb* | *T* | *T*** |
| *Tecomanthe speciosa* | *Tecomanthe (a woody liana)* | *T* | *T* |
| *Thelymitra malvina* | *Kauri swamp sun orchid* | *T** | |
| *Thelymitra matthewsii* | *Spiral sun orchid* | *T* | *T** |
| *Todea barbara* | *Royal fern* | *T** | |
| *Triglochin palustris* | *Marsh arrowgrass* | *T** | |
| *'X. it'* | *a lone small shrub, genus unknown* | *T* | *T* |

*DOC = Highly threatened plants in the Department of Conservation (1994b) Threatened Species Priority Lists A and O*
*NZBS = The top 20 plants on the New Zealand Botanical Society's Threatened Plants List (Cameron et al., 1995)*
** Indigenous to New Zealand, but also has natural populations overseas that are not considered threatened.*
*** Indigenous to New Zealand and EITHER has natural populations overseas that are considered threatened OR is thought to have natural populations overseas, but may, on revision, prove to be endemic to New Zealand.*

**Table 9.6**

**New Zealand plants which have not been seen for a number of years and may be extinct (X).**

| Taxonomic Name | Common Name/Description | DoC (A and O species) | NZBS (Top 20) |
|---|---|---|---|
| *Chiloglottis formicifera* | *Ant orchid* | *X* | *X** |
| *Deyeuxia 'Flaxbourne'* | *an oat grass* | *X* | *Unlisted* |
| *Lepidium obtusatum s. str.* | *Scurvy grass* | *X* | *X* |
| *Lepidium obtusatum subsp. 'Manukau'* | *Scurvy grass* | *Unlisted* | *X* |
| *Leptinella filiformis* | *a button daisy (Cotula)* | *X* | *Unlisted* |
| *Logania depressa* | *a prostrate shrub* | *X* | *X* |
| *Muellerina celastroides* | *a mistletoe* | *Unlisted* | *X** |
| *Myosotis laingii* | *Laing's forget-me-not* | *X* | *X* |
| *Pseudognaphalium 'Zoo'* | *Cud weed* | *X* | *Unlisted* |
| *Stellaria elatinoides* | *Native chickweed* | *X* | *X* |
| *Trilepidia adamsii* | *Adams' mistletoe* | *X* | *X* |

*DOC = Department of Conservation (1994b) Threatened Species Priority List, Category X*
*NZBS = New Zealand Botanical Society Threatened Plants List (Cameron et al., 1995)*
** Indigenous to New Zealand, but also found naturally overseas where it is not considered threatened.*

**Table 9.7**

**Habitats in which threatened plants occur, showing increases since 1989.**

| | Extinct | Critical | Endangered | Vulnerable | Rare | Insufficient knowledge | Total | Change 1989–95 |
|---|---|---|---|---|---|---|---|---|
| *Sandy shorelines* | *0* | *2* | *3* | *1* | *2* | *0* | **8** | |
| *Rocky shorelines and stony beaches* | *2* | *2* | *4* | *5* | *9* | *1* | **23** | *(+18)* |
| *Coastal cliffs and steep coastal slopes (including those with low scrub)* | *0* | *2* | *6* | *5* | *8* | *0* | **21** | |
| *Coastal and lowland forest and tall scrub* | *2* | *3* | *6* | *7* | *8* | *2* | **28** | |
| *Inland forest* | *0* | *0* | *3* | *2* | *1* | *0* | **6** | |
| *Inland scrub* | *1* | *2* | *7* | *8* | *3* | *1* | **22** | |
| *Grasslands, herbfields and dry marshland* | *2* | *1* | *3* | *9* | *12* | *6* | **33** | *(+21)* |
| *Inland cliffs and rock outcrops* | *0* | *0* | *0* | *9* | *15* | *8* | **32** | *(+27)* |
| *Limestone talus* | *0* | *2* | *1* | *2* | *2* | *2* | **9** | *(+4)* |
| *Swamps, bogs, seepages* | *2* | *3* | *1* | *10* | *12* | *8* | **36** | *(+14)* |
| *Lake margins and aquatic habitats* | *0* | *2* | *2* | *3* | *4* | *0* | **11** | *(+4)* |
| *Geothermal areas* | *0* | *1* | *1* | *1* | *3* | *0* | **6** | |
| ***Total*** | **9** | **20** | **37** | **62** | **79** | **28** | | |

*Source: Wilson and Given (1989) updated by Given*

### *The State of Our Non-vascular Plants*

New Zealand has a greater variety of mosses and liverworts than many comparable land areas around the world. Like the lowly fungi and flatworms, and the land snails and spiders, they are among our unsung biodiversity heroes—and our least known. For 400 million years, the mosses, liverworts, and their kin have lived in the shadow of the vascular plants. They have carpeted damp forest floors, clothed the decaying forms of fallen logs and colonised bare rock surfaces in the aftermath of volcanic eruptions, landslides, or other disturbances. They are as comfortable by the seaside as they are clinging tenaciously to icy wind-blasted scree on the highest peaks. Though overshadowed, they have survived longer than any of the species that now share the forests and rock faces with them. Indeed, it is their survival techniques which allow other, more showy plants, to become established where soil is thin or bare. The nursery 'bed' they provide for seeds helps to prevent soil erosion and harbours a wealth of tiny invertebrate animal life.

Today New Zealand has about 1,070 species of this ancient plant grouping. Collectively they are known as Bryophytes, a plant division (or phylum) with five classes: true mosses (Bryopsida), granite mosses (Andreaeopsida), peat mosses (Sphagnopsida), liverworts (Hepaticopsida) and hornworts (Anthocerotopsida). New Zealand's species are divided roughly equally between the mosses and the liverworts. Hornworts contribute just 26 known species to the total.

The Department of Conservation lists 85 mosses and liverworts as threatened—8 percent of our known bryophyte species. As testimony to their rarity and anonymity, all the threatened species have only Latin names. Most of them (51 species) are listed in the Department of Conservation's Category I, which contains species that are threatened but not known well enough to be ranked (Department of Conservation, 1994b). Of the 34 species known well enough to be ranked, 6 are in the top category—3 mosses and 3 liverworts. One of these is *Schistochila nitidissima,* an extremely rare liverwort restricted to the Waipoua Forest. It is semi-aquatic and grows on rocks near the water. If the forest had not been protected as a reserve for kauri trees 40 years ago, this hapless liverwort may have become extinct before anyone even knew of its existence.

**Table 9.8**

**The habitat distribution of New Zealand's threatened plants.**

| Habitat type | Percentage of our threatened plants coming from each habitat |
|---|---|
| *Littoral coastal* | 22% |
| *Wetlands* | 22% |
| *Rocky (non-coastal)* | 18% |
| *Scrub* | 15% |
| *Grassland/herbfield* | 14% |
| *Forest* | 9% |
| ***All Habitats*** | **100%** |

**Table 9.9**

**New Zealand's most threatened mosses and liverworts.**

| Moss or Liverwort | Description and Habitat | Location |
|---|---|---|
| *Archidium elatum* | *A black moss which grows in dense carpets, mainly on coastal rocks.* | *Three known locations: near Rotorua, the Bay of Islands; and Northland.* |
| *Fissidens berteroi* | *A soft green moss growing in flowing water.* | *Four known locations: 2 near Lake Wairarapa, and 2 in suburban Auckland.* |
| *Lindbergia maritima* | *A creeping brown moss which grows on coastal rocks.* | *Near Auckland.* |
| *Chloranthelia berggrenii* | *A greyish-green liverwort forming a turf on natural and roadsidebanks.* | *Known at sites in Dunedin, Mt Cook, Arthur's Pass, and West Waikato.* |
| *Pachyschistochila papillifera* | *A soft, clear green liverwort growing in soil on limestone ridges.* | *Alpine areas of the Ruahine Range.* |
| *Schistochila nitidissima* | *A pale green liverwort forming patches or cushions on soft rocks in streams.* | *The Waipoua and Puketi Kauri Forests, Northland.* |

Among the most threatened mosses is the endemic *Archidium elatum*, which grows mainly on coastal rocks. It is known from only three localities, one in the Rotorua area, one in the Bay of Islands, and the third in Northland, but since the plants are very unobtrusive, it may be more common than realised. *Lindbergia maritima*, which also features in Category A of the Department of Conservation's threatened species list, is known from only one location, near Auckland. It was discovered by an overseas botanist a little over 10 years ago. Another species known from only one location is *Epipterygium opararense*, which is one of the 51 species listed in Category I. This endemic moss was found clinging to the side of granite boulders in the Oparara Reserve in north-west Nelson.

Another moss fighting for survival is *Fissidens berteroi*, whose aquatic habitat and bright-green, soft, lax foliage distinguish it from other related *Fissidens* species in New Zealand. A century ago this attractive moss was known from scattered sites throughout the country. Now it is known from only four sites: two near Lake Wairarapa and two in the suburbs of Auckland. The 1994 Auckland water crisis almost killed off the population at one of these sites, when water stopped flowing in the drain where the moss lives, leaving just a puddle. Only quick action by botanists saved the moss. Although *Fissidens berteroi* is known overseas, it is not common and its extinction here would be a loss of international significance.

Of all the mosses, only one has caught the attention of the commercial world, sphagnum moss. New Zealand has 11 species of sphagnum, but *Sphagnum cristatum* is the most common and the species best known to the public, particularly home gardeners. This remarkable plant has antibacterial properties and the ability to absorb and retain up to 20 times its own weight in water. Sphagnum forms extensive carpets or hummocky cushions in the squelchy, rain-soaked forests of the South Island's West Coast and in Southland. It is thought to play an important role in the storage and flow of water in upland catchment areas.

Horticulturists have found sphagnum to be an ideal growing medium, particularly for orchids. Sphagnum harvesting on the South Island West Coast and in Southland has become an enormously profitable export industry providing part-time work for several hundred people, or the equivalent of about 180 full-time jobs, while earning up to $18 million per year (Tilling, 1995; Orchard, 1994). Licences are granted to collect the moss from areas which have been logged or mined. Most of it comes from Department of Conservation land with low conservation value. Two other *sphagnum* species, one in Otago and one in the northern North Island, are considered threatened, but their conservation priority cannot be assessed because so little is known about them (Department of Conservation, 1994b).

Disturbance and habitat loss are the greatest threats to the mosses, liverworts, and hornworts, but the effects of collecting and even trampling cannot be overlooked. Any activity which results in the drying out of a habitat will almost certainly cause the death of wetland species. The loss of 85 percent of New Zealand's wetlands in the past century may well have eliminated several species whose existence was unknown and will remain unrecorded.

The very nature of mosses, liverworts and hornworts makes it difficult for botanists to say with certainty that any particular plant or colony may be the only one in existence. Even the excitement of new discoveries is mixed with concern. Botanists recently found several new species in Northland and on Mount Ruapehu. They may even be new to science, not just to New Zealand. The anxiety comes from the fact that the new species are known only from single collections, and must be regarded as very rare, even threatened, until more is known about their relationships and distribution. One thing scientists can say with certainty: some species are so fussy about where they grow that they have limited options for their continued existence.

#### *The State of Our Vascular Plants*

About 2,000 species of native vascular plant species have been formally described and named, and 200–300 more plants are awaiting formal identification. If subspecies are included, the total number of vascular plant taxa may be 2,500 or more (Department of Conservation, 1994b; Druce, 1984; Halloy, 1995; Statistics New Zealand, 1995). Though our vascular plant biodiversity is low by international standards, its endemism is high. About 80 percent of our vascular plants occur nowhere else on Earth and are therefore of global as well as local significance (Wilson and Given, 1989; Dawson, 1988). Our most diverse plant communities are also the youngest. The alpine zone has more plant taxa for its small area than other ecosystems, such as forests and wetlands, abounding with small populations of flowering shrubs, cushion plants and grasses. The forests have fewer species, but greater phyletic diversity, with bryophytes, ferns, gymnosperms and flowering plants living in mixed communities.

Although the demand for native timber, particularly rimu, kauri, and kahikatea, and the conversion of land to pasture, have reduced the original forest cover from about 85 percent to about 23 percent, none of New Zealand's unique timber-producing trees has been reduced to threatened status. Most of New Zealand's threatened plant species are small herbs, grasses and shrubs with limited distributions. In total, nearly 200 species and 20 sub-species of vascular plants are listed as threatened by Department of Conservation. This amounts to almost 10 percent of our native vascular plants, though close to half of these are in the 'insufficiently known' category (Department of Conservation, 1994b).

Several of the threatened plants are very small, such as the highly threatened woodrose (*Dactylanthus taylorii*), which is known to Maori as *pua o te reinga* (flower of the Underworld) and is prized as a curio (Dawson, 1988). This 'Category A' species lives as a parasite on the roots of small trees, often in fire-induced secondary forest, in the North Island (Ecroyd, 1996). It is pollinated by a rare native bat. The reddish brown scaly flowers of the Dactylanthus protrude directly from the earth while the body of the plant remains underground. The flowers have a strong sweet perfume, which is attractive to flies and native bats. Unfortunately, the Dactylanthus scent also attracts possums and rats. The survival of the woodrose will require protection of the plants from possums, rats and humans, and will also need adequate areas of secondary forest with abundant hosts.

Some of our most seriously threatened plants are found on offshore islands. Among them is *Hebe breviracemosa*. This shrub, which grows to a height of about 2 m, is found only in the Kermadec Islands. It once flourished on the main island, Raoul, but it was almost eaten out of existence by feral goats released last century and, for many years, was considered extinct. It was believed the last known specimens had been collected in 1908, but in 1983 one plant was found on Raoul Island. The last goat was taken from the island in November 1984, and it is hoped that *H. breviracemosa* will become re-established (Wilson and Given, 1989). One remaining threat is the continued presence of Pacific rats on the island. They are suspected of nibbling away any seedlings that come up.

Slightly better off, but still on the critical list, is the Swamp Helmet Orchid (*Corybas carsei*) so named because its flowers are tubular helmet-like structures. This plant has only been found in acid peat bogs of the northern North Island. Originally discovered in the large peat bogs bordering Kaitaia during the early 1900s, drainage operations had eliminated it there by the 1920s. During the 1960s, it was discovered in some abundance within the Moanatuatua Peat Bog near Ohaupo in the Waikato. Its discovery prompted the formation of the country's first large peat bog reserve. Unfortunately, the bog proved to be too small, and peripheral draining caused the peat vegetation to thicken.

Today, the Swamp Helmet Orchid survives in part of the Whangamarino Wetlands, where hundreds of the tiny orchid plants were recorded in the early 1980s. In October 1991, only 30 plants were recorded. Only one flower has been recorded since 1991, and this failed to set seed. It is now believed that the Swamp Helmet Orchid lacks a suitable pollen distributor, while bud predation by an introduced species of cricket remains a serious threat to the plant's reproductive potential. The survival of the species depends on careful management of the peat vegetation at the site through controlled fires.

The remote Three Kings Islands group off the tip of the North Island was one of the first places where management action was taken to save plants from extinction (Wilson and Given, 1989; Templeton, 1994). In 1946, two plants, both new to science, were discovered there: a vine with beautiful tubular cream flowers, named *Tecomanthe speciosa*, and a small tree with large lush dark-green foliage, called *Pennantia baylisiana*.

The island's feral goats had pushed the plants to the verge of extinction. Although the goats were eradicated in 1946, neither the vine nor the tree has recovered. Fortunately the vine's seeds and cuttings have been easy to cultivate. Thousands of plants are grown each year and sold to gardeners throughout the warmer parts of New Zealand and overseas. Soon the vine may be listed as extinct in the wild even as its numbers increase in people's back yards. The situation with the tree is not so encouraging because the sole plant is a female and therefore incapable of producing seed (unlike the vine which can produce male and female flowers, and therefore seeds).

One species not on the threatened list, but which has been the subject of some concern since 1987, is a cabbage tree, ti kouka (*Cordyline australis*). In the warm, upper North Island 15–30 percent of these trees have died and are continuing to do so. A smaller percentage of trees are dying in the southern North Island but almost none in the South Island (Brockie, 1995), though some anecdotal evidence suggested an earlier die-off in parts of Canterbury (Hosking and Hutcheson, 1992).

Death appears to be caused by an infection, but the dying trees are out in the open, while the survivors are in areas of native forest. The pattern of infection seems to coincide with the distribution of an introduced insect, the sap-sucking Australian passion-vine hopper (*Scolypopa australis*), which is most abundant in the warm northern regions away from dense forest. If the link is confirmed, little can be done other than to wait for the wave of infection to pass and hope that an infection-resistant generation will arise from the survivors (Brockie, 1995).

**Box 9.13**

### *Culturally important plants*

Many of the plants which are culturally important to New Zealanders of European, Asian or Pacific Island origin are exotic species and are not threatened. To New Zealanders of Maori origin, however, the culturally significant plants are mostly native species, together with a small number of exotics that were introduced many centuries ago. Some of these plants are in short supply, either because they have become rare or because they are on land which is no longer in Maori ownership. The ecological, social and economic changes of the past two centuries have dramatically changed the relationship between Maori society and plants. Today the culturally significant plants are no longer necessary for survival, but they are important for traditional arts and crafts, customary food preparation and herbal remedies. Some are now largely confined to Department of Conservation land or to collections managed by Landcare Research. Others are more widespread, but are under pressure.

The Department of Conservation (1994b) lists 18 culturally important plants that have become rare in at least some iwi areas, though several are still common nationally. They include five species introduced by early Maori settlers: aute or paper mulberry (*Broussonetia papyrifera*) which was cultivated for bark-cloth; hue or bottlegourd (*Lagenaria vulgaris*), which provided food and water containers; and the staple food plants, kumara or sweet potato (*Ipomoea batatas*); taro (*Colocasia esculenta*); and uwhi or yam (*Dioscorea sativa*). Indigenous species which are culturally important and listed as locally or nationally rare include: harakeke (*Phormium tenax*); pingao (*Desmoschoenus spiralis*); kiekie (*Freycinetia baueriana banksii*); totara (*Podocarpus totara*); aruhe or bracken fern (*Pteridium esculentum*); wharariki or mountain flax (*Phormium cookianum*); karaka (*Coryncarpus laevigatus*); kutakuta (*Eleocharis sphacelata*); para or king fern (*Maratia salicina*); the rush-like herb *Sporadanthus traversii*; tawapou (*Planchonella costata*); and two endemic cabbage trees, ti pore (*Cordyline fruticosa*) and ti tawhiti (*Cordyline* 'kirkii').

Traditional Maori uses of native plants were varied and ingenious and several are still a vibrant part of Maori cultural life, particularly harakeke flax and pingao grass, and totara and other trees which are used in carving. Plants were also used to make dyes, rope, fishing lines and nets, bird snares and cloaks and blankets. Logs were used to make canoes, buildings and fortifications. Rushes, supplejack and nikau leaves were used in thatching. And, after European contact, the medicinal use of plants became significant. The native plants' only limitation was their food value. Although some 300 New Zealand plants are edible (Crowe, 1990), most are poor sources of sustenance because their roots and berries are too small or unpalatable to provide large amounts of carbohydrate (starches, sugars and oils).

Wherever the climate allowed (mainly in the north of the North Island) Maori communities relied on five imported tropical plants for carbohydrates: kumara; taro; uwhi (yams); hue (bottlegourds); and a cultivated species of ti or cabbage tree (*Cordyline terminalis*). Elsewhere, however, the main sources of carbohydrates were the barely edible rhizomes of the native aruhe or bracken fern (*Pteridium esculentum*) and the sugary roots of several endemic cabbage trees (*Cordyline* spp.).

Although many other plants were eaten, few made big contributions to the diet of meat, fish, kumara and fern-root. Despite this, some native plants are still sought after today, such as the young green shoots of the pikopiko fern (*Polystichum richardii*), the soft heart of the nikau palm trunk (*Rhopalostylis sapida*), and berries from various trees, notably tawa and karaka (which require cooking to detoxify them). ). Among the popular traditional vegetables that are commercially cultivated today are two sow thistles (*Sonchus asper* and *S. oleraceus*), known as puha and rauriki (Crowe, 1990; Wardle, 1994). These were introduced as weeds by early Europeans and have spread widely at the expense of the larger but slower growing native sow thistle (*Sonchus kirkii)* which is now rare. Though not plants, native fungi (e.g. harone or mushrooms) and algae (e.g. rimurapa or bull kelp) are also still eaten (Cooper and Cambie, 1991; Crowe, 1990; Gluckman, 1976; Walls, 1988).

With European contact came edible vegetables, such as potatoes, maize, wheat, turnips and cabbages, and edible weeds, such as toi, a kind of cress (*Barbarea* spp.), huainanga or fat hen (*Chenopodium album*), and several wild *Brassica* species (Crowe, 1990). The new vegetables also included European varieties of kumara whose vines could grow up to 5 m compared to a maximum vine length of 1.4 m for the local varieties. The Maori kumara would have been lost were it not for the efforts of a DSIR scientist, Dr Douglas Yen, who painstakingly assembled a collection of 617 kumara varieties from all over the world during the 1950s and 1960s. In 1963, when the collection became too big for the DSIR to maintain, Dr Yen arranged for its safekeeping in three gene banks in Japan. Interest in the collection was revived in 1988 at an ethnobotanical conference organised by the DSIR. Members of Pu Hao Rangi, a Manukau-based Maori Resource Centre, journeyed to Japan and brought back 9 New Zealand kumara varieties, 4 of which were identified as pre-European varieties. These are now cultivated by several Maori groups.

The most enduring traditional use of native plants has been in weaving and carving, which were developed to a high art and are still important, especially in the upper North Island. The favoured weaving plants are harakeke flax, pingao, toetoe or kakaho, and kiekie, and the favoured carving trees are totara (*Podocarpus totara*) and kauri (*Agathis australis*). The traditional experts on weaving were, and still are, women whose specialist knowledge gives them considerable mana (prestige). Each weaving family has its own traditional account of the origin and appropriate use of the local plants. As a result, these plants have acquired a large number of different names, uses and harvesting methods, each associated with a particular place and tradition.

The most useful all-round plant was harakeke (flax). Many families tended their own stands. Its sap was used to treat constipation and wounds, its nectar sweetened the diet of fern root, and its fibres were used to make baskets, mats, sandals, clothing, ropes, cords, fishing lines, nets, traps, children's kites and trumpets. The diversity of uses and local varieties gave rise to some 80 different names for harakeke and made it a valuable item of inter-tribal trade. Its tradeability increased following European contact. Dressed flax was exported for rope-making and whole families became involved in production for export. It was labour intensive; 40 tonnes of hand-scraped flax produced one tonne of fibre—the price of two muskets. In the 1820s flax exports funded most of the arms used in the inter-tribal wars, but Maori interest waned and the trade had almost ended by the 1850s, though traditional use continued (Department of Statistics, 1990; Douglas, 1993).

Exports were revived in the 1860s when the American Civil War caused a temporary world shortage of manila and sisal fibre. By now, control of the industry had passed to European entrepreneurs who introduced machine processing. With production no longer dependent on Maori knowledge and labour, flax was harvested ruthlessly and output increased 100-fold in the decade 1863–73. At the boom's peak more than 300 mills operated. By 1886, however, only 30 mills remained. The second boom coincided with the Spanish-American War (1890–91) and the number of mills rose to 177. The third and last harakeke boom was triggered by the First World War (1914–18) and lasted into the late 1920s. Production for the local market continued for four more decades, finally ending in the late 1960s (Department of Statistics, 1990).

Although flax is still widespread, relatively few large stands remain. Most of the wetlands where they flourished have been drained and replaced by pasture. Apart from a brief expansion in the mid-1920s, when several thousand hectares of harakeke were planted, the total area fell from about 25,400 hectares in 1929 to about 16,000 hectares by 1960 (Douglas, 1993; Department of Statistics, 1970). It is probably less today. Cultural users of harakeke are fortunate to have a national collection of 68 traditional varieties collated by the former DSIR, mainly from the collection of Mrs Rene Orchiston of Gisborne. The collection is located at Havelock North and Lincoln, and daughter collections have been distributed to marae in other areas.

The sand dune plant, pingao, is another culturally important species which has become rare in many areas. Its stiff, curled, three-ridged, leaves are used for weaving and for making the tukutuku panelling which lines the walls of marae. The leaves range in colour from green to golden-yellow. On the beach, pingao clumps look like separate plants, but they are usually offshoots of a single underground rhizome which forms a delicate lifeline in the sand. Pingao was never commercially harvested or planted. It has been reduced by a range of pressures that affect our dunelands—grazing, the spread of exotic dune plants (e.g. marram grass and lupins), urban development and trail bikes and dune buggies. Harvesting pressure is now adding to these pressures.

As with harakeke, the use of pingao has greatly increased. This has intensified pressure on the diminishing stocks of wild pingao. In the past, the harvesting and use of pingao (and other important plants) was governed by strict rules, or tikanga maori, designed to maintain the plants. Often rahui (temporary bans) were put on areas that were becoming depleted. The traditional weavers were steeped in knowledge of how and when to harvest the plants. They would size the strands and assess their condition before cutting began. Few have this knowledge today. Without the correct tikanga, indiscriminate pingao harvesting has occurred in many places. A survey of the Manawatu dunelands found pingao throughout, but often at densities of only one plant or clump for every 20 m (Carkeek, 1989; Turoa *et al*., 1990).

Although the most visible use of culturally significant plants is in arts and crafts, a greater variety of plants is used in Maori herbal medicine, or rongoa. This tradition is historically recent, dating largely from the nineteenth century, but it plays a significant role in contemporary Maori culture and has elevated the cultural significance of many native plants.

Before European contact, Maori society, like the rest of Polynesia, made only limited use of plant-based treatments, mainly because disease was believed to have spiritual causes, such as retribution for violating tapu (sacred rules). In James Cook's three Pacific voyages between 1769 and 1779, he found little evidence of plants being used for internal medication, despite their use in external treatments and healing rituals. For the next half-century, other European explorers, sailors and missionaries reported similar observations. External plant treatments were confined to visible ailments and injuries and included: leaf wrappings, ointments and poultices (to reduce bleeding, pain and inflammation); fern ashes (to treat burns); splints of flax leaves or rata bark (to mend fractures); and scented steam baths made by placing leaf mats on hot stones. The few plant remedies that were swallowed seem to have been cathartics for constipation, and possibly emetics to induce vomiting (Buck/Hiroa, 1949; Brooker *et al*., 1987; Cooper and Cambie, 1991; Whistler, 1992).

The standard treatment for internal ailments was not medicine but a healing ritual presided over by a priest or tohunga. The key elements were prayers and confessions, sometimes accompanied by human or animal sacrifice. Plants were sometimes used to repel demons either intact, shredded, or in fetid-smelling potions (Buck/Hiroa, 1949; Brooker *et al.,* 1987; Cooper and Cambie, 1991; Whistler, 1992). By 1820, Polynesian experimentation with herbal remedies was well under way, partly in response to the example set by European medicines, and partly in response to the wave of European diseases for which there were no traditional cures. Maori use of herbal medicine for internal complaints was first noted in the 1820s and by 1900 more than 100 native plants were in medicinal use (e.g. Williams, 1826; Lesson, 1829; Bennett, 1834; Goldie, 1905).

While most of these plants, from a pharmacological viewpoint, "could at best have no great medicinal value", some are now known to have antibiotic, analgesic or astringent properties (Brooker *et al.,* 1987). Several were poisonous (e.g. tutu, kowhai, puketea, horopito, poroporo and karaka) resulting in remedies that occasionally killed rather than cured (Brooker *et al,* 1987). Among the more effective plants are: various *Hebe* species (e.g. koromiko) which inhibit the bowel contractions in diarrhoea; harakeke, which is used as both a laxative and an anti-inflammatory treatment for wounds and burns; kakaho or toetoe (*Cortaderia toetoe*) which also has anti-inflammatory uses; pate or seven-finger (*Schefflera digitata*), whose fungicidal compounds are effective against ringworm; manuka (*Leptospermum soparium*), which has insecticidal and anti-bacterial properties, though it is more often consumed as a general tonic; and several plants with analgesic properties, such as kawakawa (*Macropiper excelsum*), the fern *Asplenium lamprophyllum*, and the poisonous plants, pukatea (*Laurelia novae-zelandiae*) and horopito or Maori painkiller (*Pseudowintera axillaris*). Horopito bark juice is used for a variety of painful conditions, ranging from stomach-aches to skin and venereal diseases (Cooper and Cambie, 1991; Brooker *et al*., 1987).

For many other plant remedies the effects appear to be more subjective. Kumarahou (*Pomaderris kumarahou*), for instance, acquired a reputation as a commercial cure-all last century, and is still used as a general panacea, despite its lack of medically active compounds (Cooper and Cambie, 1991; Health Research Council of New Zealand, 1994). The bark juice from kowhai (*Sophora* spp.) was used to treat constipation, ringworm and scabies, but it had to be from a tree growing on a hillside and a root pointing towards the sun (Cooper and Cambie, 1991; Brooker *et al.,* 1987). Despite the improvements in conventional medicine, herbal remedies have persisted and diversified since 1900. Like other forms of alternative medicine, they may even be expanding as conventional medical treatment becomes more costly. About 44 Lotto-supported rongoa clinics now operate throughout the country, and the list of recorded native medicinal plants is now more than 200 (Health Research Council of New Zealand, 1994; Riley, 1994).

Environmentally, the main significance of the rongoa movement is that it enlarges the pool of culturally important plants which need to be sustainably managed. In many areas these are now confined to land managed by the Department of Conservation and can only be harvested with the Department's permission. Although this is usually forthcoming, many iwi would like more control over customary plant use in their areas, particularly where non-iwi members and bioprospectors are also seeking permission to harvest them. Some Maori have even lodged a claim with the Waitangi Tribunal (Claim Wai-262) seeking iwi control over all indigenous biodiversity (Murray *et al.,* 1991). The need to sustain culturally significant resources is recognised in our environmental legislation, and the challenge is to develop management regimes which will safeguard cultural use rights and traditional knowledge while also maintaining the plants for their intrinsic and ecological values and the benefit of society in general (Geden and Ryan, 1995; New Zealand Conservation Authority, 1994; New Zealand Ecological Society, 1995; Te Puni Kokiri/Ministry for Maori Development, 1994; Thrush, 1995; Wright *et al*., 1995).

### The State of Our Fungi

The Fungus kingdom is the most diverse and numerous kingdom of organisms after the animals. Fungi occur almost everywhere, provided there is moisture and a nutrient source for them. Estimates of the number of known species range from about 70,000 to more than 100,000. If unknown species are estimated as well, the world total comes to a possible 1.5 million fungal species (Kendrick, 1994; Hawksworth *et al.*, 1995).

With an estimated 20,000 species here, fungi may represent more than a third of New Zealand's total biodiversity. Their most important role in our ecosystems is as humble, but vital, decomposers and nutrient recyclers. Without them, 9 out of 10 of our plants would disappear, and so would the animals that depend on them.

Traditionally, fungi have been regarded as closely related to plants, but recent genetic research suggests they are closer to animals (see Figure 9.1) (Wainright *et al.*, 1993). Apart from genetic differences, the fungi differ fundamentally from plants in having no chloroplasts and no ability to produce their food by photosynthesis. However, they differ from animals too, having no mouths or digestive organs with which to eat food, nor excretory organs to remove waste.

As it happens, the fungi do not need these complicated accessories because they get their food by a remarkably effective technique which does not involve internal digestion or waste products—they directly absorb it through their cell walls. They do this by exuding powerful digestive juices onto a plant or animal. As the organism begins to decompose, the fungi absorbs its nutrients directly from the decaying matter. The unwanted bits are left to rot into the soil. This minimalist approach to body design extends to nervous systems, sense organs, muscles and limbs, none of which are needed by fungi because they do not get about much. A fungus does all its travelling, courtesy of wind and running water, when it is still a tiny spore. Once it has landed on a potential food organism, the spore attaches and begins to develop into a mature fungus. The only organs the adult needs are reproductive organs to produce more spores.

The true fungi (or Eumycotes) are mostly multi-celled (except for yeasts). They range from microscopic threads, through shapeless moulds, to rounded puffballs and truffles, to beautifully sculpted mushrooms and toadstools. They are not related to the false fungi (or Myxomycotes) which are amoeboid slime moulds—protozoans that merge together for part of their life cycle. A fungus holds the record for the world's largest living creature. This unlikely giant, which is believed to be between 500 and 1,000 years old, extends, like a vast underground spider's web, beneath 600 hectares of pine forest in Washington State (Coghlan, 1992). It belongs to a species called the Honey or Shoestring Fungus (*Armillaria ostoyae*) which feeds by parasitising tree roots and reproduces by extending mushrooms up through the ground so that wind and rain can disperse its spores. The mushrooms of the shoestring fungus are edible, as are those of its New Zealand relative, the Bootlace Mushroom.

For most people, edible mushrooms are probably as interesting as fungi get. Many edible species exist in New Zealand, both introduced and native. More than 500 native mushrooms have been identified, though not all are edible. Some formed a small but prized part of the traditional Maori diet, and one species was used as tinder for fire lighting. The edible species which are popular today include the morel, the giant and common puffballs, the sticky bun and birch boletes, the fungus icicles, certain ink caps, the poplar mushroom, and the wood ear, which was exported to China in considerable quantities in the late 1800s.

The best known, and safest, edible mushrooms, however, are probably the introduced white button mushroom (*Agaricus bisporus*), which is grown commercially for the supermarket, and the white-topped field mushroom (*Agaricus campestris*) from the farmer's paddock. Other edible mushrooms now available at specialist food counters include shiitake (*Lentinula edodes*), oyster or Phoenix mushroom (*Pleurotus pulmonarius*), and needle mushroom (*Flammulina velutipes*). Even some fungal scientists (mycologists) will only eat shop-bought mushrooms because some species are highly poisonous and even the expert eye can be fooled by their similarity to harmless ones.

Poisonous mushrooms are often called 'toadstools'. Like many other fungi, they produce toxins, either for defence, or to kill potential food organisms. Particularly dangerous are two introduced members of the *Amanita* genus: the deadly yellow-brown Death Cap (*Amanita phalloides*), which is usually found near oak trees, and the red-topped white-speckled fly agaric (*A. muscaria*), which occurs more widely in moist shady areas. Poisoning can result simply from touching food or lips after handling these. The fly agaric gets its name from its potency as a fly killer when ground up and mixed with water. Children are particularly at risk from this toadstool because of its colourful appearance and because it often features in children's books, and even in a recent widely sold children's calendar.

Many fungi besides mushrooms have become part of our everyday life. Regular reminders range from foods such as cheeses and yoghurt, which are fermented by fungi, to the mould on the bathroom ceiling. The yeast fungi are used to bake bread, brew beer and ferment wine. Many people have been rescued from bacterial infections by the well-known antibiotic, penicillin, which is produced by a fungus called *Penicillium notatum*. Others owe their lives to cyclosporine, which is an immunosuppressant produced by a fungus called *Tolypocladium inflatum*. It reduces organ rejection in transplant patients.

Against these health-giving fungi are many which cause diseases. Athlete's foot and ringworm are two common fungal diseases afflicting humans, and *Cryptococcus neoformans*, a fungus associated with pigeon excreta, can cause a form of meningitis. In humid weather, sheep farmers are on the alert for signs of *Pithomyces chartarum*, which causes facial eczema. Fungi are the main agents of plant diseases too, affecting all plants, including commercially grown species. For example, a native species of *Armillaria* can kill kiwifruit vines and young pine trees. Fungi also invade harvested pine logs and orchard fruit, causing lost profits and high pesticide costs.

Fungi fall into two groups, depending on how they get their food. Some are parasitic, feeding off living organisms (e.g. the fungi which cause skin diseases in humans and other animals, and those which cause mildew and blight diseases in plants). Others are saprobic, dining off dead organic matter (e.g. yeasts and the various fungi which cause logs and timber to rot).

Many fungi form mutually beneficial relationships with plants. More than 90 percent of plants have symbiotic mycorrhizal fungi associated with their roots. The fungi appear to play a protective role against hostile fungi and invertebrates, and may also provide scarce nutrients such as phosphorus in return for carbohydrates from the plant's roots. Perhaps the most famous mycorrhizal species is the prized black truffle (*Tuber melanosporum*) which grows in association with oak trees.

About 20 percent of fungi form lichens. Lichens are fungi that have algae living inside them. They appear as rather flat, crinkly growths on tree trunks, fence posts, rocks, boulders, buildings and even footpaths (where they sometimes look like splashes of pale green paint). They may even hang like shaggy grey-green beards from the branches of forest trees. They come in a range of colours from subdued greys and pale greens to bright yellows and rich browns. These colours do not come from the fungus itself, but from colonies of microscopic algae which live in or on its tissue. These algae make up 5–10 percent of the lichen biomass.

Just as the mycorrhizal fungi obtain carbohydrates from their symbiotic plants, so lichen fungi obtain carbohydrates from their symbiotic algae. Until recently the lichens were believed to be a closely knit fringe group of fungi. However, research now shows that unrelated lichens occur throughout the fungus family tree, indicating that the partnership between fungi and algae arose separately several times in fungus evolution (Gargas *et al.*, 1995; Barinaga, 1995). The oldest known lichen fossil dates back 400 million years suggesting that they were an instrumental group in the early colonization of land and formation of soil (Taylor *et al.*, 1995).

New Zealand has a particularly rich variety of lichens compared to other countries. At least 1,500 species have been described, representing about a third of our known fungi species. In the Northern Hemisphere, acid rain and air pollution are reducing lichen biodiversity. In New Zealand, lichens are still common. Even though their natural forest environments have been largely removed, many have found suitable niches in towns, on footpaths, buildings and fences.

Taxonomic studies of New Zealand fungi lag well behind those of animals and plants. Of our estimated 20,000 species, only about 4,500 are known. The difficulty of finding out how many species are rare or threatened is made worse by the fact that few New Zealanders collect fungi, and even fewer experts are able to identify them with certainty. However, based on assessments of groups which have been relatively widely collected and studied, Landcare Research scientists believe more than 200 identified fungi are threatened in New Zealand—about 5 percent of known species (Buchanan and Beever, 1995).

The main threat to most fungi has been habitat destruction. Being forest dwellers which coexist with trees in shady, damp environments, the fungi were among the less visible casualties of New Zealand's lowland deforestation. Some species probably vanished without ever being seen.

Rust fungi (*Puccinia* spp.) are microscopic parasitic fungi which typically form orange or rust-coloured pustules on plant leaves. One newly recognised endemic species is threatened because it lives only on the Chatham Island sow thistle (*Embergeria grandifolia*), which is itself a threatened species. Another vulnerable species is a large polypore fungus (*Ganoderma* spp.), which forms big shelf-like fruit bodies on tree trunks. This as yet unnamed species was recorded at three sites in Waikato from 1969–1972, but has not been seen for the past 24 years (Buchanan and Beever, 1995).

Yet another doubtful survivor is the endemic truffle-like fungus, *Claustula fischeri*. This is the only known member of the family Claustulaceae in the world. It has been identified from the Fringed Hill area in Nelson, and from one site in the Wairarapa. The careless harvesting of highly priced mushrooms, such as truffles, and the habitat disturbance which can result, is placing those species under pressure. Even collecting a fungus to study it professionally or as a hobby could unwittingly place a species under threat.

Landcare Research is compiling a comprehensive list of threatened New Zealand fungi similar to the 'red data' lists produced in countries such as the Netherlands (which has 944 threatened fungi), Sweden (which has 500) and Finland (which has 325). The first red data list for New Zealand fungi is based on information from herbarium collections and scientific papers (Buchanan and Beever, 1995).

**Table 9.10**
**Some of New Zealand's threatened fungi**

| Fungus | Common name/Description | Habitat/Location |
|---|---|---|
| *Aecidium spp. (3)* | *Rust; 2 endemic and 1 indigenous species.* | *Restricted distribution on Hebe spp. Two species not seen since the 1920s.* |
| *Claustula fischeri* | *Mycorrhizal, truffle-like fungus.* | *Nelson (Fringed Hill) and Wairarapa; under kanuka or manuka.* |
| *Ganoderma (new species)* | *Polypore bracket fungus with shiny upper surface.* | *On pukatea, in the vicinity of Mount Pirongia, 1969–1972. Not found since despite searches.* |
| *Grifola sp.* | *Multi-lobed, large, fleshy polypore, with strong odour of almonds from fruit body and wood rot.* | *On large, fallen rata, probably confined to old growth forest.* |
| *Gyromitra sp.* | *Large, stalked, brain-like ascomycete.* | *Recorded once, under Nothofagus.* |
| *Lanzia griseliniae* | *Micro-ascomycete.* | *On leaves of Griselinia. Despite searches, only known from Ruapehu (1950s), and a single record at Karamea.* |
| *Perenniporia podocarpi* | *White crust-like polypore.* | *Known from only 4 records; on fallen branches of rimu and matai.* |
| *Puccinia sp.* | *Rust. An endemic plant pathogen.* | *On leaves of the threatened Embergeria, on the Chatham Islands.* |
| *Tympanella (new species)* | *Stalked mushroom, with or without closed cap.* | *Recorded once in NW Nelson under Nothofagus. Currently the genus is monotypic and confined to New Zealand.* |

*Source: Landcare Research*

## The State of Our Invertebrate Animals

Being big bony animals, humans tend to forget that the vast majority of animals are tiny and have no bones at all. These boneless animals, or invertebrates (i.e. animals which lack a backbone), make up 34 of the world's 35 animal phyla and have more species than all other domains and kingdoms put together.

The most primitive phyla, the Porifera (sponges), Cnidaria (jellyfish, anemones and corals) and Echinodermata (sea stars and sea urchins), each have 5,000–10,000 known species around the world and live exclusively in the ocean. Many other invertebrate phyla consist of worm-shaped animals which live mostly in the sea, though a few have also colonised the land, namely: the Nematodes (roundworms, threadworms), which have 25,000 described species, but may number in the millions; the Platyhelminths (flatworms), which have 20,000 known species; and the Annelids (segmented worms, such as polychaetes, leeches and earthworms), which have 12,000 identified species (Hawksworth *et al.*, 1995).

Two of the most advanced invertebrate phyla are the Arthropods and the Molluscs. The arthropods are mostly land and shore dwellers, except for the crustacean group, while the molluscs are largely confined to the sea, except for some land-dwelling slugs and snails. The main mollusc groups are the **cephalopods** (e.g. squid and octopuses), the **gastropods** (those with one shell, such as periwinkles, paua and snails), and the **bivalves** (two-shelled molluscs, such as cockles, mussels, oysters, scallops and toheroa). In total, about 70,000 mollusc species are known, though many more remain to be discovered in the mud of the ocean floor.

Of all the invertebrates, only the arthropods have flourished on land. Without a water-proof skin, most other invertebrates tend to dehydrate on dry land. They also have difficulty getting about without jointed legs or wings. Burrowing worms, parasitic worms and slippery slugs and snails have all found answers to these problems, but are nowhere near as successful as the arthropods with their hard skin, or exoskeleton, jointed legs and, in some cases, wings (e.g. beetles, crickets, flies, bees, mosquitoes, butterflies etc.). The four main arthropod classes are the **myriapods** (e.g. millipedes, centipedes), the **insects** (e.g. beetles, flies, etc.), the **arachnids** (e.g. spiders, mites, scorpions) and the **crustaceans** (e.g. crabs, crayfish or lobsters, shrimp, copepods, slaters).

The most diverse arthropods are the six-legged ones, the insects, which have 950,000 described species. Many insect groups are well known: beetles, fleas, flies, mantids, grasshoppers, crickets, locusts, wetas, earwigs, cockroaches, termites, aphids, mosquitoes, sandflies, butterflies, moths, bees, wasps, ants and many more. The beetles are the most diverse insect order, with more described species than all other insects combined. And among the beetles, weevils have more species than any other group. The eminent biologist J.B.S. Haldane is said to have replied, when asked if his research had told him anything about God: "He has an inordinate fondness for beetles." Recently, however, it has been suggested that bee and wasp species, most of which are still unidentified, may have more species than the beetles (Emberson,1995).

The total number of invertebrate species is not known and even the best guesses vary widely. In New Zealand about 21,000 invertebrate species (mainly insects) have been described, but about 50,000 may exist, almost half of them insects. Of the insect species, about 10,000 have been described, but there are good grounds for assuming that the total number is in the range 17,500–20,400, with the most likely figure being close to 20,000 (Emberson, 1994, 1995). One group alone, the tiny parasitoid wasps, is now believed to contain several thousand species, nearly all of which are undescribed.

Nematode worms are also highly diverse, though estimating the number of species is particularly difficult. Only about 400 species have been described to date, but scientists believe that 11,000–12,000 may exist here (see Table 9.1). About half of these are parasitic roundworms which live inside animals. Most are specific to particular insects, spiders and crustaceans. About 3,000 species may live in marine mud and about 2,500 may live in the soil and on plants. The deforestation of large areas of New Zealand has probably reduced many soil-dwelling nematode populations and may even have eliminated several species. Similarly, the extinction of more than 60 native vertebrates probably wiped out at least as many parasitic nematodes.

Other invertebrate groups well represented in New Zealand are myriapods (millipedes and centipedes), arachnids (spiders and mites), molluscs and flatworms. The myriapods are related to the insects and arachnids. Their distinguishing feature is having a large number of legs. The most diverse myriapods are the millipedes which have about 200 described species and perhaps 600 unidentified ones. This compares to only 35 described centipedes. The known arachnid species suggest that New Zealand has an unusually large number of spiders and mites. About 2,600 have been described and many more remain to be identified. This is about 24 arachnid species for every 100 insect species—three times the global figure of 8 arachnids per 100 insects (Hawksworth *et al.*, 1995).

New Zealand's flatworms are also diverse by world standards. Whereas Europe has only 6 native species, New Zealand has an estimated 200. Only about 50 of these have been named and described. Like most native invertebrates, the flatworms were badly affected by the vegetation changes that accompanied human settlement. One species which became confined to relic gardens and woodlands in the centre and south of the South Island is *Artioposthia triangulata*. This particular species received an unexpected new lease on life when it was accidentally exported with garden plants to Britain and Ireland. Now it is a major pest there, devastating earthworm populations wherever soils are damp and cool enough for it to become established.

About 2,000 marine molluscs have been described, and at least a thousand more have yet to be identified. On land, about 500 species (nearly all snails) have been described, with perhaps 200 more to be identified. Our land snails are among the most diverse in the world, but the larger species have been heavily reduced by vegetation change and introduced species.

Most of our known invertebrates are **land and freshwater** species (mostly insects, but also including spiders, mites, slaters, slugs, snails, nematodes, flatworms and earthworms). The rest are **marine** species, such as molluscs (e.g. shellfish and squid), various marine worms (most notably estuarine, coastal and parasitic nematodes), echinoderms (e.g. seastars, sea urchins), cnidarians (e.g. corals, sea anemones, jellyfish), poriferans (e.g. sponges) and the only class of sea-going arthropods, the crustacea (which includes crabs, lobsters, shrimps, prawns and tiny shrimp-like creatures called copepods).

### *Land and freshwater invertebrates*

Based on known species, at least 90 percent of New Zealand's land and freshwater invertebrates are likely to be endemic and, in many cases, confined to very small parts of the country. The number of alien land and freshwater invertebrates introduced since human occupation is believed to be about 2,000. Over 300 recognised invertebrate taxa (species and subspecies) are listed by the Department of Conservation as threatened or possibly extinct. More than half of these (177) have so little known about them that their priority cannot be ranked (Department of Conservation, 1994b). Others, such as our native slugs, are not listed at all because information is so sparse. Given the lack of information on most species, and the limited distributions of many of them, the true number threatened is probably several times greater than the number currently recognised.

With so many species unknown, and likely to remain so for a long time, many may disappear before they have even been identified as threatened. This has led some scientists to the view that single-species recovery programmes for invertebrates are too piecemeal and should be replaced by habitat protection programmes which scoop up many species at once. However, others have argued that simply protecting habitats is not sufficient on its own because representative habitat for many threatened species no longer exists, or is infested with predators. Towns and Williams (1993) propose a balanced approach, in which habitat protection and restoration is integrated with species recovery programmes. Because they are so small, habitat protection for land and freshwater invertebrates can be much simpler than for birds, bats and other large species. A successful invertebrate reserve may require as little as a hectare of native forest, scrub or tussock.

The luckiest of the unlucky threatened invertebrates are those whose identities are known, enabling them to receive special attention. The Department of Conservation lists 26 in Category A of its top priority threatened taxa. They comprise: 13 insects (8 beetles, 2 moths, 1 grasshopper, 1 tusked weta and 1 cave-dwelling bug); one arachnid (a mite); 11 molluscs (2 giant snails, 1 kauri snail subspecies, and 8 sub-species of flax snail); and one annelid (a leech).

#### *Land invertebrates*

Little information exists on how many invertebrates might have become extinct since human settlement because, being small and boneless, they leave few remains. The remains of beetle exoskeletons and snail shells, however, indicate that several species have become extinct or been eliminated from large areas of their former range. A dozen species are listed as possible recent extinctions (Category X) by the Department of Conservation (1994b).

The vast majority of our invertebrates are forest-dwellers, so it is likely that some unknown species with localised distributions literally went up in smoke as forests were cleared. The impacts of rats and introduced birds would have added to this. The *Amychus* click beetles, for example, were once abundant throughout New Zealand, but are now confined to a few rat-free islands.

Not all of the indigenous invertebrates have suffered, however. A review of land use effects on land invertebrates noted that some indigenous species responded positively to the removal of forest and the advent of exotic plants and animals (Yeates, 1991). Species which appear to have benefited include:

- the native bees (about 40 species) which have adapted well to pastures and crops as sources of nectar and pollen, and which, despite losing out to the European wasps in beech forests, are competing successfully in other habitats with the seven alien bee species (Donovan, 1980; Scott, 1984);

- two indigenous parasitic wasps (*Pterocormus promissorius* and *Lissopimpla excelsa*), which became widespread by parasitising the pasture pest, armyworm (*Mythimna separata*), until an alien parasitic wasp (*Apanteles ruficrus*) was introduced in 1972 to successfully control the armyworm population;
- several species of small black field crickets (*Pteronmobius* spp.) which may have been reduced in their native tussock habitat by the effects of grazing, but have been able to increase their range by exploiting lightly grazed exotic pasture previously under forest;
- the native shorthorned grasshoppers (15 species belonging to the family Acridiidae), which are restricted to the tussock grasslands, but appear to have benefited from the modifications caused by grazing to the extent that they may be considered pests (Scott, 1984);
- the compressed weevil (*Irenimus compressus*) which is endemic to New Zealand and appears to have become widespread in pasture and crop soils where its larvae feed on roots;
- the endemic grass grub moths (*Costelytra zealandica*) and porina weevils (*Wiseana* spp.), whose larvae have become successful pasture pests; and
- plant-feeding nematodes of the genus *Paratylenchus*, which are abundant in pasture but not in natural forests.

On the other side of the ledger, many invertebrate species have been negatively affected by the land use changes of the past 150 years and by the many introduced species which now prey on them or destroy their remaining habitat. The negatively affected species include:

- all 178 native earthworms which have disappeared from deforested soils throughout the country and been replaced by about 25 species of European earthworms;
- most species of large land snails, which were reduced by the removal of their forest habitat as well as by predation from rats, birds and pigs, and perhaps competition from the 26 introduced slugs and snails;
- several chafer beetles (*Prodontria* spp.), especially the Cromwell and Alexandra chafers, which are restricted to very small habitats and are preyed on by a number of introduced animals;
- all but one of the dozen giant wetas (*Deinacrida* spp.) and all three of the known tusked wetas (*'Hemiandrus'* spp.), whose forest and scrub habitats have been greatly reduced, and which are preyed on by rats (Meads, 1990);
- several ring nematodes, especially species of the genus *Criconemoides*, which are found in 60 percent of forested soils but in only 2 percent of pasture soils, and whose range has been reduced along with the forest (Yeates, 1991);
- *Amychus* click beetles, which are now limited to a few small islands, such as the Three Kings, the Chathams group and a few rat-free islands in Cook Strait;
- the large weevils, which are now less numerous and diverse in the lowlands than in the mountains, and whose depleted species include: *Anagotus stephenensis*, *A. Rugosus*, and *Ectopsis ferrugalis*, all of which have been greatly reduced since the arrival of rats and mice; and *Hadramphus tuberculatus* which appears to have gone extinct about 80 years ago through the combined impacts of introduced predators and pasture development (Kuschel and Worthy, 1996); and
- at least 250 other known species of small invertebrates, particularly beetles, which live in indigenous forests and are listed as threatened.

Among this last group are many species which are presumed threatened or extinct but on whom little information exists (Department of Conservation, 1994b). Until recently, Fiordland's bat-winged fly (*Exsul singularis*) was one example (Patrick, 1996). About the size of the common house fly, it has disproportionately large, black wings—as big as a butterfly's. It is carnivorous and changes its flight pattern when hunting to mimic a butterfly. It was regarded as the world's rarest fly (Meads, 1990), but a recent review of its distribution has recommended that it be

**Table 9.11**

**New Zealand's most threatened invertebrates**

| Taxonomic name | Common name |
|---|---|
| *Asaphodes stinaria* | *a geometrid moth* |
| *Brachaspis robustus* | *robust grasshopper* |
| *Confuga persephone* | *a cave dwelling bug* |
| *Dorcus auriculatus* | *Te Aroha stag beetle* |
| *Dorcus ithaginis* | *Mokohinau stag beetle* |
| *Dorcus 'Moehau'* | *Moehau stag beetle* |
| *Hirudobella antipodum* | *Open Bay Island leech* |
| *Mecodema costellum subsp. costellum* | *Stephens Island carabid beetle* |
| *Mecodema laeviseps* | *Ida Valley carabid beetle* |
| *Paryphanta busbyii subsp. watt* | *kauri snail* |
| *Pianoa isolata* | *a mite* |
| *Placostylus ambagiosus (8 subspecies)* | *flax snails* |
| *Powelliphanta gilliesi subsp. brunnea* | *a giant land snail* |
| *Powelliphanta traversi subsp. otakia* | *a giant land snail* |
| *Prodontria bicolorata* | *Alexandra chafer beetle* |
| *Prodontria lewisi* | *Cromwell chafer beetle* |
| *Has not yet been described* | *Middle Island tusked weta* |
| *Xanthorhoe bulbulata* | *orange cress moth* |
| *Xylotoles costatus* | *Pitt Island longhorn beetle* |

*Source: Department of Conservation (1994b)*

removed from the threatened list because it appears to be widespread in the high mountain grasslands of Fiordland and the southern Alps, particularly around alpine streams (Patrick, 1996).

Another unique New Zealand insect which is presumed threatened is the wingless bat fly (*Mystacinobia zelandica*). It is so ancient that it has no close relatives and lives its entire life with the rare native short-tailed bat. The bat flies share their hosts' roosts, feed off their droppings and use the bats' fur for public transport. The bat fly's only close relative became extinct in 1965 after the rat invasion of Big South Cape Island when its host, the larger short tailed bat, was wiped out.

Even more ancient than the bat fly is a small group of invertebrates called the Onychophora or velvet worms which are often referred to as 'living fossils' (Gleeson, 1996). With their many pairs of sac-like legs they are something of an evolutionary enigma. Some scientists consider them to be primitive arthropods, a sister group to the centipedes and millipedes, while others regard them as an even more primitive 'missing link' between the arthropods and the annelid worms (Poinar, 1996). They live in moist habitats under stones, leaves and rotting logs, and have probably become more rare as the world's forests have declined.

Velvet worms have been identified internationally as 'vulnerable' (Wells *et al.*, 1983) and as warranting priority for conservation (New, 1995). Until recently, 5 species were known in New Zealand, 4 of them endemic. Two are widespread and 3 have restricted distributions. Several new species have come to light and these also appear to have restricted distributions. They include a new genus from the Leith Valley and Caversham regions of Dunedin and a new species from Birch Island in the lower Clutha River, a habitat which is under threat of inundation for hydroelectricity development (Gleeson, 1996).

The chafer beetle group contains species whose status is still being investigated. All of the 15 or so known species are endemic to Otago, Southland or Stewart Island, and all live in restricted habitats (Emerson, 1994). Their best known member is the Cromwell chafer (*Prodontria lewisii*), which is among the species on the Department of Conservation's top priority list. It is found in only one area—an 80 hectare reserve near Cromwell in Central Otago where it lives among silver tussock (*Poa laevis*) and scabweeds (*Raoulia* spp.). Its original range was just 500 hectares, but this was reduced to 100 hectares by the activities and construction of the Clyde dam and the reconstituted Cromwell township (Meads, 1990; Watt, 1979).

The reserve was established for the Cromwell chafer in 1983, but humans are not the little beetle's only enemies. The chafer is eaten by hedgehogs (*Erinaceous europaeus*), blackbirds (*Turdus merula*) and song thrushes (*Turdus philomelos*), and is a particular delicacy of the little owl (*Athene noctua*). These alien predators were introduced from Europe; the hedgehog to control introduced snails which had become a garden pest, and the owls to control other introduced birds which had become orchard pests. Cromwell chafers make up 10 percent of the little owl's summer diet (Meads, 1990).

Habitat destruction has had a big impact on many other insect species. The effects of deforestation on beetle diversity have been studied in Auckland (Kuschel, 1990) and Wellington (Crisp, 1995). Both studies found that the number of beetle species living in grass or other exotic vegetation is much lower than the number living in native bush. The only long-term study of the relationship between habitat destruction and insect biodiversity was a survey of 150 moth species in an area of South Island tussock grassland (White, 1991).

The moth study found that, between 1962 and 1989, the tussocks and herbs on which half the moth species feed, had been replaced over about 30 percent of the study area by the exotic grass browntop (*Agrostis capillaris*). Although no species had disappeared, the populations of many of them had halved. If the browntop continues to spread, it is expected that moth populations will continue to fall until some species are lost (White, 1991).

Fifteen species of native land snails and 59 additional sub-species feature in the Department of Conservation's threatened species list. For its size, New Zealand has more kinds of land snails than almost any other country. About 500 species have been identified and up to 700 may exist. They range from tiny species with shells no larger than a few mm to giant species as long as a person's forearm. Several species, known only from shells, are considered to be extinct. More than half of our threatened snails are from one genus, *Powelliphanta*, the giant land snails. Other hard-hit genera are the kauri snails, *Paryphanta*, and the flax snails, *Placostylus*. Many more species of smaller snails may be threatened but have yet to be identified.

The larger snails are preyed on by such animals as Pacific, Norway and brown rats, possums, pigs, hedgehogs, blackbirds and song thrushes, but the greatest threat to their existence has been the destruction of their habitat (Meads *et al.*, 1984). Land snails usually live in the deep, moist, non-acidic leaf mould that accumulates under forest and scrub where shelter, food and moisture are readily available. Deforestation and drainage have drastically reduced such areas, and many snail populations have declined accordingly. The effect of forest degradation on native snail biodiversity was studied on Manakau Peninsula. In undisturbed forest, 57 species were found. The number fell to 48 in regenerating forest which had been fenced off from stock animals, and fell further to 32 in forest stands that were not fenced off and which had been either burnt or cut over (Solem *et al.*, 1981).

Habitat loss also threatens some of our unique slugs. Slugs are actually snails which have lost their shells. New Zealand has about 30 species, all endemic (Burton, 1962, 1963). Like the snails, they have some close relatives in eastern Australia, New Caledonia, Vanuatu and other Pacific Islands, and, also like the snails, they need a moist shady environment. They are often found under logs, in leaf mould and in the leaf bases of flax bushes and nikau palms.

They are easily distinguished from introduced slugs, such as the common grey European slug, by the fact that they have two tentacles instead of four, and are more attractively coloured. Some of the native slugs are also considerably larger than the imports, with one species growing up to 15 cm. The natives do not have a mantle or saddle on their bodies and often have a leaf-like shape with venous lines fanning out from a centre-line which runs down their backs. The New Zealand slugs are unique in having a tiny pinhole on their backs which, like a whale's blowhole, leads to the slugs' most distinctive feature—a highly developed lung found in no other mollusc (Burton, 1982).

Some native slugs are widespread throughout New Zealand. The euphoniously named *Athoracophorus bitentaculatus*, for example, is found throughout the North and South islands (Barker, 1978). The olive green Green Gherkin Slug (*Pseudaneitea papillata*) is also widely distributed and is common on flax bushes and even toitoi. Others are rare and seem restricted to specific locations. Five species known from four subantarctic islands (the Snares Islands, Auckland Island, Campbell Island, and Macquarie Island) have yet to be found on the mainland. *Pseudaneita dendyi* has been found only in mid-Canterbury, *Pseudaneita schauinslandi* is restricted to the Marlborough Sounds (Burton, 1962) and *Pseudaneita multistriata* is confined to two tiny islands off Stewart Island.

Three slug species found in the Chatham Islands may be lost before they are formally described. Two of them are restricted to forest remnants on the main island, the third to a similar habitat on the smaller Pitt Island. Several more species in Northland, again formally undescribed, are also dependent on habitat conservation for their survival. As with snails and birds, habitat loss is the main threat to our slugs. Predation adds to the pressure, as does competition from the 26 or so species of introduced slugs and snails. Some of the introduced species may even eat native species or pass on protozoan diseases to them. Because information on their status is so scant, no slugs are currently listed as threatened by the Department of Conservation.

#### *Freshwater invertebrates*

About 450 formally identified insect species and at least 200 other kinds of invertebrate (e.g. crustaceans, molluscs and various worm phyla) live in streams and other freshwater habitats (Collier, 1993). A recent review of their status and distribution found that 154 species (mostly flying insects) that live in or on surface waters have 'restricted' distributions in New Zealand, as do a further 20 species (mostly molluscs) which live in underground waters, and a further 36 species known only from offshore islands (Collier, 1993).

Not all of these restricted species are necessarily threatened, but several are of sufficient concern to be included in the Department of Conservation's threatened species list. The main threats come from habitat degradation by catchment clearance, removal of riverbank vegetation, wetland drainage, diffuse and point source pollution, channel engineering works, mining, and the regulation of flow regimes (Collier, 1993). In some cases (e.g. freshwater crayfish) predation by introduced fish is also a threat.

A third of the invertebrates with restricted ranges are known from specimens, but have not been formally described and named (Collier, 1993). Without taxonomic descriptions it is not possible to assess distributions or accurately target species for recovery programmes. Because time may be running out for some species, it has been argued that, instead of waiting for scientific descriptions and assessments of individual species, the immediate priority should be to protect representative freshwater habitats (Collier, 1993).

#### *Marine Invertebrates*

Many of our larger marine invertebrates are well known to shellfish gatherers, divers and beach-combers, but many of the tiny species are never seen. 'Meio-fauna' is a catch-all term for animals which are barely 1 mm long. They are bigger than single-celled micro-organisms (bacteria, protozoans and micro-algae) but too small to be classed with the crabs, snails and seaweeds as 'macro-organisms'.

Ninety-five percent of the meio-fauna in our estuaries are either threadworms (nematodes) or tiny, shrimp-like crustaceans called copepods. They are vital parts of the food chain, eating bacteria and micro-algae before being eaten in turn by baby flatfish which, in turn, are eaten by wading birds. Although they are apparently sensitive to environmental disturbances, and have even been suggested as environmental indicators of estuarine health, nothing is known of their status (Dickison, 1992).

The larger marine invertebrates are more familiar to most people. They include several species which are gathered or fished, and many which are not. The better known groups are: crustaceans (e.g. crabs, shrimps, barnacles and rock lobsters or marine crayfish); molluscs (e.g. abalone or paua, pipi, mud snails, scallops, catseyes, tuatua, oysters, toheroa, cockles, mussels and many more, plus, in deeper waters, squid and octopus); echinoderms (e.g. seastars and sea urchins or kina); poriferans (sponges); cnidarians or coelenterates (corals, jellyfish, sea anemones); bryozoans (e.g. lace corals); and brachiopods (lamp shells).

Many of the molluscs are taken recreationally as well as commercially, and have traditionally formed a large part of the Maori diet. In fact, evidence from middens suggests that every available form of shellfish was eaten by pre-European Maori—even barnacles, which are small shell-like crustaceans (Foster, 1986). A typical West Auckland midden, for example, contained the shells of 32 mollusc species, 2 barnacle species and one sea urchin (kina). The most abundant species were cockles (67 percent), pipi (13 percent), mussels (11 percent) and tuatua (2 percent). In some coastal areas, middens show that local shellfish populations declined in size or disappeared altogether by about A.D. 1500 (Davidson, 1984). In most areas, however, particularly harbour flats, they remained abundant.

Today, several of the larger marine invertebrates are harvested commercially. Most of the harvesting is controlled by catch limits imposed by the Ministry of Fisheries (see Table 9.12). A few species are subject to the Quota Management System (QMS) which regulates catches through annual quotas (see Box 9.14). Many others are subject to competitive quotas or catch limits specified on permits. These controls are necessary because many invertebrate species are of very high commercial value and are extremely vulnerable to overfishing. Good stock assessment information is available for only a few species.

Apart from harvesting pressure, some marine invertebrates are vulnerable to environmental disturbances, particularly sediment washing down from rivers, pollution, changes in sea temperatures, and fishing activities, such as the scraping of heavy nets and dredge buckets along the sea bottom (Jones, 1992; Pain, 1996a).

As pressure has intensified on some wild populations, shellfish 'farms' (aquaculture) are increasing in number because they give much greater control over populations and harvest rates. Green-lipped mussels and the introduced Pacific oysters are farmed in this way. Paua farms have recently been established, along with freshwater prawn farms, such as the *Machrobrachium rosenbergii* farm associated with the Wairakei geothermal fields. There are seaweed farms, whose 1995 output came to about 70 tonnes, in Bluff Harbour and Tory Channel. And aquaculture is also likely to be developed for dredge oysters, scallops, and rock lobsters.

### *Toheroa*

Toheroa (*Paphies ventricosa*) are large endemic clams which live in groups, mostly on the wave-pounded beaches of Northland's and Wellington's west coast and a few beaches at the bottom of the South Island. In the past, massive toheroa shells, measuring up to 33 cm (13 inches) could be found, but these days most toheroa are about half that size (Heath and Dell, 1971). They are considered a delicacy and their habit of burrowing into the

**Table 9.12**

**Commercial controls on southern region invertebrate fisheries.**

| Species | Control Methods |
|---|---|
| *Cockles* | *Catch limits on permits* |
| *Dredge oysters* | *Controlled fishery—individual quotas* |
| *Kina* | *Competitive TAC** |
| *Mussels* | *Ban on all commercial fishing* |
| *Octopus* | *No catch limit (but very small fishery)* |
| *Paddle crab* | *Competitive TAC* |
| *Paua* | *QMS* |
| *Queen scallops* | *Competitive TAC* |
| *Rock lobster* | *QMS* |
| *Scampi* | *QMS* |
| *Sea cucumber* | *Catch limits on permits* |
| *Southern scallops* | *QMS* |
| *Spider crab* | *Catch limits on permits* |
| *Squid* | *QMS* |
| *Surf clams* | *Catch limits on permits* |
| *Toheroa* | *Ban on all commercial fishing* |
| *Whelks* | *Catch limits on permits* |

* *Competitive TAC = a total allowable catch (TAC) limit which is not divided into individual quotas. Harvesting continues competitively until the total allowable tonnage has been reached.*
** *QMS = the official Quota Management System, in which total allowable catch (TAC) limits are divided into individual quotas (see Box 9.14)*

sand for protection makes them easy prey for determined shellfish gatherers.

Commercial harvesting began in the late 1800s, and the successful canning of toheroa soup and toheroa tongues was achieved in the early 1900s. The main effort was on the west coast beaches of Northland. At one stage, four factories were operating on a 20 km stretch of North Kaipara Beach (Dargaville Beach). Three closed after a few seasons, but the fourth remained in operation until 1969 when it, too, was forced to close down because of the dwindling number of toheroa. Another cannery which operated on Ninety Mile Beach from 1923, closed in 1945 because of the depleted stocks. It reopened again in 1962, but shut down for good in 1964. Other commercial harvesting occurred for brief periods at Muriwai Beach near Auckland, the west coast beaches of Wellington, and Bluecliffs Beach in Southland. Restrictions on recreational toheroa gathering were introduced in 1932, with a two-month season (October–November), a daily bag limit of 50 toheroa per person for non-Maori gatherers, and a minimum legal size of 3 inches (7.5 cm) shell length.

In 1941, a daily bag limit of 80 toheroa per person was introduced for Maori gatherers. In 1950, ethnic distinctions were revoked and all gatherers were subject to a daily bag limit of 20 toheroa per person, or 50 per vehicle. Although fisheries regulations now give special consideration to fish and shellfish gathering for Maori gatherings and funerals (hui and tangi), these are still subject to conservation restrictions. Special legislation for cultural harvesting of fish and shellfish is now in preparation. Despite these measures, toheroa stocks continued to decline, so the controls were periodically tightened until, by the late 1970s, the season had been reduced to one week, the daily bag limit was down to 10 per person (still with a car limit of 50), and the use of digging implements had been banned. In 1980, the season was further reduced to 5 days, and the legal size limit was increased to 10 cm (just over 4 inches).

Since 1962, decisions on whether toheroa seasons should be held have been based on beach surveys which are now conducted about every 3 years. No toheroa seasons were approved during the 1980s, but in 1990 and again in 1993 seasons were approved at Oreti beach near Invercargill where, for a season to be held, the survey must indicate a beach population of at least 1 million toheroa.

**Box 9.14**

### *The Quota Management System (QMS)*

Since 1986, our most commercially important marine species have been fished under the Quota Management System (QMS). New Zealand was one of the first countries to adopt this system in which catch limits for each stock are set by the Government and allocated to commercial fishers through individual quotas. Most species consist of several stocks which each inhabit different parts of our 200-mile Exclusive Economic Zone (EEZ). To help identify them, the EEZ has been divided into 10 Quota Management Areas (QMAs) (see Figure 9.5). Each stock has a unique label reflecting both its species name (e.g. SQU for squid) and its QMA address (e.g. SQU6 for those in QMA 6). The label may be further elaborated when several stocks of one species share the same QMA (e.g. the SQU6T stock occurs on plateaus accessible to trawlers, while the SQU6J stock occurs in deeper waters accessible only to jiggers).

Every year, fishery scientists analyse catch and trawler survey data to assess whether each stock is above or below its Maximum Sustainable Yield (MSY) level (see Box 9.15). The results of the stock assessments are forwarded to the Minister of Fisheries who then consults with the fishing industry, Maori representatives, environmental and recreational groups, and other interested parties, before setting the annual Total Allowable Catches (TACs). A TAC specifies the total amount that may be taken from a stock by the combined efforts of commercial, recreational and Maori customary fishers. The objective in setting TACs is to reduce (or, in some cases, rebuild) stocks to their MSY level, and hold them there. This is largely done by controlling the commercial portion of the TAC, which is called the Total Allowable Commercial Catch (TACC). The commercial catch limits are set after an allowance has been made for the estimated recreational and customary catches. The commercial catch is divided among fishers in the form of Individual Transferable Quotas (ITQs). An ITQ permits the holder to catch a specified percentage of the TACC for a particular stock. The original ITQs were allocated in perpetuity to commercial fishers in 1986, based on their catch histories. Many fishing companies and independent fishers have since bought, sold or leased their ITQs in the same way as they might buy, sell or lease property. In fact, the ITQ is a kind of property right.

Shortly before opting for the ITQ system, the Government used a different method to reduce the inshore fishing pressure. In 1984, part-timers were excluded from the industry. This effectively halved the number of commercial fishers in a single year. Shore fishing permits were reduced from 550 to 261 and the fishing fleet was cut from 4,320 to 2,747 (Department of Statistics, 1985). Fleet numbers have remained at or below this level since. Many of the excluded fishers were Maori who, in 1986, sought a High Court injunction against the ITQ allocation process. In 1987 the Court made an interim declaration in their favour which led to long negotiations between Maori representatives and the Crown. The result was a two-stage settlement costing the Crown approximately $280 million. In the first stage, the Government purchased ITQs representing 10 percent of the existing TACC and allocated these to Maori fishers through the Maori Fisheries Act 1989. It also established the Maori Fisheries Commission to facilitate this process. In the second phase, following further negotiations, the Crown signed a Deed of Settlement which is reflected in the Treaty of Waitangi Settlement (Fisheries) Act 1992. Under this, the Government funded the purchase of a 50 percent share in Sealord Products Ltd for Maori interests, agreed to allocate 20 percent of the quota for any new QMS species to Maori interests, and also agreed to establish a regulatory framework for non-commercial Maori customary fishing. Through the Sealord purchase and the quota allocations, Maori commercial interests now control 40 percent of the commercial fishing quota. The relatively small customary catch is not subject to quota. Together with recreational fishing, allowance is made for it when the TACCs for each stock are set.

The overall success of the Quota Management System has still to be assessed. Economically, it has been hailed as very efficient, but, ecologically, the benefits are uncertain. The emphasis on scientifically based sustainable yield management is a distinct improvement on previous approaches and those used in many other parts of the world. However, it cannot, in itself, overcome some of the inherent difficulties affecting all fisheries management regimes. For a start, little is known about the extent and impact of illegal fishing practices, or the level of voluntary compliance with quotas and other restrictions. Illegal practices which are known to occur include bycatch dumping (i.e. discarding accidentally caught species for which the fisher has no quota), 'highgrading' (i.e. discarding less valuable fish in favour of more valuable ones), poaching, fishing out of season, and selling illegally caught fish and invertebrates on the blackmarket. In the 1993/94 season, for example, more than 60 enforcement operations by the Ministry of Agriculture and Fisheries (MAF) led to eight major prosecutions against people and companies involved in quota fraud. It has been estimated that up to 80 percent of domestically sold fish may have been funnelled through the blackmarket (Minister of Fisheries, 1992; Duncan, 1995). The compliance problem is a feature of fisheries worldwide and is being addressed by both Government and industry.

A more fundamental question, however, concerns the impact of legal fishing. About half the QMS stocks are of unknown status, although most of these are the more lightly fished stocks. Of those whose status is known, most are still in the process of being 'fished down', so the system's ability to maintain them at the MSY level has yet to be tested. For stocks which were near or below the MSY level when the system was introduced, results have been mixed. Several stocks appear to have stabilised or begun rebuilding, but some have declined below the MSY level (e.g. some orange roughy stocks) or failed to rebuild to it (e.g. some snapper stocks). Quotas for these stocks have now been dramatically reduced and improvements are expected, though they may take some time.

The other important environmental question about the QMS concerns its impact on non-target species and their ecosystems. Until the recent passing of the Fisheries Act 1996, the QMS had been relentlessly single-species in its focus, with each stock managed in isolation from the other species in its environment. When, for example, a stock was reduced by two thirds to boost its yield, no account was taken of the possible impacts of such a reduction on the associated predator and prey populations. Little account was also taken of the effects of bycatch, or vessel and net disturbances, on non-target fish and invertebrates. Nor was any account taken of the need to maintain key ecosystems (such as coastal mangroves and deepwater seamounts) that act as nurseries, spawning grounds or feeding grounds for many target stocks. Now, however, this is all set to change. In line with the new Fisheries Act requirement to manage both the environmental impacts of fishing, as well as the yields, the Ministry of Fisheries is developing a long-term strategy entitled *Fisheries 2010*. The proposed cornerstone of the strategy will be a fundamental change of course away from resource management and toward ecosystem management (Ministry of Fisheries, 1996).

The 1993 toheroa 'season' or open day lasted just 9 hours (roughly the period of low tide). It had a bag limit of 5 toheroa per person and a minimum shell length of 10 cm. An estimated 15,000–20,000 were taken. The other toheroa beach in Southland, Bluecliffs in Te Waewae Bay, has a population trigger value of 450,000, but the beach is eroding and has been unable to support a season in recent years.

*Rock lobsters*

Rock lobsters or marine crayfish (*Jasus edwardsii* and *J. verreauxi*) are one of the most important of the commercially fished marine invertebrates, and, until recently, one of the most over-fished (see Table 9.13). *Jasus edwardsii* was listed as a commercially threatened species by the International Union for the Conservation of Nature and Natural Resources (IUCN, 1990) and the Department of Conservation (1994e). However, rock lobsters are not a protected species. Instead, their harvesting is regulated by a combination of size limits and seasonal restrictions and, in the past four years, has come under the Quota Management System (QMS).

The status of the Chatham Island and Kermadec rock lobster stocks is unknown, but all eight stocks around the North, South and Stewart Islands are below the level of Maximum Sustainable Yield (see Box 9.15). The overall rock lobster catch was relatively stable from about 1960 until 1987, though signs of over-exploitation began to show as the effort required to catch them increased steadily over this time. The number of potlifts needed to catch a given amount of lobster doubled between 1979 and 1992. Then, between 1987 and 1992, the total commercial catch declined by half (Booth *et al.*, 1994).

Fisheries scientists concluded in 1991, and again in 1993, that the fishing pressure had been too high for some time and that there was some risk of stock collapse (Breen, 1993). The Total Allowable Catch (TAC) was duly reduced by 20 percent in 1993 to 2,953 tonnes. Stocks now appear to be recovering, despite an illegal catch estimated at 650-700 tonnes. The recreational catch is estimated to be at least 160 tonnes. The Maori food-gathering catch is unknown but may be less than 20 tonnes (Booth *et al.*, 1994; Breen, 1994; Ministry of Agriculture and Fisheries, 1995; Teirney and Kilner, 1995).

*Scampi*

Scampi (*Metanephrops challengeri*) are small deep-water lobsters, 4–6 cm long, with natural lifespans of possibly 15–20 years. They began to be fished in 1987–88. Stock levels are assumed to be above the MSY level and in the 'fishing down' phase (Annala, 1995a)(see Table 9.13).

**Box 9.15**

### *Maximum Sustainable Yield (MSY)*

The Maximum Sustainable Yield (MSY) is the maximum tonnage of 'surplus' individuals that can be taken from a stock while still leaving a constant population of breeding individuals. It is a production-driven approach to fishery management, rather than an ecologically driven one, requiring fish stocks to be kept well below their natural size so that a large number of surplus offspring can be continually generated. In natural fish populations relatively few youngsters survive to adulthood. This is because food and territory are fully taken by the existing adults. However, when a population has been significantly reduced, the competition for territory and resources eases and many more offspring can survive to adulthood. Because food is more available they can also grow faster, reaching a harvestable size sooner. In nature, fish populations rarely remain at this level. Left to themselves, each year's crop of young adults become 'new recruits' to the breeding population and this causes the stock to expand back up to its natural saturation point where territory and food supplies once again limit survivorship and growth rates. Under fishery management, however, this population recovery process is interrupted by repeated harvesting, thus sustaining the population indefinitely at the MSY level.

A fish population is at the MSY level when it has reached *the maximum size that will sustain peak rates of survivorship and growth*. For most fish stocks this is between 25 percent and 60 percent of the population's pre-exploitation biomass. Above that size, 'habitat crowding' causes survivorship and growth rates to decline, taking the total yield down. Below that size, the total number of breeding females, and hence offspring, declines, again taking yields down. The first goal of fishery management, then, is to 'move' stocks to the MSY level by setting catch limits which allow stocks above that level to be 'fished down' and those below it to be 'rebuilt'. Once the MSY level has been reached, catch limits have to be finely tuned to match the tonnage of each year's new 'recruitment class' of young adults. Significant error either way can cause lower yields in following years. Getting it right, therefore, requires good scientific assessments and a precautionary approach in setting catch limits. If excessive catch limits are repeatedly set, stocks may eventually 'collapse' to the point of commercial or even biological 'extinction'. Although this has not happened to any QMS stocks, sectoral lobbying has sometimes overshadowed scientific advice in the TACC setting process, resulting in catch limits that have exceeded recruitment levels.

Setting sustainable catch limits is not the only difficulty associated with the MSY approach. Because it has the single aim of getting maximum sustainable yields from target stocks, the MSY method is blind to any adverse impacts on non-commercial fish, invertebrates and ecosystems. This presents a challenge for fishery scientists and managers now that the Fisheries Act 1996 and the proposed *Fisheries 2010* strategy demand an ecologically sustainable approach to fisheries management. It remains to be seen whether the MSY method can be adapted to the new ecosystem management regime or whether entirely new techniques will be required to produce the Ecologically Sustainable Yields (ESY) of the future.

**Table 9.13**

**Recent quotas, catches and status of some commercial marine invertebrate stocks.**

| Species | | 1990[1] | 1992[1] | 1994[1] | 1996[1] | Stocks Status 1996 |
|---|---|---|---|---|---|---|
| | | | | (tonnes) | | |
| *Packhorse rock lobster (Jasus verreauxi)* | *Quota* | *None* | *31* | *40* | *40* | *D* |
| | *Catch* | *10* | *24* | *6* | *24* | |
| *Red rock lobster (Jasus edwardsii)* | *Quota* | *3,699* | *3,616* | *2,913* | *2,913* | *B (Nth & Sth Is.)* |
| | *Catch* | *3,113* | *3,061* | *2,765* | *2,510* | *D (Chatham Is)* |
| *Scampi (Metanephrops challengeri)* | *Quota* | *No quota* | *1,230* | *1,230* | *1,230* | *A* |
| | *Catch* | *238* | *925* | *987* | *895* | |
| *Squid (Arrow squid) (Nototodarus gouldo, N. sloanii)* | *Quota* | *166,250* | *118,571* | *122,875* | *123,332* | *D* |
| | *Catch* | *46,915* | *60,509* | *74,492* | *62,333* | |
| *Paua (Haliotis iris; H. australis)* | *Quota* | *1,287* | *1,287* | *1,238* | *1,254* | *D* |
| | *Catch* | *1,287* | *1,281* | *1,051* | *1,096* | |
| *Oysters (Tiostrea chilensis) (Challenger beds)* | *Quota* | *500* | *500* | *500* | *500* | *D* |
| | *Catch* | *208* | *279* | *584* | *694* | |
| *(Foveaux Strait beds)* | *Quota* | *46,000 sacks*[2] | *18,400 sacks*[2] | *Closed season* | *4,000 sacks*[2,3] | *B* |
| | *Catch* | *46,114 sacks*[2] | *5,821 sacks*[2,4] | | *3,869 sacks*[2,3] | |

*Source: Ministry of Fisheries.*

[1] *For rock lobsters, the fishing year is the 12 months up to December, while for other species it is the twelve months up to June.*
[2] *1 sack = 0.079 tonne. Oyster quota was reduced from 115,000 to 46,000 sacks during the 1990-91 season when Bonamia was found to have spread.*
[3] *The Foveaux Strait Dredge Oyster Fishery was opened between June and August 1996 for the first time since 1992*
[4] *Fishing was only permitted in the outer areas of fishery because of* Bonamia.

Stocks Status Key
A = Above Maximum Sustainable Yield (MSY) and being "fished down".
B = Below MSY level.
C = Currently at or near the MSY level.
D = Data deficient.

### *Scallops*

Scallops (*Pecten novaezelandiae*) are dredged off Northland, the Coromandel Peninsula, and Nelson (see Table 9.14). These hermaphroditic shellfish are highly fecund and their populations are highly variable from one year to the next. This makes status assessments difficult, though it seems that commercial fishing at past levels poses no threat to the North Island stocks, each of which is managed by catch limits and seasons (Annala, 1993b).

Scallops are also sensitive to pressures other than direct harvesting. Bull (1986) found that the survival rate of scallop larvae after nine months was heavily affected by the presence or absence of fishing trawlers. In an area closed to trawlers, 20 percent of young scallops survived, compared to less than 1 percent where trawlers were working. Scallops are also highly sensitive to suspended clay particles and land use decisions which affect water run-off can have highly destructive consequences for scallop beds.

**Table 9.14**

**Commercial scallop (Pecten novaezelandiae) fisheries in New Zealand[1]**

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|---|
| *Northern Fishery* | | | | *Northland* (Season: July 15 - February 14) | | | |
| *Quota* | *600kg greenweight (unopened) per boat per day* | *600kg greenweight (unopened) per boat per day* | *600kg greenweight (unopened) per boat per day* | *600kg greenweight (unopened) per boat per day* | *600kg greenweight (unopened) per boat per day* | *600kg greenweight (unopened) per boat per day* | *188 tonnes[2]* |
| | | | | *Coromandel* (Season: July 15 - December 21) | | | |
| | *600kg greenweight (unopened) per boat per day* | *600kg greenweight (unopened) per boat per day* | *7 tonnes of meat per boat per season* | *6 tonnes of meat per boat per season* | *3 tonnes of meat per boat per season* | *Quota details not available* | *88 tonnes (2 tonnes of meat per boat)* |
| *Catch* | *143 t.* | *282 t.* | *230 t.* | *157 t.* | *202 t.* | *208 t.* | *200 t.* |
| *Southern Fishery[3]* | | | | *Nelson and Marlborough* (Season: August-December with start date based on surveys of scallop size) | | | |
| *Quota* | *No fishery-wide quota. Each vessel allocated a set catch.* | *No fishery-wide quota. Each vessel allocated a set catch* | *About 640 t. (meatweight) later increased to about 740 tonnes.* | *AAC[4] 1,100 tonnes (meatweight) per season* | *AAC[4] 850 tonnes (meatweight) per season* | *AAC[4] 720 tonnes (meatweight) per season* | *AAC[4] 720 tonnes (meatweight) per season* |
| *Catch* | *240 t.* | *672 t.* | *710 t.* | *805 t.* | *850 t.* | *521 t.* | *672 t.* |

*Source: Ministry of Fisheries*

1 *This table contains no assessment of stock status because scallop stocks vary markedly from year to year. Catch limits have been based on annual abundance surveys since*
*1992 in the Northern Fishery and since 1993 in the Southern Fishery.*

2 *For the 1995-96 fishing season, the quota allocation for the Northland Zone of the Northern Fishery was changed from a quota per boat system to an overall area system.*

3 *Since 1986, the Southern Fishery has been "farmed" with a rotational fishing strategy and stock from a seeding programme contributing to the annual yield.*

4 *The Southern Fishery has 48 licensed vessels whose catch limits were initially set on a per boat basis but, from 1993 on, have been subject to a fishery-wide Allowable Annual Catch (AAC) allocated through a transferable quota (ITQ) system.*

The large Southern Scallop fishery, based near Nelson, is augmented by scallop farming, has a season based on annual surveys of scallop size (see Table 9.14) and is fished on a rotational basis. The fishery was placed under a transferable quota management system in 1992. In the late 1970s, it experienced a classic boom and bust phase and is now recovering.

From small beginnings in 1959, catches rose to 1,246 tonnes in 1975 then crashed to zero in 1981 and 1982. The stocks' recovery has been assisted by a re-seeding, or enhancement, programme. Although catches have increased throughout the 1990s, the 1995–96 quota had to be reduced from 850 tonnes to 720 tonnes because many scallops were small, probably due to a seasonal food shortage.

*Squid*

The most commercially important marine invertebrates are the two arrow squid species (*Nototodarus gouldi* and *N. sloanii*). By invertebrate standards, these ten-legged molluscs and their eight-legged relatives, the octopuses, are big and brainy. They are widely distributed around New Zealand, but population estimates are uncertain and vary widely from year to year. Because squid live for only one year, scientists cannot predict stock size nor determine if recent catch levels and quotas are sustainable (Annala, 1995a).

Commercial squid fishing began in the 1970s and peaked in the early 1980s when more than 200 vessels, mainly from Japan, fished in our deeper waters using spinning hooks on long-lines (jigging). The number of foreign jiggers has declined since the late 1980s, leaving most of the catch to New Zealand trawlers operating in the shallower continental shelf zones around the mainland and the Auckland Islands.

Since 1986–87, the annual squid catch has consistently been lower than the Total Allowable Catch (TAC), averaging 65,000 tonnes against an average TAC of 128,000 tonnes (see Table 9.13). Although the total catch has fluctuated widely over this period, from as low as 37,000 tonnes (1992–93) to as high as 114,000 tonnes (1988–89), it has shown no overall trend. Both the 1986–87 and 1993–94 catches were just over 74,000 tonnes (Annala, 1995a). The only example of a squid catch exceeding quota was in the southern squid fishery (SQU6T) in 1993–94 when 34,534 tonnes were caught—14 percent above the TAC of 30,369. Whatever their impacts on the squid stock, high catches in this fishery pose a bycatch hazard to the rare New Zealand (Hooker's) sea lion (see Box 9.18 and Table 9.34).

*Paua*

Paua, or abalone, are gastropod molluscs and, hence, relatives of the snails and slugs. Two species are caught: the common black-footed paua (*Haliotis iris*) and the smaller and less abundant yellow-footed paua (*H. australis*). They are not differentiated in the fishing statistics, but 90 percent of the catch consists of black-footed paua. Paua have been commercially fished since the mid-1940s, at first only for the shells, but later for the meat as well. Commercial paua fishing must be done by hand without underwater breathing apparatus.

For most of the past decade, the annual commercial catch has been about 1,250 tonnes and the annual TAC has been slightly above this. In 1993–94, however, the total catch slipped to barely 1,000 tonnes, the lowest for more than a decade. Besides the commercial catch, an estimated 400 tonnes are taken illegally each year and a further 200 tonnes are taken by recreational gatherers (Teirney and Kilner, 1995). This is equivalent to half the commercial take and suggests that the overall TAC is regularly being exceeded.

Most of the catch is from the South Island, Stewart Island, and the Chatham Islands, with some off the Wairarapa coast. It is not known if recent catch levels or the current TACCs are sustainable, or if the overall population is increasing or declining (Annala, 1995a). Although stocks around the South Island appear to be abundant, they may be declining around Stewart Island and also on the west coast where "the fishery may be serially depleting an accumulated stock of presumably very old individuals" (McShane *et al.*, 1994) (see Figure 9.5 and Table 9.13).

#### *Oysters*

Dredge or Bluff oysters (*Tiostrea chilensis*) are Gondwana veterans which were native to New Zealand and Chile long before dredges or the city of Bluff were invented. Their wild populations have been commercially harvested for more than100 years and research is now under way to farm them commercially (Jeffs, 1995). The commercially farmed Pacific oysters (C*rassostrea gigas*) are not native, having been introduced here from Japan in the early 1970s. The two main stocks of dredge oysters are at the top and bottom of the South Island—the Challenger beds near Nelson and the Foveaux Strait beds near Bluff (see Table 9.13).

The TAC for the Challenger beds has been 500 tonnes since 1987 and has been reached or exceeded 7 times in the past 14 years. No information has been collected on customary and recreational fishing. Scientists do not know whether the catch is sustainable or whether the population is above or below the MSY level (Annala, 1995a).

The Foveaux Strait oyster beds were closed to fishing from 1993 after the spread of an infectious parasite called *Bonamia* which was first identified in 1986. By 1993, the combination of disease and harvesting pressure had reduced the stock to 20 percent of its 1975 level and 10 percent of its original level (Annala, 1993a). Since the oyster beds have been closed, the commercial fishers have been carrying out research to see if the population can be increased through an enhancement programme similar to that used for the scallop beds at the other end of the island. The 1995 oyster beds survey showed that the *Bonamia* infestation had declined, and oyster numbers had increased enough for the Minister of Fisheries to agree to a short commercial season during the winter of 1996.

#### *Cockles*

Cockles (*Austrovenus stutchburyi*) have been commercially picked from tidal flats since the early 1980s. They have been collected for much longer in many areas by Maori and recreational shellfish gatherers. The commercial harvesters operate in three areas: Whangarei Harbour, Golden and Tasman Bays (near Nelson), and Papanui and Waitati inlets (near Dunedin).

In Whangarei Harbour, the overall number of cockles has not changed, but their age and size distribution has, with harvestable-sized cockles down to a third of their original levels. Large old cockles have declined by more than 90 percent. Although small cockles appear to have increased, it is not known whether recent catch levels are sustainable. Catches have grown in the past decade, except for the 1992–93 year when toxic algal blooms caused a closure of the fishery (Annala, 1995a).

Commercial fishing of the Papanui and Waitati stocks is relatively light and fishing at current levels is unlikely to reduce the biomass of cockles to low levels, though some recreational cockle pickers have complained that the proportion of large cockles has decreased in recent years. This is a normal consequence of the 'fishing down' phase as older individuals are replaced by an increasing number of young ones (Annala, 1995a).

#### *Other molluscs*

Besides the arrow squid and various shellfish species that are harvested commercially or recreationally, many more molluscs go unnoticed in our waters. These range from several other species of cephalopods (squids and octopuses) to several thousand species of marine snails and shellfish, many of which thrive in the marine mud 1–2 km below the ocean surface. Approximately 2,280 species and subspecies of marine molluscs have been recorded from the New Zealand region, and approximately 1,000 specimens held in the National Museum have yet to be described. At least as many species may still be awaiting discovery on the sea floor (Marshall, 1994).

The great majority of molluscan species are less than 1 cm in size and many of those are in the millimetre size range. Virtually all groups need taxonomic revision. Many species once thought to have limited distributions are now known to be more widespread. None of the unharvested species of marine molluscs is known to be threatened, though the habitats of some may be at risk (Marshall, 1994).

#### *Crabs and other crustaceans*

Although lobsters earn more money, crabs are probably the best known crustaceans. Lesser known crustaceans include the numerous, but tiny, copepods and amphipods. In total, New Zealand has about 1,500 known species of marine crustaceans, of which 93 are crabs. Half of our crabs are endemic, including 10 spider crabs and 12 pill-box crabs. Most species are widespread around our coastline and many are found elsewhere in the Pacific. Only two endemic species are considered rare *(Elamena momona* and *Halimena aotearoa*) and one subspecies (*Leptomithrax tuberculatus mortenseni*), which is confined to the Hauraki Gulf, is considered rare and potentially threatened by intensive fishing. Three other non-endemic natives have restricted distributions, as do two introduced species, but none are threatened (McLay, 1994).

New Zealand's only freshwater crab, *Amarinus lacustrus*, did not evolve here, but seems to have been introduced from Australia by migratory waterfowl. It is confined to the upper North Island and is listed by the Department of Conservation (1994b) as threatened in New Zealand but secure overseas. The main causes of its restricted distribution appear to be predation by trout and habitat destruction (McLay, 1994).

### *Sponges*

The sponges belong to the most primitive animal phylum of all, the Porifera. The cells which make up their bodies are almost identical to those of the single-celled choanoflagellates from which the animal kingdom seems to have sprung. Sponges vary in shape and size, but all have a simple body plan. They have no nervous system, no organs of any kind, and no limbs. What they do have is a body that is hollow on the inside and full of thousands of small holes everywhere else. Tiny food particles are caught in these pores as water continually filters through them into the central cavity.

Dead sponges were once standard bathroom items. Today they are of interest to drug companies prospecting for potentially useful biochemical compounds. Scientists from several institutions (e.g. NIWA and Canterbury University) have investigated the compounds that may be obtained from sponges found on the Chatham Rise and off Kaikoura. One species belonging to the genus *Lissodendoryx* holds the promise of a new anti-cancer drug (see Box 9.7).

At least 350 sponges have been identified in New Zealand, and several additional species are probably lurking among the 120 unnamed specimens which lie on museum shelves waiting for a taxonomist to describe and name them (Dawson, 1993). Being sessile (attached to the sea bottom), sponges are vulnerable to disturbances of the sea floor. Sediment and detritus can clog their pores. Dredging and trawling can uproot and kill them. At present, the status of New Zealand's sponges is unknown.

### *Cnidarians (corals, anemones, jellyfish, hydroids)*

About 600 cnidarian species are known in New Zealand waters, about half of them 'corals' of one sort or another. Although they look very different, jellyfish, anemones and corals all spring from a common ancestor and share a similar body design—basically, a bag whose open end forms the mouth. In some species these 'bags' take on an upright tube-like shape with one end stuck to the sea bottom (a polyp). In others, they assume a free-swimming bell-like shape (a medusa). In either case, all cnidarians are hunters. Their mouths are fringed with tentacles armed with tiny stinging cells called cnidae. The phylum Cnidaria gets its name from these stinging cells which immobilise small animals, allowing the tentacles to draw them into the mouth.

Cnidarians are divided into three broad classes: the Scyphozoans (jellyfish); the Hydrozoans (hydroids, hydrocorals); and the Anthozoans (anemones, corals). They all start life as polyps. The jellyfish eventually grow into medusae, spending their adult lives roaming the oceans. The Hydrozoans contain some species that remain as polyps and some that develop into medusae. All Anthozoans remain as polyps, staying more or less permanently in one place all their lives. The colourful anemones prefer shallow water, and some can be found within the tidal zone, while most of the corals inhabit deeper water.

New Zealand's corals and other polyps are vulnerable to harvesting by divers for jewellery-making and curio-collecting. They are also at risk from disturbances of the sea floor by sedimentation, dredging and trawling (Saxton, 1980; Jones, 1992). Recent research into trawler bycatch on the Chatham Rise suggests that some of our deep water corals may be seriously affected (Probert, 1996; Probert *et al.*, in press). Similar concerns have been raised in Australia over the damage inflicted on Tasmania's deep-water corals by orange roughy trawlers (Fisher, 1995).

'Corals' are not a united group. Almost any cnidarian that has hard body parts can be called a coral, though the term is usually restricted to Anthozoans. Hydrozoans with hard body parts are often called corals but, technically, they are referred to as hydrocorals. Most corals wear their hard parts on the outside, as a protective tube or exoskeleton, but many prefer to carry them on the inside, either as internal skeletons (e.g. black corals), quill-like backbones (e.g. sea pens) or small splinter-like spicules (e.g. soft corals).

Some cnidarians live independently as solitary polyps on the sea floor, but many others live in colonies where their tissues, nerves and skeletons become fused together. These colonies often look like trees or bushes whose branches are decorated by the colourful mouths and tentacles of many polyps living side by side. The individual polyps are generally small (i.e. no wider than 1–2 cm and no longer than 2–5 cm) but the colonies can be very large, forming underwater 'trees' which sometimes stretch to 5 m. In the tropics these colonies can become truly vast, grow into huge coral reefs. The corals which build these reefs have symbiotic algae living in their polyps. Because the algae need sunlight to survive, the corals tend to live in shallow waters where they spread out over wide areas. Hundreds of species compete in the same limited zone, building colonies on top of each other and on the skeletal remains of previous generations. Over thousands of years these colonies have grown into enormous reefs which are home not only to the corals and algae, but also to many fish and other organisms.

New Zealand has no coral reefs because our water temperatures are too cool for the algae-dependent corals to thrive here. Some 15–20 reef-building species have straggled into our waters, forming clumps on the sea floor around the northern Kermadec Islands, but they are very atypical of the 320 or so coral species found around New Zealand. Although they are not thriving, these stragglers are fortunate to have settled in a marine reserve.

They probably face a more secure future than many of their tropical relatives which are threatened by growing pressures from human development, particularly in the Pacific and Oceania. The pressures include: sediment washing down from deforested river catchments; nutrient pollution; fishing activities; blasting reefs for building materials; collecting of aquarium specimens; climate change; and disease. Already, in the past two decades, an estimated 10 percent of the world's coral reefs have been damaged, and a recent study predicts that about 60 percent will disappear within the next 2 to 4 decades (Pain, 1996a; Stone, 1995b).

New Zealand's 200 or so colonial corals do not form reefs but can form underwater 'gardens' and 'thickets' of red, white, pink, brown and black. The 100 or so solitary species scattered around the sea floor are less conspicuous but, in some cases, the individuals can reach lengths of nearly 20 cm (Cairns, 1995). New Zealand's corals belong to three major groups:

- the Hydrocorals (Hydrozoan corals) which are mostly colonial and have 62 known species (Cairns, 1991);
- the Hexacorals (Anthozoans whose tentacles are in multiples of 6) which include about 130 known coral species (mostly stony corals and a small number of black corals) as well as about 70 non-corals (various anemones); and
- the Octocorals (Anthozoans with eight tentacles) which consist of about 60 horny corals (or gorgonians) and about 60 other coral species (soft corals, sea pens, and related groups).

#### The Hydrocorals (or Stylasterids)

New Zealand's 62 known hydrocorals are mostly colonial and tend to live at depths of 100 m or more (Cairns, 1991). They are sometimes referred to as 'red corals' because they look like the gorgonian 'red corals' which are harvested overseas and sold as jewellery. Despite their common name, they are not all red. Some are pink and white. Apart from several populations inhabiting shallow waters in Fiordland, little is known of their ecology and lifestyle. The Fiordland populations appear to be fragile and slow-growing and some colonies may occasionally be damaged by divers and boat anchors. The Department of Conservation has contracted NIWA scientists to study the damage caused by divers. Hydrocorals in deeper water may be vulnerable to trawl nets, but no research has been published on this. All species are legally protected, but their status is unknown.

#### The Stony Corals (or Scleractinians)

The stony corals are our most diverse coral group. They are found throughout New Zealand's fishing zone, but most species can only tolerate the warmer northern waters. More than 100 species are found north of Cook Strait compared to only 20 or so south of there. Approximately 30 species are endemic (25 percent) while the remaining 90-odd are also found in other seas (Cairns, 1995). The stony corals' exoskeletons are usually white, sometimes mottled or streaked with black, brown or pink pigment, while their waving tentacles are often red.

About 80 species are solitary and 40–50 are colonial, including the 15–20 reef corals around the Kermadec Islands. Most stony corals live at depths of 200 m–1,000 m and some, particularly on seamounts, are vulnerable to deep-sea trawling along the seafloor. About 40 species are found in shallower waters and may be vulnerable to sedimentation and other forms of pollution. Some of the colourful, larger, branched species (such as *Oculina* spp.) may be threatened by scuba collectors in northern New Zealand. Little is known about most stony corals and they are not legally protected, except those lucky enough to live in marine reserves.

#### The Black Corals (or Antipatharians)

Black corals form coral 'trees' which range from 1 m–5 m in height. They are found on steep reef edges and rock faces in all oceans, generally in areas with reasonable currents at depths greater than 30 m. They cannot survive in estuarine waters or in areas where sedimentation is high. Growth rates are slow and large colonies are likely to be centuries old (Grange, 1994). Since ancient times, they have been exploited to make jewellery. Black coral amulets were once thought to ward off evil spirits and ill health. Now black corals around the world are regarded as threatened and are listed by the Convention on Trade in Endangered Species (CITES).

Because most of New Zealand's 13 known species have narrow geographic ranges, all have been legally protected since 1981. Four species have been recorded within scuba diving range, all of them endemic and all with restricted distributions. One is considered endangered and the other three are considered rare, though one of these is actually abundant within its limited range (Grange, 1994). The rare and endangered species are:

- *Antipathes fiordensis*, whose 5 m 'tree colonies' are known only from Fiordland and Stewart Island where an estimated 7 million trees are found at depths of 6 m–160 m;
- *Antipathes lillei*, whose 4 m tall trees are known from only a few sites around Northland and the offshore islands along the north-east coast, including the Poor Knights, Hen Island and Great Barrier Island;
- An unidentified species of *Antipathes* whose 1.5 m trees have been found at several sites in the Bay of Plenty; and
- The endangered *Aphanipathes fruticosa* whose only known colony, a 2 m tall tree at Kapiti Island, was damaged several years ago by a boat anchor (Grange, 1994).

#### The Anemones (Actinarians and others)

Although they have no hard parts, anemones are closely related to the stony and black corals and are therefore classed among the Hexacorals. New Zealand has 73 known anemone species, 64 of them sea anemones (Actinarians). They are probably the cnidarians best known to school biology classes as they live close to the shore and are often brightly coloured. Despite this, little is known of their status. Their proximity to the coast is likely to make them vulnerable to sedimentation, pollution and other forms of habitat disturbance.

*The Horny Corals (or Gorgonians)*

New Zealand's 61 known horny corals (sometimes called sea fans) form tree colonies. They are rare in shallow waters and relatively little is known about them. Their scientific name comes from gorgonin, the rubbery protein which makes up their internal skeleton. The 'red coral' gorgonians which are used in jewellery are not New Zealand species, but are harvested overseas. Like other large corals the horny corals are common on unexploited seamounts (underwater plateaus) but disappear where orange roughy trawlers are operating (see Chapter 7, Box 7.4). The main species affected is a large gorgonian called *Paragorgia arborea* which can grow to a height of 4 m. Horny corals are not legally protected.

*The Soft Corals, Sea Pens and other Octocorals*

The 63 known species in this group are related to the horny corals and, like them, have protein-based internal hard parts rather than exoskeletons. They are colonial and some grow very large. Nearly all the soft corals and sea pens are deep water species, though some are found in Fiordland at depths that can be reached by divers. The soft corals grow on hard bottoms, such as seamounts, while the sea pens occur in soft sediments. Both habitats are vulnerable to trawling. None of these corals are protected outside of marine reserves and little is known of their status.

*Bryozoans ('moss animals' and 'lace corals')*

Another phylum of sessile invertebrates which has attracted the attention of biochemists is the Bryozoa. Like the corals, these tiny tubular animals, each only a few millimetres long, encase themselves in exoskeletons. They form small colonies (1 mm–50 cm in size) which are often mistaken for seaweeds or corals. New Zealand has about 900 recognised species of bryozoa with some 200 still to be named and described. Only about 120 species are commonly encountered by divers and only a third of these are conspicuous enough to be noticed. Although none appear to be threatened, some of their habitats are, and one endemic species, the Scarlet Alcyonidium, is considered rare, being known from only one site in the world, the Leigh Marine Reserve (Bradstock and Gordon, 1983; Gordon, 1994).

In December 1980 an area of seabed in Tasman Bay was closed to power-fishing methods, such as trawling, Danish seining and dredging. The reason for the closure was to protect two endemic bryozoan species, *Celleporaria agglutinans* and *Hippomenella vellicata*, whose tall, dense mounds served as important nursery grounds for commercial fish species, such as snapper and tarakihi. According to the Ministry of Agriculture and Fisheries the closure is permanent. Habitat restoration is not being monitored (Gordon, 1994).

*Echinoderms (sea urchins, sea cucumbers, sea stars)*

New Zealand has about 400 known species of echinoderms with about 100 specimens awaiting description. Only one of the known species is listed as threatened by the Department of Conservation—a large starfish, or sea-star, called *Eurygonias hyalcanthus*. Described as one of the most spectacular and conspicuous of all New Zealand sea-stars, it is known from barely 20 specimens and has only been found around the lower North Island, Stewart Island and the Snares Islands, mostly at depths of about 10 m (Clark, 1994). Nothing is known of its biology.

Only one species of echinoderm is commercially harvested. This is the sea urchin or kina (*Evechinus chloroticus*). Kina look like spine-covered balls whose underside has a small mouth with large triangular teeth that munch on kelp and other seaweeds. They inhabit shallow coastal waters (generally less than 10 m deep), often forming dense populations on subtidal reefs. After larval settlement, kina are quite sedentary and rarely move more than 100 m in the rest of their life. Distributions tend to be patchy, and reproduction and growth rates vary markedly between local populations, probably reflecting the quantity and quality of the food in their immediate surroundings.

Kina are prized for their gonads, or roe, a traditional Maori food which is also sold on the domestic market. They are caught by diving, shorepicking, bottom trawling or dredging. At present they are managed as if they form a single stock with a quota set at 200 tonnes (Annala, 1995a). The fishery is small and does not seem to have affected local populations. An attempt to develop a large-scale kina industry in Fiordland has apparently been discontinued for commercial reasons.

*Brachiopods (lamp shells)*
Only about 300 lamp shell species are known worldwide and 30 of them are in New Zealand. Nine of these species occur at depths of less than 30 m, giving New Zealand a greater diversity and abundance of shallow-water brachiopods than any other comparable region in the world. Eight of the shallow-water species are endemic and one of these, *Pumilus antiquatus*, is considered rare. Most of the other species have extremely patchy distributions and some populations could be described as 'vulnerable'. Sedimentation, pollution and human interference, such as the removal of boulders, have been identified as risk factors for some populations. One population in Whangarei Harbour may have vanished between 1968 and 1990 and another, at Ripa Island in Lyttelton Harbour, appears to have been reduced (Lee, 1994).

**The State of Our Fish**
Fish are the most ancient of the five vertebrate classes. Their (and our) ancestors, the earliest vertebrates, were tiny eel-like animals called conodonts which first introduced teeth and backbones to the world during the Cambrian Explosion 520 million years ago (Janvier, 1995; New Scientist, 1995; Palmer, 1995c). Conodonts gave rise to the first true fish about 485 million years ago and these subsequently diversified into so many species that the Devonian period, from 355 to 410 million years ago, is referred to as 'the age of fishes' (Dayton, 1993).

Today, fish are by far the most diverse vertebrates on Earth with at least 20,000 species worldwide. They are also the most heavily harvested wild animals on Earth. According to the UN Food and Agriculture Organisation, 70 percent of the world's fish stocks are now 'either fully-exploited, over-fished, depleted, or are rebuilding from previous over-fishing' (FAO, 1995; Hagler, 1995; Pearce, 1995a).

Global fish and shellfish catches peaked six years ago, averaging 98 million tonnes per year through 1989–91 (plus about 27 million tonnes of discarded bycatch and about 13 million tonnes of farmed fish and shellfish). By 1993, the global catch had declined to just under 86 million tonnes, with marine yields falling by 6 percent to 78.8 million tonnes and freshwater yields falling by 52 percent to 6.9 million tonnes (Alverson *et al.*, 1994; FAO, 1995; Welcomme, 1995). Most of the decline in marine catches occurred in northern oceans.

New Zealand's annual marine catch peaked in 1992 at more than 650,000 tonnes, made up of more than 530,000 tonnes of fish and nearly 120,000 tonnes of invertebrates, principally squid. This excludes discards, illegal catches, recreational catches and catches for customary Maori food-gathering. The year before, the total marine catch had been 608,000 tonnes and, the year after, it fell to 590,000 tonnes. Marine fish make up 99.8 percent of the total catch because we have only a small number of freshwater fish species. Apart from freshwater eels and farmed salmon, oysters and mussels, New Zealand's fisheries are almost totally based on wild populations of marine species.

Besides the commercial fish catch, a large number of inshore fish and shellfish are taken by non-commercial fishers and gatherers. About 390,000 people (16 percent of the population) engage in recreational sea fishing (Teirney and Kilner, 1995). An unknown number catch freshwater fish, both native fish fry (whitebait) and introduced trout and salmon. A smaller but unknown number of Maori engage in customary or cultural harvesting of fish, crustaceans and shellfish for household consumption and social gatherings.

***Freshwater fish***
New Zealand has 29 identified species of native freshwater fish. One of these, the grayling, became extinct earlier this century, and 10 of the remaining species are considered threatened. However, new species are still being identified (e.g. Mitchell, 1995). The number of identified species is expected to rise in the near future as a result of recent genetic research. Geneticists have found that some fish currently classified as sub-populations

of a single species are really genetically distinct species that happen to look alike. As more 'new' species are discovered, or uncovered, the final species count could reach 35 or 36, and the threatened species count may, accordingly, rise to 15 or 16.

Although the total number of native fish is low compared to other countries, nearly 90 percent are endemic. Their Gondwana origins are obvious from the fact that most have close relatives at the genus or family level in other Gondwana countries, notably south-eastern Australia (McDowall, 1990). This is best reflected in the distribution of our most diverse genus, the galaxiids (*Galaxias* spp.) which are found not only in New South Wales, Victoria and Tasmania, but also throughout southern South America and even the southern tip of South Africa.

**Table 9.15**
**New Zealand's native freshwater fish**

| Fish | Description | Indigenous Species | Endemic Species | Threatened Species |
|---|---|---|---|---|
| *Grayling* | *A trout or salmon-like fish up to 450 mm long. Colour variable, ranging from completely silvery or golden to red-brown with grey or yellow speckles on the back, and a yellow or golden belly.* | *1* | *1* | *Almost certainly extinct.* |
| *Galaxiids* | *Mostly small with varied shapes, and leathery skin without scales. Nine threatened species include the giant kokopu, the short-jawed kokopu, the koaro, three mudfish, several Otago non-migratory galaxiids, and one inanga.* | *14* | *12* | *9* |
| *Torrentfish* | *The only freshwater species of a family of marine fish (Mugiloididae). One of the few native species apparently unaffected by the clearance of riverbank forest cover.* | *1* | *1* | |
| *Bullies* | *Mostly small, stocky fish with blunt round heads, noted for their rapid stop-start darting movements in the water. One freshwater species, the Tarndale bully (Gobiomorphus alpinus) is threatened.* | *7* | *7* | *1* |
| *Southern smelts* | *Small, long, silvery fish. Some lake populations spend their entire life in freshwater, others spend much of their lives at sea.* | *2* | *2* | |
| *Black flounder* | *A broad fish of typical even oval flounder shape, black to deep olive-green in colour with brick-red spots on the upper surface.* | *1* | *1* | |
| *Freshwater eels* | *Two long-lived 'snake-like' species which return to the ocean to breed (probably north west of Samoa for the shortfinned Anguilla australis, and possibly east of Tonga for the longfinned Anguilla dieffenbachii).* | *2* | *1* | |
| *Lamprey* | *Very primitive jawless 'sucker' fish, without scales or paired fins.* | *1* | | |
| ***Total*** | | ***29*** | ***25*** | ***10*** |

About 20 alien species of freshwater fish have been introduced since European settlement. They include trout, salmon, koi carp, catfish, tench, rudd and perch. Another six marine species often stray into New Zealand rivers from the sea (McDowall, 1990). In all, this brings the number of fish species that either inhabit or visit New Zealand's rivers and streams to between 55 and 60.

Generally, New Zealand's indigenous fish are small, well-camouflaged, bottom-dwellers (Richardson and Jowett, 1994). Only 4 species (the 2 eels, the giant kokopu, and the extinct grayling) exceed 2 kg in body weight (McDowall, 1980). Although they are freshwater dwellers most of the time, many species have a marine stage in their life-cycles. This peculiarity may be related to New Zealand's long period of inundation during the Oligocene drowning.

One of the most distinctive of the sea-going freshwater fish is the torrentfish (*Cheimarrichthys fosteri*)—the 'black sheep' of a sea-dwelling family called the Mugiloididae. Other species in this family are exclusively marine dwelling, living in the oceans around Africa, Asia and various parts of the Pacific (McDowall, 1990). The wayward torrentfish, however, evolved into a freshwater species whose only acknowledgment of its oceanic heritage is a brief sea visit soon after hatching. Details are still sketchy, but it is believed that the torrentfish larvae are swept downstream to the sea where they develop into fry before returning to fresh water. On their way home, the maturing fry undergo an important rite of passage when they enter the river estuary. Vital developmental changes take place to equip them for freshwater life, including alterations to their body shape, colour, eating and escape behaviour and internal fluid regulating mechanisms (Glova *et al.*, 1995).

Though closely related to blue cod, torrentfish are much smaller, growing to about 10–12 cm. They live in open-bedded rivers and streams, using their large ventral fins, like hands and feet, to anchor themselves to the river or stream bed. Their pointed, flattened heads cut easily through fast-flowing water. Though rarely seen, the torrentfish is one of our more common species. Others have fared less well.

Today, a third of our native fish are threatened and several others are rare. A recent survey of the larger rivers found 16 native species and 3 introduced species (Richardson and Jowett, 1994). Only 8 native species were described as common. They included eels, torrentfish, various bully species and the common river galaxiids. Eels alone accounted for two-thirds of the biomass. The most abundant introduced species was the brown trout.

The National Institute of Water and Atmospheric Research (NIWA) maintains a freshwater fish database which now has about 13,000 records of fish sightings from all over the country (Richardson, 1993). The database gives some idea of the relative abundance of fish species. Whereas longfinned eels have been found at 48 percent of sites, the five migratory galaxiids are far less abundant. Inanga have been found at only 15 percent of sites, koaro at 10 percent, the banded kokopu at 8 percent, the giant kokopu at 4 percent and the short-jawed kokopu at a mere 2 percent of sites. All but the inanga were limited to heavily forested catchments.

The threats to our native fish come from introduced species and from human activities that have removed or altered their habitats. These activities include: forest clearance, pastoral farming, effluent discharge, nutrient pollution, water abstraction, barriers to migration, channels and drains and changes to river courses and banks, and possibly even whitebaiting.

No fish are known to have become extinct in the five or six centuries of Maori exploitation that preceded European settlement. For inland tribes in particular, freshwater fish were very important. Efforts were made to conserve and sometimes enhance fish stocks (McDowall, 1990). Eels, smelt, koaro and possibly bullies and banded kokopu were actively transferred to land-locked lakes to boost fish stocks (Strickland, 1993). One chief even tried to introduce 70 snapper to Lake Rotorua. A team of slaves carried the fish in a huge patua (a watertight vessel made of totara bark). A hundred more slaves were stationed along the way to replenish the saltwater from calabashes. Only one snapper survived the journey but died as soon as it was put in the lake (Mair, 1923).

Today, exotic species have displaced or become important predators of some of our native fish. The most widespread exotic intruders

**Table 9.16**

**Distribution of native fish in New Zealand lakes**

| Species | Common Name | Distribution |
|---|---|---|
| *Geotria australis* | *Lamprey* | *Little known but probably widespread in tributaries of coastal lakes.* |
| *Anguilla australis* | *Short-finned eel* | *Widespread in coastal lakes and lagoons.* |
| *Anguilla dieffenbachii* | *Long-finned eel* | *Occasionally present in both coastal and inland lakes.* |
| *Retropinna retropinna* | *Common smelt* | *Common and widespread in coastal and tidal lakes, as well as in lakes of the North Island's Volcanic Plateau; populations in some coastal lakes of Northland and Wellington and some upland/alpine lakes of the eastern Southern Alps.* |
| *Galaxias maculatus* | *Inanga* | *Diadromous stocks in some coastal and most tidal lakes and lagoons; land-locked populations in Northland dune lakes.* |
| *Galaxias gracilis* | *Dwarf inanga* | *Coastal dune lakes of North Kaipara Harbour, and Kai Iwi Lakes near Dargaville.* |
| *Galaxias brevipinnis* | *Koaro* | *Diadromous populations in a few West Coast lakes; land-locked populations throughout New Zealand in cool upland/alpine lakes.* |
| *Galaxias argenteus* | *Giant kokopu* | *Often found in lowland lakes; widespread.* |
| *Galaxias fasciatus* | *Banded kokopu* | *Diadromous or landlocked populations in a few West Coast lakes; land-locked populations in Lake Okataina and Kaihoka Lakes, northwest Nelson.* |
| *Rhombosolea retiaria* | *Black flounder* | *Common and widespread in tidal lakes and lagoons.* |
| *Gobiomorphus cotidianus*<br>*Gobiomorphus alpinus* | *Common bully*<br>*Tarndale bully* | *Widespread and abundant in tidal, coastal, upland and alpine lakes throughout New Zealand.*<br>*Tarns of inland Marlborough.* |
| *Gobiomorphus beviceps* | *Upland bully* | *Upland and alpine lakes of the eastern Southern Alps.* |
| *Gobiomorphus huttoni*<br>*Gobiomorphus hubbsi*<br>*Cheimarrichthys fosteri* | *Red-finned bully*<br>*Blue-gilled bully*<br>*Torrentfish* | *Tributaries of a few tidal and lowland lakes, e.g. Lake Wairarapa.* |

*Source: McDowall et al. (1975) updated by McDowall*

are brown and rainbow trout (*Salmo trutta* and *Oncorhynchus mykiss*) which were introduced, along with the closely related salmon (*Salmo* and *Oncorhynchus* spp.), as sports fish and are still protected as such. Their introduction had a serious impact (see Box 9.9). As an example of the pre-trout abundance of native fish, Buck/Hiroa (1921) described a feast at Lake Ohinemutu in 1873 where the guests dined on 4,000 baskets of dried koura (freshwater crayfish) and inanga (a name then applied to several different galaxiid species). Such abundance apparently declined after trout entered the lake.

Maori tribes petitioned government on several occasions to stop further introductions of exotic fish, but without success (Strickland, 1993). However, not all fish introductions were unwelcome. Goldfish (*Carassius auratus*), which multiplied rapidly in some parts of the central North Island lakes, became a popular food fish with local Maori who protested when the Government temporarily prohibited the taking of goldfish in the early 1900s (McDowall, 1990).

A significant conservation problem continues to be the unauthorised liberation of fish. Current law requires, among other things, an environmental impact assessment before fish can be released or transferred. The requirement applies to both native and introduced species. Furthermore, some introduced species are designated as noxious and must be killed if caught. The noxious fish regulations were introduced in the 1970s after the deliberate release of exotic fish by irresponsible anglers (or 'biological hooligans' according to one commentator) who were trying to re-create an English-style 'coarse' fishery here (McDowall, 1990). Coarse fish are those with large scales compared to trout and salmon. Their release began in the upper North Island in the late 1960s with rudd. Then came tench and perch and, most recently, European carp and orfe. In the early 1970s, there were also misguided moves to introduce several smaller exotic species, such as European dace, minnow, roach and gudgeon as forage fish for trout.

The distribution of noxious coarse fish has gradually became more widespread. All are threats, not only to native fish and stream ecology, but also, in some cases, the waterways themselves. None is a greater problem in this regard than the European carp (*Cyprinus carpio*) which is now well-established in the upper half of the North Island, particularly the Waikato catchment, despite firm Government policy to contain its spread. This fish is a native of Europe, the Mediterranean and western Asia but has become widespread throughout Asia where it is a popular aquaculture species bred for food and ornamental purposes. The brightly coloured variety living in New Zealand was developed by Japanese fish-breeders who refer to it as koi. European carp are closely related to goldfish and can hybridise with them. They are mud-feeders, which can undermine stream banks, turn clear waters muddy brown and cause significant damage to aquatic ecosystems. Controlling them is a priority for the Department of Conservation.

Other designated noxious fish which could cause damage if released here include three species of the ferocious and much feared South American piranha (*Serrasalmus* spp.), and the predatory walking catfish (*Clarias batrachus*), an African species which has been troublesome in Florida and is popular with anglers and fish fanciers. At present, the only known piranha in New Zealand are in captivity at the Napier Aquarium and Kelly Tarlton's Underwater World in Auckland. The only catfish species to have become established in the wild here is the North American brown bullhead (*Ictalurus nebulosus*). It is becoming more abundant in the lower Waikato and Lake Mahinapua, where it is accused by fishers of competing with the eel population (McDowall, 1990). Though not designated as noxious, it is considered to be a nuisance species. Another nuisance species is the mosquitofish (*Gambusia affinus*), which preys on insect larvae.

Introduced plants have also had an impact on our native fish, altering their habitat and food distribution. At least 200 introduced wetland plants have been identified. In addition, nutrient pollution from run-off and waste discharges have caused algae and

**Table 9.17**

**Alien fish which have been introduced to New Zealand**

| Species | Introduced | Present Status |
|---|---|---|
| *Atlantic salmon* | *1868–1911* | *Rare. Waiau River system (Southland).* |
| *Brook char* | *1877–1887* | *Very local: mostly South Island.* |
| *Brown trout* | *1867–1960* | *Abundant. Widespread except in far north.* |
| *Catfish* | *1876–1877* | *Local: Northern and central North Island, especially Waikato; Lake Mahinapua.* |
| *Crucian carp* | *1864–1868* | *Unknown. May never have been introduced.* |
| *European (koi) carp* | *1960s* | *North Island, mainly Waikato River and its lakes.* |
| *Golden orfe* | *1980s* | *Very local: Broadmore's Pond, near Auckland, and probably Waikato.* |
| *Goldfish* | *1867–1868* | *Common and widespread.* |
| *Guppy* | *1920s* | *Local: Reporoa, north of Lake Taupo.* |
| *Mackinaw* | *1906* | *Uncommon. Lake Pearson (Canterbury).* |
| *Mosquitofish* | *1930* | *Local northern half of North Island.* |
| *Perch* | *1868–1877* | *Widespread. Local in both North and South Island.* |
| *Quinnat salmon* | *1875–1907* | *Common in parts of South Island, mainly east coast.* |
| *Rainbow trout* | *1883–1930* | *Widespread; North and South Islands. Abundant in some areas.* |
| *Rudd* | *late 1960s* | *Local but widespread (e.g populations around Christchurch).* |
| *Sailfin molly* | *unknown* | *Swamps around southern end of Lake Taupo.* |
| *Sockeye salmon* | *1902* | *Rare: Lakes Ohau and Waitaki.* |
| *Swordtail* | *unknown* | *Local: Waipahihi Stream, NE corner of Lake Taupo.* |
| *Tench* | *1867–1868* | *Local in North and South Island.* |

*Source: McDowall et al. (1975); McDowall (1990)* cyanobacteria to proliferate on stony river bottoms changing the invertebrate communities on which fish feed. Pressures on native fish have probably been mildest in north-west Nelson, Westland, Fiordland, and Stewart Island, where large river systems are still surrounded by unmodified catchments. Even there, however, most riverine plant and animal communities contain introduced species.

So far, only one native fish, the grayling (*Prototroctes oxyrhynchus*) has been exterminated by these pressures. It was abundant when Europeans first arrived, and died out in the 1930s. Forest clearance and pasture development probably contributed to its sudden decline, with trout giving it the final nudge (McDowall, 1990). Of the remaining 28 species, 10 (36 percent) are listed as threatened (see Table 9.18). Top of the list is the short-jawed kokopu (*Galaxias postvectis*), the only Category A fish on the Department of Conservation's threatened species list. Not much is known about this fish. It has been found at a small number of locations from Northland to Fiordland, suggesting a wide distribution in earlier times. Sightings have usually been made in smallish streams surrounded by unmodified broadleaf/podocarp forest, and in pools with very thick vegetation cover.

The brown mudfish (*Neochanna apoda)* and the Canterbury mudfish (*Neochanna burrowsius*) are also high on the threatened species list, but, fortunately, not as high as they were just a few years ago. Listed in 1992 as Category A species, the mudfish have now been downlisted to Category B, thanks largely to progress with habitat protection (Department of Conservation, 1994b). The mudfish are 10–15 cm in length and appear to be relic populations from former swampy wetlands and wet riverbanks. As the wetlands disappeared and the riparian tree cover was removed, the mudfish were relegated to weedy drains, irrigation ditches and shallow muddy creeks. They spawn in mud and, if this dries, the newly hatched mudfish wriggle down into the soil in search of moisture. They have sometimes been found more than a metre underground, to the amazement of early settlers.

Most of the other threatened fish are, like the short-jawed kokopu, galaxiids. Adult galaxiids are rarely seen, but the juveniles are familiar to most New Zealanders as whitebait—once readily available in fish shops, but these days an increasingly rare and expensive treat. Whitebait are caught in river mouths each Spring, as the teeming shoals of fry enter freshwater from the sea. Inanga (*Galaxias maculatus*) juveniles make up most of the highly prized catch, but on the West Coast of the South Island, up to 5 species are involved, including the koaro, the short-jawed kokopu and the giant kokopu. In the whitebait stage, koaro and short-jawed kokopu are difficult to distinguish from the other species, but the giant kokopu is more recognisable. Smelt fry may also occur in the whitebait catch.

As its name suggests, the giant kokopu (*Galaxias argenteus*) is larger than other galaxiids, with adults growing to half a metre in length. Loss of preferred habitat, nutrient pollution and competition with trout are some of the factors believed to have contributed to the decline in giant kokopu numbers. In 1994, the Government considered introducing regulations to reduce the whitebaiting pressure on the giant kokopu. Because the juveniles enter West Coast rivers in November, a little later than other whitebait, the regulations would have brought the 6 week season forward so that it ended on 31 October instead of 14 November. However, following submissions from West Coast whitebaiters on the timing of the juvenile giant kokopus' return to the rivers, the regulations were not introduced.

Until recently, the most resilient of the native fish were the eels. New Zealand has two native species. The larger of these, the longfinned eel (*Anguilla dieffenbachii*), is endemic, while the smaller shortfinned eel (*Anguilla australis*) is also found in South Australia, Tasmania and New Caledonia. Although longfin and shortfin habitats overlap, longfins predominate in stony rivers and high country lakes, while shortfins are more abundant closer to the coast in the lowland lakes (e.g. Ellesmere or Waihora) and muddy rivers.

Average eel life-spans are almost the same as the pre-industrial human life-span—in the

**Table 9.18**

**Conservation status of threatened native freshwater fish**

| |
|---|
| ***Category A: Native fish facing extinction and with the highest conservation priority*** |
| *Short-jawed kokopu (Galaxias postvectis)* |
| ***Category B: Seriously threatened native fish with the second highest conservation priority*** |
| *Giant kokopu (Galaxias argenteus)* |
| *Dwarf inanga (Galaxias gracilis)* |
| *Brown mudfish (Neochanna apoda)* |
| *Canterbury mudfish (Neochanna burrowsius)* |
| ***Category C: Threatened native fish with the third highest conservation priority*** |
| *Koaro (Galaxias brevipinnis)* |
| *Banded kokopu (Galaxias fasciatus)* |
| *Long-jawed kokopu (Galaxias prognathus)* |
| *Tarndale bully (Gobiomorphus alpinus)* |
| *Black mudfish (Neochanna diversus)* |

*Source: Department of Conservation (1994b)*

20–40 year range—and, as with humans, very old individuals have been recorded. Female eels are longer-lived and bigger than the males, with the oldest on record being a 60-year-old shortfin and a 106-year-old longfin. They breed only once and leave New Zealand to do it. Their spawning grounds appear to be several thousand miles away, in the tropical waters to the north of Fiji and Western Samoa (Castle, 1995).

After spawning, the parent eels never return, but their tiny young elvers drift back on the ocean currents that sweep in an arc through the western Pacific, past New Caledonia and Australia and on to New Zealand. Once in our waters, the elvers randomly enter rivers as they encounter them. Recently the Australian longfinned eel (*Anguilla reinhardtii*) has been discovered here, presumably because its elvers were swept down on the same currents and missed their usual stop. Our native shortfin probably arrived here in a similar way thousands of years ago.

Though still abundant, eel biomass has fallen in some areas, particularly Lake Ellesmere and the lower Waikato River, as a result of habitat decline (i.e. pollution, wetland drainage) and human predation (i.e. commercial fishing). Eels are the only commercially significant native freshwater fish. Although they have always been harvested for food by Maori communities, commercial harvesting for export markets by Europeans only began in the late 1960s.

**Figure 9.4**

**Estimated eel catch, 1965 - 96[1]**


*Source: Ministry of Fisheries*

[1]Data are for December years 1965 - 1990, and for June years 1991 - 1996

The estimated annual catch peaked in the 1970s, exceeding 2,000 tonnes several times. Since the early 1980s, the catch has settled to an average of just under 1,400 tonnes (see Figure 9.4). Concerns about declining biomass in Lake Ellesmere (Waihora) led to it being declared a controlled fishery in 1978. The number of eel fishers was cut from 30 to 17, and the total allowable catch (TAC) quota was set at 256 tonnes. In following years, both the fishers and TAC quota were progressively reduced to the current 136.5 tonnes distributed among 11 fishers.

Consideration is being given to bringing all eel fishing under the Quota Management System. Regulation at present is through restrictions on entry, gear limitations and a minimum size limit on eels caught. Amateur fishers are restricted to six eels a day, regardless of size. For commercial fishers, a new national minimum size of 220 g took effect in April 1993, replacing the previous 150 g size limit. However, the minimum size for eels in Lake Ellesmere was set at 140 g, reflecting the extent to which the lake's large old eels have been reduced. The Lake Ellesmere limit will be incrementally raised each year to bring it into line with the national size limit.

Ironically, the minimum legal size limit is probably threatening the sustainability of the eel stocks rather than helping them. It offers total protection to shortfinned males, which normally migrate when they weigh between 140 and 160 g, and has redirected the fishing effort onto the rarer longfins and the female shortfins. To counter this, a maximum legal size of 4 kg now covers the whole of the South Island. This was introduced to offer some protection for the larger longfin females, which are at the greatest risk because they remain in the river systems the longest.

One obstacle to successful eel quota management is the lack of good data. Eel stock size and levels of exploitation cannot be assessed accurately for several reasons: stocks are replenished from the ocean rather than from resident populations; commercial catch data are of poor quality; and non-commercial catch data are nonexistent.

Besides fishing, eels, like other native fish, are affected by environmental pressures, such as pollution, loss of overhanging vegetation, river straightening, lake lowering and wetland drainage. Another source of pressure is the increasing number of river obstructions impeding their migrations. With more than 400 dams of 1.8 m or more in height and thousands of smaller dams and weirs, returning elvers now run a formidable obstacle course. The Electricity Corporation (ECNZ) has assisted with feasibility studies on installing passes for incoming elvers in the Waikato, Waitaki, Clutha, and Waiau rivers.

Sometimes, Government, industry and iwi have cooperated to physically transfer elvers to headwaters, lakes or farm dams. This can involve up to a dozen people working over several consecutive nights with boats, buses, tankers and collectors. When eels are transferred to landlocked waterways they are effectively taken from the ocean-going breeding population so a special permit from the Ministry of Fisheries is needed for transfers, even small ones. Freshwater fishing regulations now prohibit the taking of more than six eels (of any size) per person per day. Technically this applies to elvers, 1,000 of which weigh less than a kilogram.

**Box 9.16**

### *Eel fishing, past and present*

Freshwater eels (called tuna in Maori) are prized as taonga (treasures) in Maori culture (Taylor, 1992). Eels are important for hui (gatherings), tangi (funerals) and other social activities, including gift exchanges. They also feature in tribal traditions and mythology. More than 160 names for eels have been recorded, reflecting the diversity of local traditions and the significance attached to variations in size, shape, colour, taste, behaviour and habitat (Best, 1929). Eel fishing took many forms, varying according to tribal tradition, location, season and habitat. The main fishing methods included hinaki (eel pots), pa-tuna (eel weirs), toi (eel bobbing without hooks), korapa (hand netting), rapu tuna (feeling with hands and feet then catching with hands), rama tuna (by torch light) patu tuna (eel striking), mata rau (spearing) and koumu (eel trenches). During the annual tunaheke (eel migration) channels were dug into stream banks and lake shores, trapping vast numbers of eels on their way to the oceanic breeding grounds. The returning elvers (baby eels) were taken by placing bundles of bracken fern at the top of falls or at known congregation points during their upstream movement.

Maori communities regulated eel harvests and controlled access to fishing areas through a system of tapu (sacred) rules, usages, beliefs and ceremonies whose violation could bring retribution from both supernatural and human agents (Habib, 1989). Individual iwi (clans or tribes), hapu (septs or sub-tribes) and whanau (extended families) were restricted to fishing specific waters. Examples of traditional practices include: transferring juvenile eels to land-locked waters with no eels; refraining from fishing during the first three days of the migration (which, it is now known, protected mostly the male eels which migrate first); releasing the largest of the migrating eels (which are now known to be older females); imposing rahui (temporary bans) on fishing in particular areas; and minimising wastage of eel carcasses (Butler, 1993; Carkeek, 1989).

Although eel use has declined, it is still important to Maori as shown in various protests, petitions and court cases, including submissions to the Planning Tribunal and the Waitangi Tribunal. Eel fishing is still seen as a part of the traditional dimension of people's lives (Todd, 1978). Although modern technology is now used, the aim is not to increase catches but to reduce catch effort and time spent on equipment maintenance. In adapting new technology, key elements of traditional design and ritual have often been retained. Despite the social changes of the past 150 years, and the movement of people away from their family lands, many customary practices continue. Traditional 'gathered' foods are preferred to 'bought' foods on ceremonial and festive occasions, such as hui and tangi where the serving of traditional food upholds the mana (prestige) of the marae (tribal gathering place) (Butler, 1993; Marshall, 1987).

Eels were particularly important in the South Island where climate prevented kumara from being a staple food. The two most favoured eel fishing lakes were on the southern side of Banks Peninsula—Waihora (Lake Ellesmere) and Wairewa (Lake Forsyth). Waihora had a reputation as a food basket throughout the country. The Ngai Tahu people at Taumutu on the southern end of Waihora were renowned for taking large quantities of eels to hui throughout New Zealand. Today tribal members believe the polluted and overfished lake can no longer sustain this practice, causing them to suffer a loss of mana (Jull, 1989). According to Don Brown:

> *The eel fishery right up to 1960 would have been considered a Maori fishery in Waihora because only the Maori used the reserve... Generally speaking it was no trouble to catch a good feed of eels within a short time. I mean a sugar bag of eels in about half an hour would have been normal. That would have been around Spring or Christmas time, not at the migration time. Today that would be an impossibility... There's a strong possibility in Waihora that things that happened traditionally with catching and processing eels ... and storing them ... are all going to be lost to that hapu. But as long as Wairewa keeps going I guess Ngai Tahu won't lose that great tradition.* (Butler, 1993).

In 1868, the Government established several Maori fishing reserves in Canterbury to honour a promise made in the Kemp Deed when the land was purchased from Ngai Tahu. However, the effectiveness of the reserves was limited by the Government's insistence that eel weirs and fisheries should not interfere with the general settlement of the country (Law Commission, 1989). In 1873 the Timber Floating Act was passed over protests from several Maori Members of Parliament that it would permit damage to Maori eel weirs (Law Commission, 1989). Nationally, 10 eel fishery protests were registered from 1881 to 1895. The main concerns were: reserving eel fishing areas; protecting traditional fishing rights and eel weirs; and wishing the return of various lakes and rivers (Waitangi Tribunal, 1988). Evidence was given that access to eel fisheries had been denied by land settlement, insufficient reserves, drainage of wetlands, river straightening, acclimatisation regulations and diversion of water from rivers for power-supply dams (Waitangi Tribunal, 1991).

Drainage pressures were particularly acute in Waihora and Wairewa. Both lakes are kept at low levels by the periodic opening of cuts to the sea through Kaitorete Spit (Waihora) and Pourinui Spit (Wairewa). As a result, Waihora is only two-thirds its original area and the surrounding wetland has been reduced by 80 percent. Until the late 1960s lake levels were set solely to meet the needs of surrounding farmers. The local iwi, Ngai Tahu, was not consulted about drainage, irrigation or reclamation. This has changed in recent decades, particularly since the passing of the Resource Management Act 1991, which requires local authorities to consult with iwi on issues affecting traditional resources and food gathering areas. In 1993, for example, the Taumutu runanga was able to stop a bid by local farmers to have Waihora opened to flush out decomposing weeds. The runanga argued that lowering the lake further would interfere with the eel migration.

In the 1960s an additional threat to the traditional eel fisheries emerged with the development of export markets for eels. Maori concerns were overlooked in the rush to meet export orders from Europe and Japan. The fishers were mostly pakeha labourers who caught eels for seasonal employment, though some were farmers whose land bordered fishable waters. Initially the industry was centered in the South Island with Waihora providing more than half the national eel catch in the early 1970s (Jellyman, 1992). By 1978, the North Island had become more important and Waihora's share of the national catch had dropped to 12 percent. For most of that first decade the export demand was for short-finned eels rather than the larger longfins. Longfins were often killed as pests when fishers found them crowding and sometimes tearing nets. Meanwhile, the largest shortfins (mostly females) were fished so heavily that, between 1974 and 1977, the average length of Waihora's shortfins declined by 20 percent from 474 to 375mm. Today longfins are almost absent from Waihora and male shortfins vastly outnumber females (Jellyman, 1992).

In some areas traditional eel fisheries have been protected by conservation legislation (which bars commercial fishing in all national parks and reserves but permits customary fishing subject to the Minister's approval) and fishery regulations (which reserve some areas, including an arm of Waihora, exclusively for traditional and recreational fishing). Most of these protected areas are controlled by the Department of Conservation and the Ministry of Fisheries and are accessible to all Maori fishers, but two (Wairewa and Lake Horowhenua near Levin) are directly controlled by the local runanga. Wairewa's eel fishery was reserved exclusively for the Ngai Tahu people in the 1960s. The runanga operates a permit system to preserve its mahinga kai (food source) and to set a general code of conduct for catching eels. The eels are bigger than in Waihora, partly because commercial fishers have been kept from the lake, and partly because big eels were considered kaitiaki (food guardians). When the "big eel broached fishing stopped" (Butler, 1993). However, the runanga had little control over the tributary streams where eels were still exposed to commercial fishing and habitat loss (Tau *et al.*, 1990). In 1993 the annual eel migration failed to occur at Wairewa and the following year regulations were brought in to close commercial fishing in the lake's tributaries. Commercial eel fishing has also been brought to an end in the Chatham Islands where the Ministry of Fisheries has decided not to issue any more permits.

Recent developments in the South Island suggest the tension between commercial and traditional eel fishers may soon become a thing of the past. In 1991 the Waitangi Tribunal recommended that fisheries in Waihora and Wairewa be jointly managed by Ngai Tahu and the Department of Conservation. Ngai Tahu and the commercial fishers were strongly opposed to this and, instead, continued to deal with the Ministry of Fisheries. After much discussion and negotiation all South Island iwi entered a joint accord with the South Island Eel Industry Association. One result of the accord is the formation of a Waihora Eel Management Committee, with equal representation from Ngai Tahu and the Ellesmere eel fishers. Another result is that the Wainono coastal lagoon near Waimate (one of the 1868 eel reserves which has been heavily fished by commercial fishers) is now closed to commercial eel fishing. Many other non-commercial fishing areas are likely to be agreed in the future. It may only be a matter of time before North Island fishers follow the South Island example.

Taken together, the Resource Management Act, the Conservation Act, the fishery regulations and the South Island Eel Accord provide a range of safeguards for traditional eel fisheries which should enable them to withstand the pressures from commericial fishing and surrounding land and water uses. The settlement of Maori land claims also contributes to this process. Landowners can bar anyone from crossing their land, including commercial fishers wishing to access streams and lakes. By regaining control of alienated lands, therefore, iwi can also regain some control over their waterways and traditional fisheries, as well as land uses which may affect them. While most of these measures have been slow in coming, it seems that they have not been too late, and the credit for that must go largely to the resilience of the eels themselves.

### *Marine fish*

More than 1,000 species of fish have been identified within 200 nautical miles (320 km) of our coast—our Exclusive Economic Zone (EEZ) (Paulin *et al.*, 1989). A further 200 or so have yet to be formally identified. Each fortnight another unidentified species is added to the list. About 110 marine fish (11 percent) are endemic to New Zealand waters, but less than half of these live in the open sea. Most of them (61) are confined to coastal rockpools where 62 percent of species are endemic. The most diverse rockpool species are the triplefins (or cockabullies) with their distinctive line of three fins on the back. New Zealand's rockpools have 21 species, accounting for a third of the world's known triplefins and making our region a biodiversity 'hotspot' for cockabullies (Paulin and Roberts, 1993; Roberts, 1994).

Although little is known of the status of most marine fish in the EEZ, an assessment has been made of the rockpool fishes. Eleven are listed as threatened, all of them endemic (Paulin and Roberts, 1994). None are endangered, but they are rare and vulnerable to habitat disturbance (see Table 9.18). The threatened species represent 12 percent of all rockpool fish and 18 percent of the endemic ones. Away from the coastline, only two of the sea-dwelling fish species are known to be threatened and neither is endemic. The great white shark (*Carchardon carcharias*) and the basking shark (*Cetorhinus maximus)* are threatened in all oceans (Department of Conservation, 1994e; IUCN, 1990).

Only 5 percent of the marine fish living beyond the rockpools are endemic (50 out of about 1,100 species). Most, nearly 60 percent, are found throughout the world and a further 30 percent are found elsewhere in the Southern Hemisphere. Many arrived here by a gradual process of migration and expansion over long periods of time, while others are recent or intermittent arrivals. Orange roughy, for example, have probably been here for a long time. They are also found as far away as the North Atlantic, where they were first discovered. Peruvian jack mackerels, however, are recent immigrants. They were first noted in 1987 and now are caught far more frequently than the two endemic jack mackerels. Tuna are migratory visitors which come and go every year, covering vast areas of ocean. In many cases, 'foreign' fish arrive as stragglers which remain rare in our waters but abundant elsewhere.

**Table 9.19**

**Threatened rockpool fish in New Zealand's coastal waters.**

| Taxonomic name | Common name |
|---|---|
| *Parma kermadecensis* | *Kermadec damselfish* |
| *Cologrammus flavescens* | *Clinid* |
| *Blennodon dorsale* | *Giant triplefin or cockabully* |
| *Gilloblennius abditus* | *Obscure triplefin or cockabully* |
| *Ennapterygius new species* | *Kermadec triplefin or cockabully* |
| *Odax cyanoallax* | *Bluefinned butterfish* |
| *Congiopodus leaucopaeilus* | *Southern pigfish* |
| *Gastrocymba quadriradiata* | *Subantarctic clingfish* |
| *Bovichtus psychrolutes* | *Subantarctic thornfish* |
| *Priolepis psygmophilia* | *Kermadec goby* |
| *Forsterygion jenningsi* | *Jenning's triplefin or cockabully* |

*Source: Paulin and Roberts (1994)*

**Box 9.17**

### *Our changing fishing industry*

Before the 1960s, New Zealand's fishing industry was confined to the coast and the 12-mile territorial sea limit, and was restricted to a small number of licensed commercial fishers. In the mid-1960s, the Government removed entry restrictions and began to actively encourage new entrants and investment in the industry through subsidies, grants and incentives. The fleet and the catches grew accordingly, but the fishing effort was still concentrated entirely on the fishery within the territorial zone. The deep water beyond this territorial limit was left to the large Japanese, South Korean and Soviet fleets.

During the 1970s, pressure intensified on the limited inshore species such as snapper, tarakihi, trevally, gurnard, rock lobsters and scallops. The lucrative snapper catch, for example, peaked at 18,000 tonnes in 1978 but had fallen to 9,000 tonnes by 1983 and has remained below this level since (Annala, 1995b). Just as the inshore fisheries were reaching their limit, however, the world's governments agreed to set up Exclusive Economic Zones (EEZ), giving each country exclusive control of the marine resources within 200 nautical miles of their coastline. With the fourth largest EEZ in the world, New Zealand now had the opportunity to reduce pressure on the inshore fishery and begin exploiting deep water species such as hoki, orange roughy and squid.

Realising that the inshore fishery was over-capitalised (i.e. had too many boats, nets and fishers) the Government restricted permits for new entries in 1980 and developed plans to restructure the fishing industry. By 1986, the Quota Management System (QMS) was in place and the coastal fishing fleet was in the process of being reduced by 40 percent. Small and part-time fishers almost disappeared, while the larger companies invested in deep-water vessels and technology. Today, the vast bulk of the catch consists of deep-water species and 60 percent of the quota is owned by the three largest companies, Sealord, Sanford and Amaltal. Ninety percent of the catch is exported.

The growth of the domestic deep-water fishery since 1980 is revealed in the total tonnages of fish landed. In 1980, New Zealand companies caught nearly 77,000 tonnes of fin-fish, including tuna, while licensed foreign vessels caught more than twice this. By 1992, the domestic catch had risen to an all-time high of 536,000 tonnes and the foreign catch had declined to 1,300 tonnes. (Both catches receded the following year with 495,000 tonnes landed by domestic vessels and 400 tonnes landed by foreign boats.) Similarly, the catch of invertebrates, mostly squid, rose from about 24,000 tonnes in 1980 to almost 120,000 tonnes in 1992 receding to 96,000 tonnes in 1993. The industry's growth is also reflected in its export receipts which totalled $162 million in 1980. By 1992–93 they had reached $1,200 million, 10 times the value of domestic sales. They have remained at about that level through recent seasons, but the industry is aiming for $2,000 million by the year 2000, mainly through improved processing and marketing, and the growth of aquaculture, assisted by the introduction of a further 117 species to the QMS.

Despite the growth in catch and income, the industry is not a large employer, providing about 9,000 full-time equivalent jobs, nearly half of which are in the processing sector (Ministry of Fisheries, 1996). With low labour costs and few costs for stock replenishment or maintenance, other than some research and monitoring, the industry has ploughed its capital into highly mechanised catching and processing equipment, making the New Zealand industry one of the most economically efficient in the world. The last decade has involved the refinement of the QMS system, the clarification of Government and industry roles in research, monitoring and stock assessment, and the introduction of laws to enact Maori fishing rights which include: a guaranteed percentage of the total quota (10 percent of existing QMS species, 20 percent of future ones); customary food-gathering rights; a half-share in Sealord Fisheries; and provisions for iwi to manage fisheries of tribal significance (taiapure and mataitai).

The culmination of this reform process was the passing of the Fishing Act 1996. It has an explicit requirement to sustain not only the fisheries, but also associated and dependent species, aquatic biodiversity, and any habitats significant to fisheries. The Act also contains provisions for dealing with bycatch, or 'fishing induced mortality' of protected species and for bringing new species into the QMS. The 1996 Act consolidated a series of amendments to the previous legislation under which user charges for fisheries administration and research were introduced (e.g. the Conservation Services Levy, which enables the Department of Conservation to undertake research on fishing related mortality). The earlier amendments also split the former Ministry of Agriculture and Fisheries (MAF) into two separate ministries, one for agriculture (which has retained the acronym MAF) and one for fisheries (which is now known as Mfish). Following these amendments, MAF's fisheries research facilities and vessels were sold to the Crown Research Institute, NIWA, which now undertakes fish stock analysis and assessment, and other fisheries-related research, under contract to MFish.

Most fishing in New Zealand is confined to places where the water is less than 1 km deep. Such areas cover approximately a third of the EEZ. Scientists and fishing companies are continually exploring these waters to find new stocks and new species which may be exploitable. Trawl surveys have found more fish species in the north than in the south and more species in deep rather than shallow water. The areas of greatest species diversity are concentrated along the margins of the Chatham Rise and are associated with the subtropical convergence of cold and warm waters (McClatchie, 1995).

Two-thirds of our fishing zone is considered commercially barren, consisting of deep low-nutrient waters which plunge more than a kilometre down. Though many species live in the deep water, few are considered fishable at present, with the significant exception of orange roughy. Few surveys have been done to identify species living at depths greater than 1.5 km, which is roughly the lower limit of the orange roughy trawl. In some areas, such as the subduction zone of the Kermadec Trench, the water is more than 10 km deep and its inhabitants are unknown.

A little over 100 marine fish species are harvested commercially—10 percent of our known fish species. Stock assessments are made on the 42 species harvested for Maximum Sustainable Yield (MSY) under the Quota Management System (QMS). Stock assessments are also made on species such as Southern Blue Whiting, which are fished commercially, although they are not part of the QMS. Provision exists for a further 117 species to be brought into the system.

The QMS species are not all assessed separately. Some are lumped together into groups (such as the jack mackerels, the oreos, and the flatfish) bringing the number of assessed fish 'species' down to 30. These are subdivided into 179 stocks (150 if the little-fished Kermadec area is excluded). Large amounts of data on many other species have been collected in trawl surveys. The information is stored in huge databases, but has not been analysed because a limited number of fishery scientists are available to do the work. As a result, low priority species and those which are only lightly harvested are not assessed.

Migratory species, such as tuna and billfish, are also fished commercially, but they are not covered by the Quota Management System. Because they range so widely across the world's oceans, these fish are caught in many different waters and need to be managed under an international system, rather than by different sets of national regulations. So far, the only such system in operation is the Convention for the Conservation of Southern Bluefin Tuna (CCSBT). Under this trilateral agreement between New Zealand, Australia, and Japan, separate southern bluefin quotas are set for each nation (see Table 9.23). Management regimes for other migratory species have recently been the subject of a United Nations-brokered agreement on the management of straddling stocks.

Because fish stocks are wild populations living in inaccessible environments, population data and models are often uncertain or inadequate. This is particularly true for species living in areas not suited to trawling. Data for these species are sparse and often limited to commercial catch/effort data. However, in areas that are more suited to trawling, good quality data are collected from regular trawl surveys by NIWA's fishery research vessels. This information, along with data derived from the commercial fishery, is used to make assessments on 74 of the 161 QMS stocks. Sufficient data are also available to assess many non-quota stocks, but resource constraints have prevented this to date.

**Figure 9.5**

**Quota Management Areas (QMAs) for commercial fish stocks within New Zealand's Exclusive Economic Zone (EEZ)**

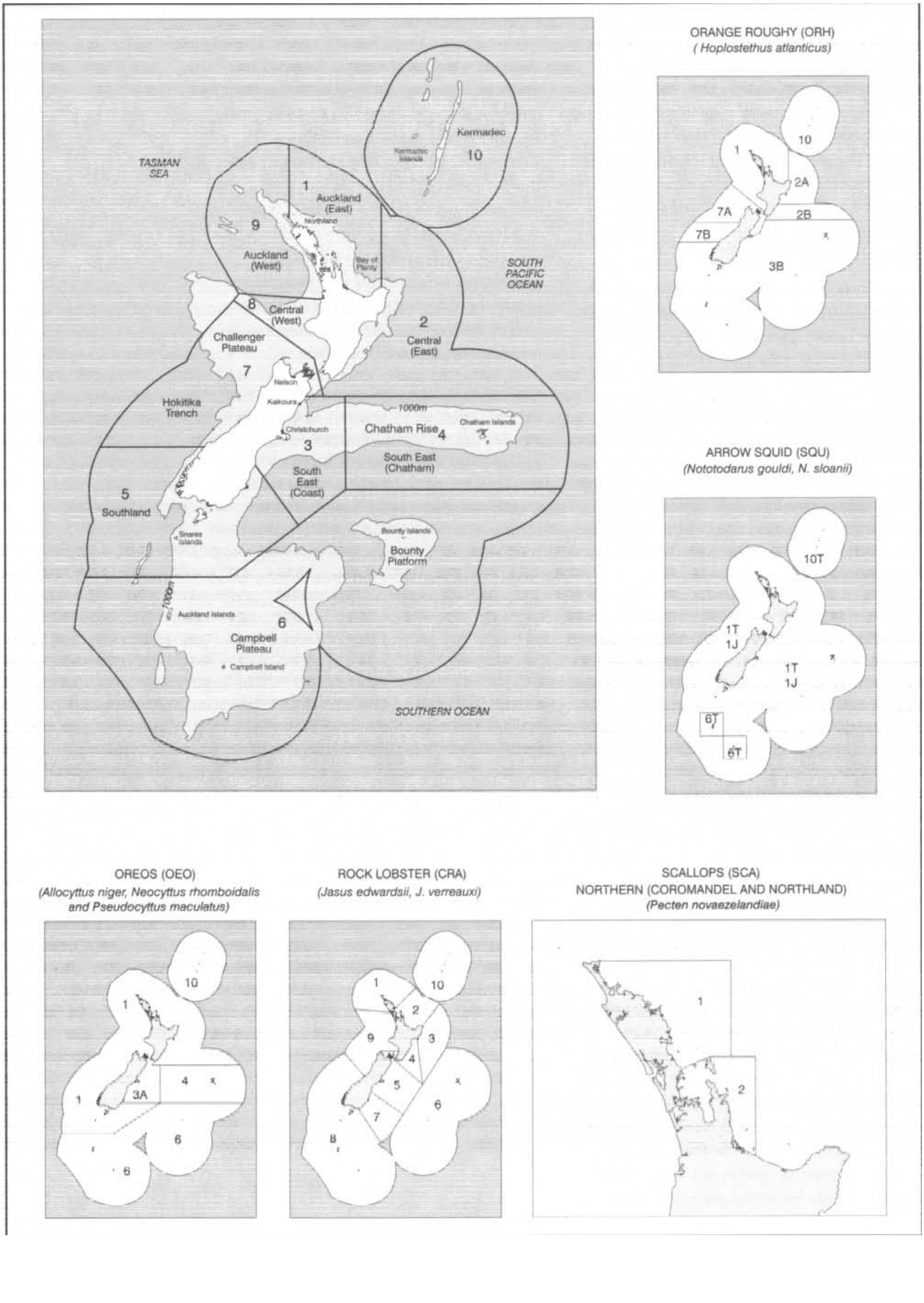


**Table 9.20**

**Commercial fish and invertebrate stocks and the Quota Management Areas in which they occur (see Figure 9.5)**

| Species and stock designation | QMA1 | QMA2 | QMA3 | QMA4 | QMA5 | QMA6 | QMA 7 | QMA 8 | QMA9 | QMA 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Alfonsino (BYX)* | *BYX1* | *BYX2* | *BYX3* | | | | *BYX7* | *BYX8* | *BYX1* | *BYX10* |
| *Barracouta (BAR)* | *BAR1* | | | *BAR4* | *BAR5* | | *BAR7* | | | *BAR10* |
| *Blue cod (BCO)* | *BCO1* | *BCO2* | *BCO3* | *BCO4* | *BCO5* | | *BCO7* | *BCO8* | *BCO1* | *BCO10* |
| *Bluenose (BNS)* | *BNS1* | *BNS2* | *BNS3* | | | | *BNS7* | *BNS8* | *BNS1* | *BNS10* |
| *Blue moki (MOK)* | *MOK1* | | *MOK3* | *MOK4* | *MOK5* | | *MOK1* | | | *MOK10* |
| *Blue warehou (WAR)* | *WAR1* | *WAR2* | *WAR3* | | | | *WAR7* | *WAR8* | *WAR1* | *WAR10* |
| *Elephant fish (ELE)* | *ELE1* | *ELE2* | *ELE3* | | *ELE5* | | *ELE7* | *ELE2* | *ELE1* | *ELE10* |
| *Flatfish (FLA)* | *FLA1* | *FLA2* | *FLA3* | | | | *FLA7* | *FLA2* | *FLA1* | *FLA10* |
| *Gemfish (SKI)* | *SKI1* | *SKI2* | *SKI3* | | | | *SKI7* | | *SKI1* | *SKI10* |
| *Grey mullet (GMU)* | *GMU1* | *GMU2* | *GMU3* | | | | *GMU7* | *GMU2* | *GMU1* | *GMU10* |
| *Groper/Bass (HPB)* | *HPB1* | *HPB2* | *HPB3* | *HPB4* | *HPB5* | | *HPB7* | *HPB8* | *HPB1* | *HPB10* |
| *Hake (HAK)* | *HAK1* | | | *HAK4* | *HAK1* | | *HAK7* | *HAK1* | | *HAK10* |
| *Hoki (HOK)* | *HOK1* | | | | | | | | | *HOK10* |
| *Jack mackerel (JMA)* | *JMA1* | | *JMA3* | | | | *JMA7* | | | *JMA10* |
| *John Dory (JDO)* | *JDO1* | *JDO2* | *JDO3* | | | | *JDO7* | *JDO2* | *JDO1* | *JDO10* |
| *Kahawai (KAH)* | *KAH1* | *KAH2* | *KAH3* | | | | | | *KAH9* | *KAH10* |
| *Ling (LIN)* | *LIN1* | *LIN2* | *LIN3* | *LIN4* | *LIN5* | *LIN6* | *LIN7* | | *LIN1* | *LIN10* |
| *Paua (PAU)* | *PAU1* | *PAU2* | *PAU3* | *PAU4* | *PAU5* | *PAU6A* | *PAU7* | *PAU2* | *PAU1* | *PAU10* |
| *Red cod (RCO)* | *RCO1* | *RCO2* | *RCO3* | | | | *RCO7* | *RCO2* | *RCO1* | *RCO10* |
| *Red gurnard (GUR)* | *GUR1* | *GUR2* | *GUR3* | | | | *GUR7* | *GUR8* | *GUR1* | *GUR10* |
| *Rig (SPO)* | *SPO1* | *SPO2* | *SPO3* | | | | *SPO7* | *SPO8* | *SPO1* | *SPO10* |
| *Scampi* (SCI)* | *QMA1* | *QMA2* | *QMA3* | *QMA4* | *QMA5* | *QMA6* | *QMA7* | *QMA8* | *QMA9* | *QMA10* |
| *School shark (SPO)* | *SCH1* | *SCH2* | *SCH3* | *SCH4* | *SCH5* | | *SCH7* | *SCH8* | *SCH1* | *SCH10* |
| *Silver warehou (SWA)* | *SWA1* | | *SWA3* | *SWA4* | | | *SWA1* | | | *SWA10* |
| *Snapper (SNA)* | *SNA1* | *SNA2* | *SNA3* | | | | *SNA7* | *SNA8* | | *SNA10* |
| *Stargazer (STA)* | *STA1* | *STA2* | *STA3* | *STA4* | *STA5* | | *STA7* | *STA8* | *STA1* | *STA10* |
| *Tarakihi (TAR)* | *TAR1* | *TAR2* | *TAR3* | *TAR4* | *TAR5* | | *TAR7* | *TAR8* | *TAR1* | *TAR10* |
| *Trevally (TRE)* | *TRE1* | *TRE2* | *TRE3* | | | | *TRE7* | | | *TRE10* |

*Source: Annala (1995a)*

* *The stock structure for scampi is not well known. At present, quotas are set for each QMA, though preliminary studies suggest that scampi in QMA 6 are genetically distinct from the rest and that stocks in QMA 1 and QMA 2 are also different.*

**Table 9.21**

**Commercial fish and invertebrates with non-standard stock boundaries (see Figure 9.5)**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Orange (ORH) roughy** | **ORH1** | **ORH2A 'North'** | **ORH2A, ORH2B, ORH3A 'East Coast'** | **ORH3B 'Chatham'** | **ORH3B 'Puysegur'** | **ORH3B 'Other'** | **ORH7A** | **ORH7B** | | |
| *(See Figure 9.5)* | *QMA 1, 9 (northern Nth Island)* | *QMA 2 (north of East Cape)* | *QMA 2, 3 (East Cape to Christchurch)* | *QMA 4 (Chatham Rise)* | *QMA 5 (south of Fiordland)* | *QMA 6 (southern oceans)* | *QMA 7 (Challenger Plateau)* | *QMA7 (Sth Island West Coast)* | | |
| | | | | | | | | | | |
| **Oreos (OEO)** | | **OEO1** | | | **OEO3A, OEO4** | | **OEO6** | | | |
| *(See Figure 9.5)* | | *Otago-Southland coast and Puysegur* | | | *Chatham Rise* | | *Campbell Plateau and Bounty Platform* | | | |
| | | | | | | | | | | |
| **Oysters (OYS)** | | | **Challenger** | | | **Foveaux Strait** | | | | |
| | | | *Part of QMA 7: Golden Bay, and Tasman Bay except for an area of outer Tasman Bay* | | | *Part of QMA 6: Foveaux Strait* | | | | |
| **Packhorse (PHC) rock lobster** | | | | | **PHC1** | | | | | |
| | | | | | *(Managed as a single stock throughout New Zealand)* | | | | | |
| **Scallops ((SCA)** | | | **Northern** | | | **Southern** | | | | |
| *(See Figure 9.5)* | | *Area 1 East Northland* | *Area 2 Hauraki Gulf-Coromandel Peninsula* | | | *Nelson and Marlborough* | | | | |
| **Southern (SBW) blue whiting** | | | **Bounty Platform** | | **Campbell Island Rise** | | **Pukaki Rise/Auckland Islands** | | | |
| | | | | | *All these stocks are within QMA 6* | | | | | |
| **Squid (SQU)** | | **SQU1T** | **SQU1J** | | | **SQU6T** | **SQU10T** | | | |
| *(See Figure 9.5)* | | *South Island (east and west)* | | | | | *Subantarctic islands* | *Kermadec islands* | | |
| **Red rock (CRA) lobster** | **CRA1 (NTH)** | **CRA2 (BOP)** | **CRA3 (GIS)** | **CRA4 (WHB)** | **CRA5 (CBM)** | **CRA7 (OTG)** | **CRA8 (STM)** | **CRA9 (WKI)** | **CRA6** | **CRA10** |
| *(See Figure 9.5)* | | | | *North and South Islands (including Stewart Island) (NSI)* | | | | | *Chatham Is (CHI)* | *Kermadec Is (KER)* |

*Source: Annala (1995a)*

**Table 9.22**

**Recent quotas, catches and status of commercial fish stocks.**

| Species | | 1989-90 | 1991-92 | 1993-94 | 1995-96 | Stocks Status 1995-96 |
|---|---|---|---|---|---|---|
| | | | | (tonnes) | | |
| *Alfonsino (Beryx splendens; B. decadactylus)* | *Quota* | *2,422* | *2,648* | *2,718* | *2,721* | *A (BYX3)<br>C (BYX2)<br>D (BYX1,7,8,10)* |
| | *Catch* | *1,688* | *1,641* | *2,001* | *2,865* | |
| *Barracouta (Thrysites atun)* | *Quota* | *33,073* | *34,190* | *33,202* | *33,202* | *C (BAR1,4,5,7)<br>D (BAR10)* |
| | *Catch* | *23,568* | *22,212* | *19,345* | *26,258* | |
| *Blue cod (Parapercis colias)* | *Quota* | *2,666* | *2,722* | *2,689* | *2,665* | *C (BCO1,2,3,4,5,8)<br>D (BCO7,10)* |
| | *Catch* | *1,527* | *1,480* | *1,812* | *2,106* | |
| *Blue moki (Latridopsis ciliaris)* | *Quota* | *299* | *306* | *404* | *604* | *C (MOK1,3,4,5)<br>D (MOK10)* |
| | *Catch* | *303* | *355* | *476* | *507* | |
| *Blue warehou (Seriolella brama)* | *Quota* | *5,459* | *4,499* | *4,512* | *4,512* | *C (WAR1,2,3,7,8)<br>D (WAR10)* |
| | *Catch* | *1,696* | *3,905* | *1,500* | *2,901* | |
| *Bluenose (Hyperoglyphe* | *Quota* | *1,765* | *1,847* | *2,033* | *2,170* | *C (BNS2)<br>D (BNS1,3,7,8,10)* |
| *antarctica)* | *Catch* | *1,541* | *2,031* | *2,325* | *2,290* | |
| *Elephant fish (Callorhynchus milii)* | *Quota* | *623* | *636* | *639* | *715* | *C (ELE3)<br>D (ELE1,2,5,7,10)* |
| | *Catch* | *510* | *597* | *568* | *855* | |
| *Flatfish (flounders,* | *Quota* | *6,568* | *6,670* | *6,671* | *6,670* | *D (All 5 stocks)* |
| *soles etc.) (8 spp. including 4 Rhombosolea)* | *Catch* | *3,482* | *3,202* | *4,605* | *4,456* | |
| *Gemfish* | *Quota* | *7,218* | *7,350* | *7,470* | *7,480* | *D (All 5 stocks)* |
| *(Rexea solandri)* | *Catch* | *4,369* | *3,096* | *2,616* | *1,701* | |
| *Grey mullet (Mugil cephalus)* | *Quota* | *1,070* | *1,086* | *1,086* | *1,086* | *C (GMU1)<br>D (GMU2,3,7,10)* |
| | *Catch* | *913* | *852* | *706* | *828* | |
| *Groper (Hapuku)/* | *Quota* | *2,117* | *2,163* | *2,167* | *2,179* | *C (All 8 stocks)* |
| *Bass (Polyprion oxygeneios/P. americanus)* | *Catch* | *1,098* | *1,319* | *1,525* | *1,437* | |
| *Hake (Merluccius australis)* | *Quota* | *6,930* | *13,780* | *13,847* | *13,997* | *A (HAK1,4)<br>C (HAK7)<br>D (HAK10)* |
| | *Catch* | *7,783* | *8,196* | *7,363* | *15,809* | |
| *Hoki* | *Quota* | *251,884* | *201,897* | *202,155* | *240,010* | *A (Entire stock)* |
| *(Macruronus novaezelandiae)* | *Catch* | *209,000* | *215,000* | *190,000* | *208,753* | |
| *Jack mackerel (Trachurus spp. - 3 species)* | *Quota* | *40,707* | *40,749* | *49,546* | *32,547* | *A (JMA7)<br>C (JMA1,3)<br>D (JMA10)* |
| | *Catch* | *30,102* | *38,676* | *45,498* | *12,268* | |

*Continued on next page...*

*Source: Ministry of Fisheries*
*Stocks Status Key*
*A = Above Maximum Sustainable Yield (MSY) and being "fished down".*
*B = Below MSY level.*
*C = Currently at or near the MSY level.*
*D = Data deficient.*
* *Commercially important fish species not included in the Quota Management System (QMS).*
† *Includes 10% Maori allocation of kahawai and 15% acceptable bycatch.*
†† *Preliminary estimate for 1993-94 southern blue whiting catch from Licensed Fish Receivers.*

*Continued from previous page...*

| Species | | 1989-90 | 1991-92 | 1993-94 | 1995-96 | Stocks Status 1995-96 |
|---|---|---|---|---|---|---|
| | | | | (tonnes) | | |
| *John Dory (Zeus japonicus)* | *Quota* | *1,094* | *1,102* | *1,106* | *1,107* | *C (JDO1)*<br>*D (JDO2,3,7,10)* |
| | *Catch* | *701* | *837* | *864* | *864* | |
| *Kahawai ** *(Arripis trutta)* | *Quota* | *none* | *6,500†* | *4,390†* | *4,390†* | *A or C (All 5 stocks)* |
| | *Catch* | *8,466* | *5,018* | *5,164* | *4,365* | |
| *Ling (Genypterus blacodes)* | *Quota* | *19,672* | *19,711* | *19,741* | *22,111* | *A (LIN3,4,5,6,7)*<br>*C (LIN1,2)*<br>*D (LIN10)* |
| | *Catch* | *9,028* | *17,778* | *15,961* | *21,084* | |
| *Orange roughy (Hoplostethus atlanticus)* | *Quota* | *47,537* | *38,117* | *35,490* | *21,330* | *A (ORH1; ORH2A "North")*<br>*B (ORH3B - Chatham Rise)*<br>*(ORH3B - Puysegur)*<br>*(ORH7A - Challenger Plateau)*<br>*(ORH7B - Sth Is. West Coast)*<br>*C (ORH2A/2B/3A - East Coast)*<br>*D (ORH3B - Other)* |
| | *Catch* | *48,312* | *37,012* | *29,688* | *20,700* | |
| *Oreos (Allocyttus niger; Neocyttus rhomboidalis; Pseudocyttus maculatus)* | *Quota* | *25,139* | *25,139* | *26,160* | *26,160* | *D (All 5 stocks)* |
| | *Catch* | *18,703* | *21,718* | *23,318* | *23,571* | |
| *Red cod (Pseudophycis bacchus)* | *Quota* | *16,537* | *15,840* | *15,930* | *16,066* | *D (All 5 stocks)* |
| | *Catch* | *7,502* | *9,104* | *11,508* | *15,295* | |
| *Red gurnard (Chelidonichthys kumu)* | *Quota* | *4,730* | *4,975* | *4,978* | *4,982* | *C (GUR1)*<br>*D (GUR2,3,7,8,10)* |
| | *Catch* | *2,745* | *3,390* | *3,141* | *2,879* | |
| *Rig (Mustelus lenticulatus)* | *Quota* | *1,727* | *2,070* | *2,097* | *2,098* | *D (All 6 stocks)* |
| | *Catch* | *1,514* | *1,770* | *1,619* | *1,829* | |
| *School shark (Galeorhinus galeus)* | *Quota* | *2,996* | *3,086* | *3,093* | *3,105* | *D (All 8 stocks)* |
| | *Catch* | *2,377* | *2,508* | *2,607* | *3,353* | |
| *Silver warehou (Seriolella punctata)* | *Quota* | *9,133* | *9,509* | *9,514* | *9,884* | *D (All 4 stocks)* |
| | *Catch* | *8,625* | *7,066* | *8,647* | *9,327* | |
| *Snapper (Pagrus auratus)* | *Quota* | *7,932* | *7,962* | *6,884* | *6,893* | *B (SNA1,7,8)*<br>*D (SNA2,)* |
| | *Catch* | *8,034* | *8,191* | *6,835* | *6,838* | |
| *Southern blue whiting ** *(Micromesistius australkis)* | *Quota* | *None* | *None* | *32,000* | *32,000* | *A All 3 stocks* |
| | *Catch* | *24,514* | *83,427* | *13,300††* | *15,625* | |
| *Stargazer (Kathetostoma giganteum)* | *Quota* | *4,502* | *5,296* | *5,329* | *5,353* | *A (STA4)*<br>*C (STA1,2,3,5,7,8)*<br>*D (STA10)* |
| | *Catch* | *2,763* | *3,239* | *3,097* | *3,243* | |
| *Tarakihi (Nemadactylus macropterus)* | *Quota* | *5,873* | *5,953* | *5,990* | *5,992* | *A (TAR4)*<br>*D (TAR1,2,3,5,7,8,10)* |
| | *Catch* | *4,473* | *5,417* | *4,876* | *5,249* | |
| *Trevally (Pseudocaranx dentex)* | *Quota* | *3,906* | *3,921* | *3,932* | *3,932* | *C (TRE1,7)* |
| | *Catch* | *3,122* | *2,733* | *3,620* | *3,368* | *D (TRE2,3,10)* |

*Source: Ministry of Fisheries*
*Stocks Status Key*
*A = Above Maximum Sustainable Yield (MSY) and being "fished down".*
*B = Below MSY level.*
*C = Currently at or near the MSY level.*
*D = Data deficient.*
** Commercially important fish species not included in the Quota Management System (QMS).*
*† Includes 10% Maori allocation of kahawai and 15% acceptable bycatch.*
*†† Preliminary estimate for 1993-94 southern blue whiting catch from Licensed Fish Receivers.*

**Table 9.23**

**Reported catches (greenweight tonnes) of non-Quota Management System fish.**

| Species | | 1989-90 | 1991-92 | 1993-94 | 1995-96 | Stocks Status |
|---|---|---|---|---|---|---|
| | (tonnes) | | | 1995 | | |
| *Blue mackerel (Scomber australisicus)* | *No quota* | | | | | *D* |
| | *Catch* | *5,673* | *15,279* | *6,093* | *5,646* | |
| *Cardinal fish (Epigonus telescopus)* | *No quota* | | | | | *D* |
| | *Catch* | *2,374* | *1,651* | *3,793* | *4,565* | |
| *Frostfish (Lepidopus caudatus)* | *No quota* | | | | | *D* |
| | *Catch* | *2,536* | *3,298* | *2,964* | *1,575* | |
| *Ghost shark (Hydrolagus novaezelandiae)* | *No quota* | | | | | *D* |
| | *Catch* | *903* | *1,264* | *1,591* | *1,927* | |
| *Skate (Squalus acanthias)* | *No quota* | | | | | *D* |
| | *Catch* | *1,330* | *1,879* | *2,022* | *1,456* | |
| *Spiny dogfish (Squalus acanthias)* | *No quota* | | | | | *D* |
| | *Catch* | *2,952* | *3,274* | *6,151* | *5,974* | |
| *Swordfish (broadbill) (Xiphius gladius)* | *No quota* | | | | | *D* |
| | *Catch* | *200* | *8* | *1* | *22* | |
| *White warehou (Seriolella caerulea)* | *No quota* | | | | | *D* |
| | *Catch* | *1,286* | *2,419* | *1,719* | *1,901* | |
| *Albacore tuna (Thunnus alalunga)* | *No quota* | | | | | *D* |
| | *Catch* | *3,144* | *3,417* | *5,315* | *6,259* | |
| *Skipjack tuna (Katsuwonus pelamus)* | *No quota* | | | | | *D* |
| | *Catch* | *3,972* | *988* | *3,136* | *4,105* | |
| *Southern bluefin tuna (Thunnus maccoyi)* | *CCSBT quota** | | | | | *D* |
| | *Catch* | *529* | *60* | *277* | *133* | |
| *Other tuna (5 Species)* | *No quota* | | | | | *D* |
| | *Catch* | *161* | *105* | *146* | *303* | |

*Source: Ministry of Fisheries*

* *The Global Catch Limit for Southern bluefin tuna agreed to under the Convention for the Conservation of Southern Bluefin Tuna (CCSBT) for the 1993-94 was 11,750 tonnes (6,065t. for Japan, 5,265t. for Australia, and 420t. for New Zealand).*

Many of the stocks whose status is unknown are either unexploited or only lightly exploited and are assumed to be in the fishing-down phase or fluctuating within natural limits. What is unknown, however, is whether those natural limits are changing in response to fishing activities and other environmental disturbances. Commercial fishing can alter predator-prey relationships and habitat quality through such practices as: significantly reducing the biomass of prey or predator species; dumping waste; stirring up sediment clouds; and killing non-target species of fish, marine invertebrates, seaweeds, seabirds and marine mammals through bycatch, bottom trawling or dredging.

There is often a noticeable decline in the invertebrate animals brought up by trawls when new deep-water fishing grounds are exploited. Because no records are kept, the extent of these effects has not been quantified and their possible contribution to fishery declines has generally been ignored in fisheries management literature. Some marine biologists believe there is an urgent need to carry out trawling impact studies in water deeper than 500 m because this is where the effects could be severe with flow-on impacts on the fisheries themselves (Jones, 1992).

Non-commercial fishing can also be a source of pressure on commercial species, such as snapper and blue cod, and non-commercial species, such as red moki. As much as a third of the annual snapper catch is taken by recreational fishers. Set-netting and spear-fishing have forced some stocks of reef-dwelling red moki (*Cheilodactylus spectablis*) into a decline. On some Northland reefs, stocks have been almost wiped out. Because they are long-lived (60 years) and slow-growing, their recovery is likely to be slow.

Of the 74 QMS fish stocks which have been scientifically assessed, most are thought to be near or above the level of Maximum Sustainable Yield (MSY) and still in the fishing-down phase (e.g. all stocks of hoki). Among those thought to be at or near the MSY level are most stocks of barracouta, blue moki, blue warehou and groper. Other species with at least some stocks above, at or near, the MSY level are alfonsino, blue cod, bluenose, hake, jack mackerels, ling, orange roughy, red gurnard, southern blue whiting, stargazer, tarakihi and trevally.

Two QMS species (blue moki and elephantfish) have stocks which are believed to be recovering from previous over-fishing and may be below the MSY level. Several other species (gemfish, grey mullet, rig) have one or more stocks whose catches are declining or are well below the allowable quotas. It is unclear whether the low catches are caused by economic or biological factors. Two species (smooth oreo and snapper) have one or more stocks which may be at risk of depletion given 1995 catch rates. Overall, only 7 of the 74 assessed fish stocks (10 percent) are considered to be below the MSY level. Four of these are orange roughy and 3 are snapper (see Table 9.23).

### *Snapper*

Snapper (*Pagrus auratus*) are the dominant inshore species in the warmer waters around the North Island and the top of the South Island. Although several species occur in temperate and tropical coastal waters in all oceans, only one is known in New Zealand. They eat invertebrates, squid and small fish at, or near, the sea bottom and rarely go deeper than 200 m. They are most abundant above 60 m. Unlike orange roughy, they were already depleted before they came under the QMS. However, they do share some traits with their deeper-water cousins. They are long-lived (up to 60 years), have low natural rates of birth and death and, like roughy, their flesh commands high prices, particularly in Japan.

Snapper have been caught commercially for many years, and the fishery is one of the largest and most valuable coastal fisheries in New Zealand. It is also one of the largest recreational fisheries. Recent surveys indicate that up to one-third of all snapper caught are taken by amateurs (Teirney and Kilner, 1995). Snapper are also part of the bycatch taken by the tarakihi, gurnard and other inshore fisheries. The customary Maori catch is unknown.

Three of the four snapper stocks (SNA1, SNA7 and SNA8) have been reduced below the MSY level (see Table 9.22). These stocks surround the top and west coast of the North Island. The fourth stock (SNA2) extends along the east coast of the North Island from Gisborne to Wellington. Its status is unknown, but its TACC has constantly been exceeded since 1987–88 because of bycatch losses to the tarakihi and red gurnard fisheries.

The largest snapper stock (SNA1) consists of two separate populations, both of which have been heavily reduced. The east Northland population is now close to the MSY level, while the Hauraki/Bay of Plenty population is well below it (see Figure 9.6). In 1995, scientists predicted that, at prevailing catch rates, both sub-stocks would decline further over the next five years (Annala, 1995b). The Fisheries Minister responded to this new information by announcing quota reductions for SNA1 (Minister of Fisheries, 1995). A year earlier, the Minister had accepted proposals by the Recreational Fishing Council to reduce the take of juvenile snapper in SNA1 through measures other than quota reductions. These had included an increase in the minimum legal size from 25 cm to 27 cm for recreational fishers and a cut in the daily bag limit from 20 fish to 15.

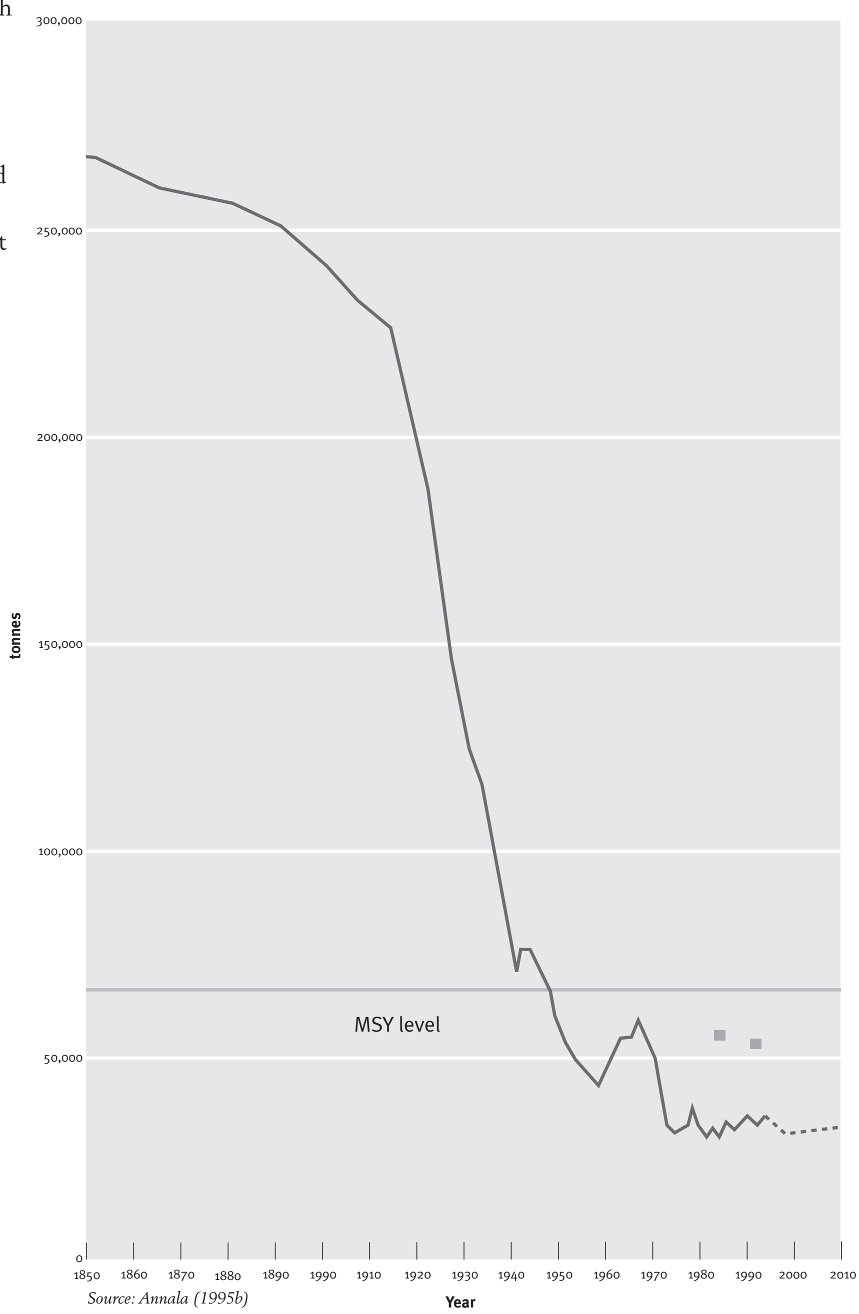
Based on the new evidence, however, the estimated recreational catch was reduced to 2,300 tonnes by lowering the daily bag limit from 15 fish to 9. The commercial quota was reduced from almost 5,000 tonnes to 3,000, and an allowance was made for a Maori customary take of 300 tonnes. Additional measures, to reduce snapper bycatch, included a year-round minimum net mesh size of 12.5 cm in shallow waters and a six-month closed season to commercial fishing in the inner Hauraki Gulf. No changes were made to management controls for the other snapper stocks. Catch levels for the other depleted stocks (SNA7 and SNA8) were considered to be sustainable and at levels that would allow them to rebuild to the MSY level. A year after these measures were implemented, the catch limits for Hauraki snapper had to be reduced yet again.

### *Orange roughy*

Orange roughy (*Hoplostethus atlanticus*) has been heavily fished since 1982. It is one of five roughy species found in our waters and is by far the most valuable. The first known New Zealand specimen was netted at the bottom of Cook Strait by scientists in 1957, but it was not properly identified until 1979. Adults range between a third and half a metre in length, and are

**Figure 9.6(a)**

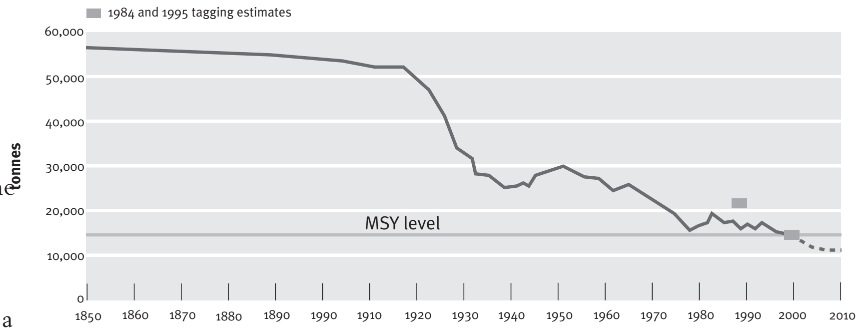
**Estimated biomass changes in the Hauraki Gulf/Bay of Plenty snapper sub-stock (SNAI)**




*Source: Annala (1995b)*

**Figure 9.6(b)**

**Estimated biomass changes in the East Northland snapper sub-stock (SNAI)**




*Source: Annala (1995b)*

highly valued. Although they make up less than 5 percent of the total marine catch by weight, orange roughy account for nearly 17 percent of the fishing industry's income—about $200 million.

Living at depths of 700 m to at least 1,500 m, the orange roughy's life is still somewhat mysterious. From gut contents, it is known to eat squid, crustaceans and other fish. It is also known to be eaten by larger species, such as sperm whales. Those that avoid being eaten are long-lived. Individuals can survive for up to 120–130 years and many which end up in fish fillets are far older than the people consuming them. They also have one of the longest childhoods of any species, not reaching sexual maturity until they are about 33 years old. By fish standards, they produce relatively few eggs each spawning season (40,000–50,000). The eggs are large and drift upward. Those not eaten by predators hatch after 10 days and begin the slow process of growing up in the ocean depths.

In just 15 years, from 1978 to 1993, the total biomass of known orange roughy stocks was reduced to an estimated 15–30 percent of its original size. The decline was greater for some stocks than for others, depending on their initial size and the intensity of the fishing. Some stocks live as isolated populations on underwater plateaus or in deep-sea canyons and valleys, while others are spread over wide areas. It is now clear that the actual stocks do not always correspond to the fishery stocks for which TACCs have been set in the past. At present eight stocks are recognised, four of which are below the MSY level.

The four depleted stocks are around the west, south and lower east of the South Island. They are: the Challenger Plateau stock (ORH7A); the West Coast stock (ORH7B); the Puysegur stock (ORH3B Puysegur); and the Chatham Rise stock (ORH3B Chatham). A fifth southern 'stock' (ORH3B Other) consists of separate populations which may be one stock and which are too poorly known to make an assessment (Annala, 1995a).

The two stocks still above the MSY level and being fished-down are the Northern stock (ORH1) to the north and west of the North Island, and the East Cape stock to the north of Gisborne (ORH2A North) (Annala, 1995a). The only stock which is currently at the MSY level is the 'East Coast' stock extending from Cape Runaway in the North Island down to Banks Peninsula in the South Island. It was originally classified as three separate stocks (ORH2A, ORH2B and ORH3A) but is now assessed as a single stock. Since 1986, catches and quotas for this stock had averaged almost 10,000 tonnes. Following scientific advice, the TACC was reduced to 6,660 tonnes in 1994 and then 2,100 tonnes in 1995, barely a fifth of its original level (Annala, 1995a; Minister of Fisheries, 1995).

Because of its extremely slow growth, very high economic value and ecological remoteness, orange roughy has been a difficult test case for the Quota Management System, embodying some of the biological and economic extremes that make quota decisions difficult for scientists and politicians. The entire history of the fishery represents less than a fifth of one fish's lifespan. So far the QMS has not emerged with flying colours. The four depleted stocks were all driven below the MSY level under the QMS regime. The challenge now is to achieve stock recoveries while avoiding the same mistakes with the remaining stocks.

Recent quotas reflect this goal. Although the two 'new' northern stocks have had their quotas increased, all other stocks have had substantial quota decreases. The overall orange roughy TACC for 1995–96 was just over 21,000 tonnes, one third of its peak in 1988–89 when it exceeded 62,000 tonnes. However, stock sustainability is only part of the challenge facing the orange roughy fishery in this era of ecological sustainability. Trawler impacts on deep-sea ecosystems, such as seamounts and coral communities, also need to be assessed and addressed before it can be considered to be truly sustainable (Jones, 1992; Fisher, 1995; Probert, 1996; Probert *et al.*, in press; Raloff, 1996).

#### *Hoki*

In contrast to snapper and orange roughy, hoki (*Macruronus novaezelandiae*), which is fished as a single widespread stock, is under no stress. In fact, it is the most abundant of our commercially fished species. Foreign vessels began catching hoki in the 1970s, and today it makes up nearly one-third of the industry's total catch of all species. The hoki stock is well above the MSY level and is still being 'fished down'. The TACC was reduced from more than 250,000 tonnes in 1989 to just over 200,000 the following year. Since 1994, it has been cautiously increased and, for the 1995–96 season, was 240,000 tonnes (Minister of Fisheries, 1995).

While scientists believe the current hoki catch and quota levels are sustainable during the fishing-down phase, the catch has a significant impact on other species which may be less sustainable. Some stocks of ling, hake and silver warehou have had their quotas exceeded because too many are taken as bycatch in hoki nets. The hoki fishery also has a significant effect on non-fish species, such as seals and sea lions (see Box 9.18) and on mud-dwelling corals and other sea-floor invertebrates (Grange, 1993).

**Box 9.18**

***The non-fish bycatch problem***

Nets and baited hooks do not always discriminate in the species they catch. Besides the fish intended for the table, many other species also get caught, including protected species, such as corals, marine mammals and seabirds. One of the worst offenders was the 65 km 'wall of death' drift-net which New Zealand played a key role in getting banned from the South Pacific six years ago. But less notorious examples are commonplace. Trawler nets can kill corals and other sea floor dwellers as well as marine mammals near the surface. Poorly secured inshore setnets (or gill nets) can billow in the water, entangling anything that encounters them—mammal, fish, or bird. Even when properly set and securely anchored to keep the mesh taut and open, they can entangle dolphins. And nets are not the only threats. Tuna boat longlines are well-named. Each 135-km line carries up to 3,000 baited hooks, which often attract and catch hungry seabirds.

Coral and other inveretbrate bycatch is not monitored but marine mammal and seabird bycatches are. By law, all marine mammal captures must be reported and similar legislation is proposed for protected species of seabirds. Up to 1993, most data came from Government observers on board joint venture and foreign licensed vessels. They covered about 20 percent of the squid trawlers and less than 10 percent of the tuna longliners. Few observers were on domestic boats. As foreign boats declined and were replaced by domestic vessels, Government observers decreased and the fishing industry assumed a greater observer role on domestic, joint venture and foreign boats. Aside from the standard observer duties of recording fish species and catch effort, a strong emphasis is now placed on recording and reporting non-fish bycatch.

Estimates from Government observers for the period 1988–95 show that the seabird bycatch from Japanese longliners has declined from several thousand per year to several hundred (Baird, 1996). This reflects the sharp reduction in the Japanese fleet. The seabird bycatch from domestic longliners is not known but is believed to be less than the Japanese toll (see discussion later in this chapter).

Official estimates also show that about 950 New Zealand fur seals and nearly 70 New Zealand sea lions are drowned in trawl nets each year (see Tables 9.34 and 9.35). The fur seals are caught mainly in the southern blue whiting and West Coast hoki fisheries and also in the hake and southern squid fisheries. Some are hooked on longlines. The sea lions are mostly taken by southern squid trawlers operating within an 80 km radius of the Auckland Islands marine mammal sanctuary (where the sea lions breed). Both sea lions and fur seals were almost wiped out last century and are still only a fraction of their former population sizes. As they recover, their soaring birth rate may lead to more frequent encounters with trawlers near rookeries, haul out sites and feeding grounds. Dolphins are also bycatch victims. Common and bottlenose dolphins are sometimes trapped in jack mackerel nets off the west coast of New Zealand, usually one or two at a time, but multiple catches do occur, perhaps averaging 70 a year (see Table 9.36). Because these dolphins are abundant the bycatch is unlikely to threaten their populations. A far more serious threat, however, is the impact of inshore setnets on the rare Hector's dolphin.

Hector's dolphins are not the only setnet victims, but they are the most endangered (see discussion later in this chapter). Other setnet victims include: Dusky dolphins (near Kaikoura), fur seals and seabirds—especially shags, yellow-eyed penguins, shearwaters, gannets and diving petrels. Most of these are protected species and several are threatened. The areas most at risk of setnet bycatches are: (a) those near the populations or feeding areas of vulnerable species; (b) areas of deep water close to shore (e.g. Kaikoura); (c) the Tamaki Estuary and Panmure Basin; and (d) Banks Peninsula. Although setnets now account for barely 5 percent of the overall domestic fish catch, the setnet fisheries still involve more than 600 vessels seeking the following species: rig and other sharks, butterfish, mullets, moki, flatfish and Kaikoura groper. A 1987 national survey found that setnets are also used by some 66,000 recreational fishers, accounting for about 7 percent of the national marine recreational catch. A survey of 647 recreational setnetters found that 30 percent had come across birds or marine mammals in setnets at some time (Taylor, 1992). Nationally this represents at least 19,800 recreational bycatch incidents over an unspecified period.

Government and the fishing industry are taking steps to reduce the protected species bycatch. In December 1988, a marine mammal sanctuary was established around Banks Peninsula to protect the local Hector's dolphins from setnets. Commercial setnets are banned, and amateur setnets are only permitted, subject to restrictions, from March to October. In 1993 the Marine Mammals Protection Code of Practice was introduced. That same year, fisheries regulations were amended to require bird-scaring devices, such as tori lines, on all tuna longliners. These measures have had some impact on the bycatch rate, but are far from a total solution (Mattlin, 1994a, 1994b; Duckworth, 1995).

Because zero mortality is seen as an unattainable goal, the Minister of Conservation has set marine mammal bycatch limits which the industry must not exceed. In future, the Maximum Allowable Fishing Related Mortality (MALFIRM) for all protected species will be determined through a consultative process set down in the new fisheries legislation and consequent amendments to the Marine Mammal Protection Act 1978. Setting MALFIRMs will require high quality population and bycatch data.

Other efforts to resolve the bycatch problem include a slight expansion of the Ministry of Fisheries Observer Programme. Bycatch assessments will continue to be made by the Non-fish Species and Fisheries Interactions Working Group, which is made up of Government, industry and environmental group representatives, and is convened by NIWA for the Ministry of Fisheries. Other research on bycatch species and mitigation techniques is being carried out by NIWA, the Department of Conservation and the fishing industry, with funding coming from the Ministry of Fisheries and from a Conservation Services Levy which is paid to the Department of Conservation by the fishing industry (Baird, 1996).

### The State of Our Frogs

Frogs are amphibians, evolutionary intermediates between fish and reptiles. We now know that New Zealand had at least seven native frogs when humans arrived with their rats and fire-sticks. Three species subsequently became extinct and the remaining four were heavily reduced. The survivors are: Archey's frog; Hochstetter's frog; the Stephens Island frog and the Maud Island frog, the latter two of which, until recently, were classified as members of a single species, Hamilton's frog (Daugherty *et al.*, 1994; Bell, 1994).

Since European settlement last century, three species of Australian tree frogs were introduced to New Zealand to provide duck food and eat mosquito larvae (Druett, 1983; Sharell, 1966). One species, the Golden Bell frog (*Litoria aurea*), preys on native frogs and, together with another species, *L. raniformis*, may compete with them for food and habitat (Bell, 1994). Both of these species are widely distributed.

All the native New Zealand frogs belong to a single genus, *Leiopelma*, which is found nowhere else in the world (Green and Cannatella, 1993). Members of this genus are almost the same as extinct fossil frogs which existed in late Jurassic times 140–160 million years ago, when New Zealand was still under the sea. These primitive frogs were ultimately driven to extinction in Gondwana but, before they had disappeared, a number found sanctuary on the newborn New Zealand landmass where they quietly founded a small dynasty of unique species.

Unlike other frogs, the leiopelmids do not croak, having neither vocal sacs nor eardrums. The surviving species are very small, less than 5 cm in length, though at least one of the extinct species grew up to 9 cm. Three of the four species live on dry land where they breed under logs, rotten stumps or loose stones. Only Hochstetter's frog prefers an aquatic habitat, but survives well on dry land. None of the New Zealand frogs has a free-swimming tadpole stage. The tadpole phase occurs mostly inside the egg and the young hatch as tiny froglets. Nevertheless, adult frogs retain the fish-like tail-wagging muscles associated with tadpoles throughout their lives.

By the time Europeans arrived, the frogs had become so rare that local Maori appear to have had little knowledge of them. According to Arthur Saunders Thomson, who witnessed the first discovery of a native frog by

Coromandel gold-panners in 1852: "The frog was shown to many of the natives and was carefully examined by several intelligent old men. None of these individuals had ever seen the animal before, nor could they give any name to it." (Sharell, 1966).

Sub-fossil skeletal remains show that New Zealand's frogs were widespread before the first Maori canoes arrived. Their bones have been found by the tens of thousands in some places, suggesting that the mossy forest floor was alive with them (Flannery, 1994). Hochstetters's, Archey's and Hamilton's frogs occurred in both the North and South Islands (Worthy, 1987; Towns and Daugherty, 1994; Bell, 1994). Since then, the frogs have disappeared entirely from the South Island and from the lower half of the North Island. Archey's frog is now limited to the Waikato region, where widely separate populations are found in the Whareorino Forest and on the Coromandel Peninsula (Bell, 1994).

The only surviving Hamilton's frogs are restricted to 2 islands in Cook Strait. On Stephens Island a tiny population of about 170 frogs clings to a small, severely deforested, habitat of about 600 square metres (Brown, 1994). On Maud Island about 19,000 frogs survive in fragmented forest partially restored by the Department of Conservation and the former Wildlife Service (Bell and Bell, 1994; Brown, 1994).

Although they are similar to look at, the Hamilton's frogs on Maud and Stephens Islands have been isolated from each other for so long that they have become genetically distinct species (Daugherty *et al.*, 1994; Bell, 1994). This raises the question of whether the Hamilton's frogs that became extinct in the North and South Islands were genetically distinct species as well. If so, the toll of extinct frog species would rise from three species to five. It would rise even higher if the extinct South Island populations of Archey's and Hochstetter's frogs were also genetically distinct from their North Island counterparts.

Hochstetter's frog is now the most widespread of the surviving frogs, though it covers only a fraction of its former range. It probably escaped the worst impacts of rats and fire by its preference for streams. However, the streams provided no escape from the Norway rat, which is an adept swimmer, nor from the siltation and stream degradation caused by deforestation. Hochstetter's frog survives in at least 12 distinct populations scattered through the upper North Island from Gisborne to Northland. Some of the populations are very vulnerable, being cut off by hostile farmland, areas of volcanic activity or arms of the sea (Green, 1994; Bell, 1994).

**Table 9.24**
**Living and extinct New Zealand frogs**

| Taxonomic name | Common name | Conservation Priority* |
|---|---|---|
| *Leiopelma archeyi* | *Archey's frog* | *B* |
| *Leiopelma hochstetteri* | *Hochstetter's frog* | *B* |
| *Leiopelma hamiltoni (Stephens Is)* | *Stephens Is. frog* | *A* |
| *Leiopelma n. sp. (Maud Island)* | *Maud Island frog* | *B* |
| *Leiopelma auroraensis* | *none* | *Extinct* |
| *Leiopelma markhami* | *none* | *Extinct* |
| *Leiopelma waitomoensis* | *none* | *Extinct* |

** Department of Conservation (1994b)*

The native frogs were first granted 'absolute' protection in 1922 but this has not protected them from rat, cat and mustelid predation and the effects of habitat fragmentation. Seventy years on, the Stephens Island frog is ranked as a Category A threatened species and the other frogs are ranked as Category B threatened species (Department of Conservation, 1994b) (see Table 9.24). Of the Category B species, the Maud Island frog is the most vulnerable, followed by Archey's frog and then Hochstetter's (Bell, 1994).

## The State of Our Reptiles

Although the dinosaurs and their many close relatives have gone, four orders of reptiles remain on Earth. They are: the ancient Sphenodontida ('wedge-toothed' reptiles whose fossils are found all over the world, but whose sole surviving members are the tuatara); the Squamata (lizards and snakes); the Chelonia (the shell-covered reptiles, namely turtles and tortoises); and the Crocodilia (crocodiles, caimans and alligators).

New Zealand has two of the four reptile orders. They are represented by the tuataras (2 species) and the lizards (at least 29 gecko species and 30 skinks) (Daugherty *et al.*, 1994). Tens of millions of years ago there were many more reptiles. Prehistoric tortoises and turtles swam around our coasts and, before them, large plesiosaurs and mososaurs did the same. Dinosaurs stalked the land and pterosaurs flew above it (Cox, 1991; Hyde, 1993). However, New Zealand has never had terrestrial snakes, these having evolved from burrowing lizards after the split with Gondwana. Nor has it had crocodilians.

Although the tuatara has become well-known, the diversity of our lizards has been described as one of New Zealand's best kept secrets, making them part of our 'forgotten fauna'. Few people realise that New Zealand has more lizard species per thousand hectares than any other temperate country, including Australia (Daugherty *et al.*, 1994). All the native lizards are endemic. Only one alien, the Australian Rainbow skink (*Lampropholis delicata*) has become established here.

Some of our lizards have adapted to the alpine region, which is one of the coldest reptile habitats on Earth, but most are forest dwellers, whose populations have shrunk with the lowland forests. All are at risk from introduced predators such as rats, stoats, ferrets and even wild pigs. The cat is also a prime offender. Though they were once abundant on the mainland, about 40 percent of our lizard species are now confined to small predator-free islands (see Tables 9.25 and 9.26). Both tuatara species are also confined to islands.

**Table 9.25**

**Summary of the conservation status and distribution of New Zealand's reptiles.**

| Taxon | Living Species | Extinct species | Number and percentage of species which are rare and threatened | | | | Number and percentage distributed mainly or entirely on islands | |
|---|---|---|---|---|---|---|---|---|
| | | | Daugherty et al. | | DoC | | | |
| ***Tuataras*** | ***2*** | ***1*** | ***2*** | ***100%*** | ***2*** | ***100%*** | ***2*** | ***100%*** |
| ***Skinks*** | ***30*** | ***2*** | ***17*** | ***57%*** | ***15*** | ***50%*** | ***15*** | ***50%*** |
| *Cyclodina* | *8* | *1* | *5* | *62%* | *5* | *62%* | *6* | *75%* |
| *Oligosoma* | *22* | *1** | *12* | *54%* | *10* | *45%* | *9* | *41%* |
| ***Geckos*** | ***29*** | ***1*** | ***7*** | ***24%*** | ***8*** | ***28%*** | ***7*** | ***24%*** |
| *Naultinus* | *7* | *-* | *0* | *-* | *0* | *-* | *0* | *-* |
| *Hoplodactylus* | *22* | *1*** | *7* | *32%* | *8* | *36%* | *7* | *32%* |
| ***All reptiles*** | ***61*** | ***4*** | ***26*** | ***43%*** | ***25*** | ***41%*** | ***24*** | ***39%*** |

*Sources: Daugherty et al. (1994); Department of Conservation, (1994b) Towns and Daugherty (1994)*
** One species, Oligosoma gracilicorpus, whose taxonomic affinities remain unclear.*
*** One species, Hoplodactylus delcourti, for which evidence of a New Zealand origin is still circumstantial.*

**Table 9.26**
**Habitat differences among lizards of the tussock grasslands**

| Species | Active time | Size (mm) snout to vent | Habitat |
|---|---|---|---|
| *Hoplodactylus spp. ** | *Night* | *59–80* | *Rock outcrops, boulder piles* |
| *Jewelled gecko (Naultinus gemmeus)* | *Day* | *71.7* | *Shrubs* |
| *Green skink (Oligosoma chloronoton)* | *Day* | *108* | *Damp valleys* |
| *Grand skink (Oligosoma grande)* | *Day* | *108* | *Rock outcrops* |
| *Oligosoma inconspicuum* | *Day* | *70* | *Herb and shrub cover* |
| *McCann's skink (Oligosoma maccanni)* | *Day* | *72.5* | *Rocky areas* |
| *Common skink (O. nigiplantare polychroma)* | *Day* | *77* | *Tussock cover* |
| *Otago giant skink (Oligosoma otagense)* | *Day* | *135* | *Rocky outcrops and stream canyons* |

*Source: Towns and Daugherty (1994)*
** At least four species which are under review by R. Hitchmough.*

In all, more than 40 percent of our surviving reptiles are now threatened with extinction. One tuatara species is highly endangered. The other is still abundant but is considered threatened because the number of independent populations has declined by 25 percent this century. Among the lizards, half the skinks (15–17 species) and a quarter of the geckos (7–8 species) are threatened (Daugherty *et al.*, 1994; Department of Conservation, 1994b) (see Tables 9.25 and 9.26).

Debate continues about the number of geckos, skinks and tuataras that became extinct after humans arrived in New Zealand. A species of tuatara which was described in 1886 from bones on the East Coast of the North Island (*Sphenodon diversum*) has been accepted as valid and listed as extinct (Daugherty *et al.*, 1990). It is hard to tell, without genetic analyses, whether other tuatara bones from various parts of the country belong to existing species or to unrecognised extinct ones.

A firm case can be made for the recent extinction of a large skink, *Cyclodina northlandi*, whose bones have been found in Northland (Worthy, 1991). Two other lizards, known only from museum specimens, are listed as possible extinctions. One of these, a skink classified as *Oligosoma gracilicorpus*, may belong to a living species. The other, a large gecko named *Hoplodactylus delcourti*, was found in a French museum and assumed to have come from New Zealand, but firm evidence of its origin has not been established (Towns and Daugherty, 1994).

While examples of extinction are few, the evidence of drastic population declines is overwhelming. Lizard bones found in caves, dunes and middens show that many of the species now threatened on the mainland or confined to small islands were once widespread (Towns and Daugherty, 1994). Species which once had continuous populations are now absent from large areas or limited to isolated populations hundreds of kilometres apart. In the northern North Island, for example, 10 (56 percent) of the 18 resident lizard species have gone. Most of the remaining 8 species persist in low numbers and in scattered localities (Towns and Daugherty, 1994).

Human predation probably played little direct role in the decline of the lizards, though it may have affected the tuataras, first by reducing the seabird populations on whom coastal tuataras preyed, and second by reducing the tuataras themselves. Tuatara bones are common in Maori middens. Several lizard species are also found in middens but were probably trapped there while scavenging (Towns and Daugherty, 1994). Lizards were viewed with fear by Maori because of their presumed magical powers. They were generally avoided, though some were killed when encountered because of their evil powers, while others were called on for protection, some species more than others. Lizard and tuatara carvings sometimes guarded sacred places (Buck/Hiroa, 1949; Sharell, 1966).

European settlers had little interest in hunting lizards, but museum collectors in the late

1800s harvested tuataras intensively and may also have put pressure on some lizard populations. The collectors appear to have eliminated one tuatara population (on East Island) before legislation stopped the trade (Towns and Daugherty, 1994).

Habitat loss has had a significant impact on the reptiles. In recent decades, for example, two species of South Island 'giant' skinks (*Oligosoma grande* and *O. otagense*) declined when their native tussock habitat was converted to exotic pasture grasses. Another skink, *O. striatum*, has been seldom seen since forests in the western central North Island were cleared for grazing. Not all reptiles respond negatively to habitat modification, however. Tuataras on some islands, for example, can reach artificially high densities when areas of forest are converted to pasture—provided predators are not present (Towns and Daugherty, 1994). In such circumstances, hungry tuataras may be a threat to other endangered species confined to the islands with them, such as giant wetas and click beetles.

Predatory mammals appear to have taken the greatest toll of New Zealand's reptiles. The first predator onslaught occurred when the Pacific rat arrived. The tuatara, the Robust skink (*Cyclodina alani*) and McGregor's skink (*Cyclodina macgregori*) were among the first reptilian casualties. By the time Europeans reached New Zealand, these species had disappeared from the mainland, where they were once widespread (Towns and Daugherty, 1994).

The second onslaught occurred about 500 years later when Norway rats arrived in European ships. They were accompanied by pigs, which also eat lizards and tuataras. Norway rats are bigger and more aggressive than Pacific rats and can swim up to 1.4 km in salt water, making them a threat even to lizards on some islands close to the coast. The dense tuatara population on Whenuakura Island off the Coromandel coast was wiped out within two years of being invaded by these rodent Vikings (Newman, 1986).

The third onslaught came in the late 1880s. This time even tree-dwelling skinks and geckos became victims as ship rats, stoats and cats joined the chase. The lizards most vulnerable to the predator onslaughts were the larger ones and those which were active at twilight or at night (Whitaker, 1978). Today, predator-free islands carry much greater species diversities and population densities than are found on the mainland or on islands where rats are still present. Lizard populations on islands where rats have been eradicated have shown rapid increases in numbers and habitat range (Towns and Daugherty, 1994).

A good example of what skink and gecko life must have been like on the mainland before human settlement can be seen on Middle Island in the Mercury Islands group where 11 reptile species co-exist in an area of just 13 hectares. A study site in native tussockland in central Otago also shows how a relatively small area can support a dense and diverse population of lizards. Eight species live together, but they occupy very specific niches, vary considerably in size, and have slightly different tastes in food (see Table 9.26) (Towns and Daugherty, 1994). On island sanctuaries the tuataras, skinks and geckos are relatively safe, though their populations often remain small and, hence, vulnerable. On the mainland, however, several of our reptiles are at considerable risk, even in reserves.

Since 1955, the number of known lizard species has more than doubled, from 29 to 61, as scientists have discovered new ones or reclassified old ones. More rare species are probably awaiting discovery but, given their small populations and the threats facing them, identification will be a race against time. In late 1995 the Department of Conservation began investigating reports from forestry workers that large lizards had been seen in the Bay of Plenty. To many people, however, one lizard looks the same as any other, a perception which herpetologists are trying to dispell. Not only are geckos and skinks quite different from each other, the species themselves show considerable diversity.

#### *Geckos*

Geckos are distinguishable from skinks by their wide eyes, benign smile and slightly baggy skin. They are seen less often than skinks because few geckos inhabit urban areas. Well camouflaged, and with excellent hearing and eyesight, they can easily avoid detection. Geckos are long-lived; some are known to live for more than 40 years. The ancestors of both the skinks and the geckos have been established in New Zealand for more than 15 million years (Patterson and Daugherty, 1995).

New Zealand's 29 gecko species are all unusual in the way they produce their young. They give live birth to baby geckos, almost always twins, instead of laying eggs. Only one other gecko, a New Caledonian species, is known to bear live young. Recent research indicates that some geckos may play a significant role in plant pollination. Pollen, which smears the lizard's chin when it sips the nectar from the flowers of flax bushes and pohutukawa trees, can stay there for up to 24 hours (Higham, 1995). The most notable pollinators are the Pacific gecko (*Hoplodactylus pacificus*) and New Zealand's largest lizard, Duvaucel's gecko (*H. duvaucelii*).

#### *Skinks*

Skinks are the streamlined members of the New Zealand lizard fraternity. The 30 known species are all endemic, and all but one give birth to live young instead of laying eggs. The one exception is known as the egg-laying skink (*Oligosoma suteri*). Skinks are faring much worse than geckos at present, with twice as many on the threatened species list. One of the rarest species is Whitaker's skink (*Cyclodina whitakeri*) a 20 cm lizard once found throughout lowland forest areas of the North Island. It is now reduced to one tiny mainland population, and two small island populations with a total occupied area of less than 20 hectares (Towns, 1992; Towns and Elliott, 1996).

Among the rare species is New Zealand's largest and longest skink, the Chevron skink (*Oligosoma homalonotum*). With its pale head and brown body bearing 'lance corporal' markings, the Chevron skink measures up to 30 cm. It has a Category A ranking in the Department of Conservation's threatened species list and is found only on Great Barrier and Little Barrier Islands. Their feeding habits and behaviour are still largely a mystery. Cats are thought to be the Chevron skink's main predator, but pigs, ship rats, Pacific rats, and even mice, all add to the pressure. Habitat loss and degradation through residential subdivision and tourist development, and forest browsing by feral goats and cattle, have placed added pressure on the Chevron skink's survival on Great Barrier Island (Towns and McFadden, 1993; Close, 1994a).

#### *Tuatara*

Tuatara are the oldest and best known of New Zealand's reptiles. They are also the most long-lived, with some individuals having reached their 100th birthday. The order to which they belong, the Sphenodontida, had species in many parts of the Earth about 200 million years ago, but they were gradually driven to extinction as the closely related dinosaurs became more dominant. Most were gone or on the way out by 130 million years ago, except the tuataras which found a haven in the new-born New Zealand landmass.

Once abundant throughout the North and South Islands, both in forests and among coastal seabird colonies, the tuataras became extinct on both main islands after humans arrived. Today, two species survive on about 30 rat-free islands. Gunther's tuatara (*Sphenodon guntheri*) is limited to a small island in Cook Strait where about 300 adults and their young share a 1.7 hectare patch of scrub. In late 1995, 50 individuals were transferred to another island as part of an effort to extend the species' range (Holmes, 1995).

The common tuataras (*Sphenodon punctatus*) number about 60,000 and are divided into a Cook Strait sub-species and a Northern sub-species, the latter located on islands in the Bay of Plenty and the Hauraki Gulf. Though tuataras have been fully protected since 1895, the number of populations has fallen from 40 to 30 in the past century. Apart from rats and cats, tuataras are also threatened by international wildlife smugglers (Ansley, 1995).

#### *Visiting Reptiles*

In addition to the land-based reptiles, four species of marine turtles regularly visit with New Zealand. One of them, the leatherback turtle, is the heaviest reptile on Earth and can reach weights of nearly a tonne (the record-holder weighed 961 kg). Two species of highly venomous sea-snakes also slip in from time to time but, as denizens of warmer waters in tropical climes, their visits are probably accidental.

**Table 9.27**

**New Zealand's threatened, non-threatened and island-bound reptiles**

| Species | Common Name | Rare or Threatened * | Conservation priority** | Limited mainly to islands |
|---|---|---|---|---|
| ***Tuatara (2 species)*** | | ***2*** | ***2*** | ***2*** |
| *Sphenodon guntheri* | *Brothers Islands tuatara* | + | *A* | + |
| *Sphenodon punctatus* | *Tuatara* | + | *B* | + |
| ***Skinks (30 species, 25 formally described)*** | ***17*** | ***16*** | ***18*** | |
| *Cyclodina aenea* | *Copper skink* | - | | - |
| *Cyclodina alani* | *Robust skink* | + | *B* | + |
| *Cyclodina macgregori* | *McGregor's skink* | + | *B* | + |
| *Cyclodina oliveri* | *Marbled skink* | - | | + |
| *Cyclodina ornata* | *Ornate skink* | - | | - |
| *Cyclodina whitakeri* | *Whitaker's skink* | + | *B* | + |
| *Cyclodina new sp. 1 (Mokohinau Is. and Hen and Chicken Is.)* | *Mokohinau skink* | + | *A* | + |
| *Cyclodina new sp. 2 (Poor Knights Is.)* | *(No common name)* | + | *C* | + |
| *Oligosoma acrinasum* | *Fiordland skink* | - | | + |
| *Oligosoma chloronoton* | *Green skink* | - | | - |
| *Oligosoma fallai* | *Three Kings skink* | + | *C* | + |
| *Oligosoma grande* | *Grand skink* | + | *A* | - |
| *Oligosoma 'Garston skink' **** | *Garston skink* | - | *A* | - |
| *Oligosoma homalonotum* | *Chevron skink* | + | *A* | + |
| *Oligosoma inconspicuum* | *(No common name)* | - | | - |
| *Oligosoma infrapunctatum* | *Speckled skink* | - | | - |
| *Oligosoma lineoocellatum* | *Spotted skink* | - | | - |
| *Oligosoma maccanni* | *McCann's skink* | - | | - |
| *Oligosoma microlepis* | *Small-scaled skink* | + | *A* | - |
| *Oligosoma moco* | *Moko skink* | - | | + |
| *Oligosoma nigriplantare nigriplantare* | *Chatham Is. skink* | + | | + |
| *" " polychroma* | *Common skink* | - | | - |
| *Oligosoma notosaurus* | *Southern skink* | + | *I* | + |
| *Oligosoma otagense form 'otagense'* | *Otago giant skink* | + | *A* | - |
| *" " form 'waimatense' ***** | *Scree skink* | + | *B* | - |
| *Oligosoma smithi* | *Shore skink* | - | | - |
| *Oligosoma stenotis* | *Small-eared skink* | + | *C* | + |
| *Oligosoma striatum* | *Striped skink* | + | *A* | - |
| *Oligosoma suteri* | *Egg-laying skink* | - | | + |
| *Oligosoma zelandicum* | *Brown skink* | - | | - |
| *Oligosoma n. sp. 1 (long-toed form)* | *Long-toed skink* | + | *B* | - |
| *Oligosoma n. sp. 2 (Open Bay Island)* | *Open Bay Is. skink* | + | *A* | + |
| ***Geckos (29 species, 16 formally described)*** | | ***7*** | ***8*** | ***8*** |
| *Hoplodactylus chrysosireticus* | *Gold-striped gecko* | + | *C* | - |
| *Hoplodactylus duvaucelii* | *Duvaucel's gecko* | - | | + |
| *Hoplodactylus granulatus* | *Forest gecko* | - | | - |
| *Hoplodactylus kahutarae* | *Black-eyed gecko* | + | *B* | + |
| *Hoplodactylus maculatus* | *Common gecko* | - | | - |
| *Hoplodactylus nebulosus* | *(No common name)* | - | *B* | + |
| *Hoplodactylus pacificus* | *Pacific gecko* | - | | - |
| *Hoplodactylus rakiurae* | *Harlequin gecko* | + | *B* | + |
| *Hoplodactylus stephensi* | *Stephens Is. gecko* | + | *B* | + |
| *Hoplodactylus n. sp. Nth'n Kaikouras* | *(No common name)* | - | | - |
| *Hoplodactylus n. sp. Marlborough* | *(No common name)* | - | | - |
| *Hoplodactylus n. sp. Mount Arthur* | *(No common name)* | + | *B* | - |
| *Hoplodactylus n. sp. Canterbury* | *(No common name)* | - | | - |
| *Hoplodactylus n. sp. Southern Alps* | *(No common name)* | - | | - |
| *Hoplodactylus n. sp. Danseys Pass* | *(No common name)* | + | *B* | - |
| *Hoplodactylus n. sp. Eastern Otago* | *(No common name)* | - | | - |
| *Hoplodactylus n. sp. Western Otago* | *(No common name)* | - | | - |
| *Hoplodactylus n. sp. 'Southern mini'* | *(No common name)* | - | | - |
| *Hoplodactylus n. sp. Westland* | *(No common name)* | - | | - |
| *Hoplodactylus n. sp. Three Kings Is.* | *(No common name)* | - | | + |
| *Hoplodactylus n. sp. Matapia Island* | *(No common name)* | + | *B* | + |
| *Hoplodactylus n. sp. Poor Knights Is.* | *(No common name)* | - | | + |
| *Naultinus elegans elegans* | *Auckland green gecko* | - | | - |
| *" " punctatus* | *Wellington green gecko* | - | | |
| *Naultinus gemmeus* | *Jewelled gecko* | - | | - |
| *Naultinus grayii* | *Northland green gecko* | - | | - |
| *Naultinus manukanus* | *Marlborough green gecko* | - | | - |
| *Naultinus rudis* | *Rough gecko* | - | | - |
| *Naultinus stellatus* | *Nelson green gecko* | - | | - |
| *Naultinus tuberculatus* | *(No common name)* | - | | - |
| ***Totals for all reptiles*** | ***26*** | ***25*** | ***25*** | |

* *Status assessed by Daugherty et al.(1994)*
** *Conservation priority assigned by the Department of Conservation (1994b)*
*** *The 'Garston Skink', listed by the Department of Conservation, is not included in the species totals as it is based on one dead specimen from central Otago whose taxonomic status is unclear.*
**** *The 'waimatense' form of Oligosoma otagense is now generally accepted as a distinct species.*

**The State of Our Indigenous Birds**

Although New Zealand's birds are a well-researched group, it is not possible to say with precision how many species and sub-species have lived and died here. New genetic studies and newly discovered bones continually revise our count of existing and extinct species. Such revisions improve our knowledge of the birds' story but, unfortunately, they do not make it read any better. Each newly identified species merely adds to the extinction list or the currently threatened list.

Apart from taxonomic revisions, the statistics on New Zealand birds can be confusing for other reasons. Many species are divided into several subspecies, or geographically isolated populations, some of which have their own distinctive characteristics. These populations are often treated as separate taxonomic units (or taxa) thus adding to the overall bird count. Further sources of confusion arise when whole groups of birds are excluded from the statistics, such as seabirds, or introduced birds, or non-endemic native birds (i.e. those native to both New Zealand and Australia).

If all New Zealand's bird taxa (species plus additional subspecies) are counted, including seabirds, non-endemics and introduced species, the total number of bird taxa currently in New Zealand comes to 231, comprising 33 alien species, 126 native land species and subspecies, and 72 native seabird species and subspecies. The threat of extinction is not spread evenly among them, however. The taxa most at risk are those which happen to be the most unique—the endemics. All our extinct species and nearly all our threatened species are endemic.

In contrast, the introduced and non-endemic birds tend to be mobile and adaptable. Most of the introduced birds were brought from Europe or Australia within the past 150 years and are well-adapted to the open landscape humans have created here. Most of the non-endemic natives are also open-space birds. Some are migratory species, for whom New Zealand is a necessary part of their international range. Others are accidental tourists that flew or blew here within the last few thousand years from Australia or the Antarctic. They include such successful species as the harrier hawk, the pukeko and the black-backed gull. As if their success in modern New Zealand were not enough, the introduced and non-endemic species are also buffered from extinction by having secure populations overseas. In contrast, the endemic birds are on their own.

Most of the following discussion is concerned with the state of our endemic birds. Land and sea-going species are discussed separately. Where relevant, statistics are given for both species and taxa (i.e. species plus additional subspecies). The species classification generally follows the Ornithological Society's 1990 checklist (Turbott, 1990), but also includes four extinct seabirds yet to be formally described and named.

Ignoring subspecies, it appears that, when humans reached New Zealand, they found at least 131 full species of land birds (that is birds whose primary habitat is on land, freshwater or the coast) and 65 species of seabirds (e.g. gulls, albatrosses, petrels and penguins). More than two-thirds of the land birds (93 species) and one-third of the seabirds (22 species, including the four unnamed ones) were endemic or unique to New Zealand (see Tables 9.28 and 9.29).

Today, 43 of the endemic land species (46 percent) are extinct, and 4 of the endemic seabirds (18 percent). A further 7 subspecies of land birds are also extinct. In the towns and farmland of New Zealand it is hard to imagine the scale of the country's bird losses because birds still seem plentiful. Sparrows, starlings, blackbirds, chaffinches, song thrushes and magpies are everywhere. Asian mynas dominate the road verges in the upper North Island. Introduced pigeons form dense clusters in city centres. Rooks have become closely watched agricultural pests in Canterbury and the Wairarapa. But all these birds, 33 species in total, are interlopers brought here in the past 150 years. They bear little resemblance to the giants they have replaced—the great Haast's eagle, the giant swan, the pelican, the rails and, of course, the moas.

***Endemic land birds (i.e. land, freshwater and coastal birds)***

By the time Europeans arrived, 34 species and 1 subspecies (35 taxa) of endemic land birds had gone. Following European settlement 9 more species and their constituent subspecies (13 taxa in all) were wiped out and a further 6 subspecies were lost. This leaves 50 surviving endemic species (comprising 102 taxa), of which 37 (comprising 66 taxa) are now listed as threatened (Department of Conservation, 1994b).

Overall, then, 84 percent of New Zealand's endemic land bird species have become extinct or threatened since human occupation. Of today's 50 surviving species, 74 percent are threatened (see Figure 9.7). These statistics are only likely to worsen in the foreseeable future as palaeontologists and archaeologists bring more evidence of extinct species to light, and as pests and habitat degradation push more birds onto the threatened list or into oblivion.

The irony of this is that the thing which makes the endemic birds unique and globally important—their evolutionary isolation—is also what has rendered them so vulnerable (Holdaway, 1989; Anderson and McGlone, 1992). They evolved no defences against humans and other hungry mammals (see Table 9.28). For the first time they faced predators that could hunt by smell at night and that could follow them into their tunnels and hollows. Many had little or no ability to fly, so they could not escape forest fires and hunters, nor emigrate to safer habitats.

**Table 9.28**
**The state of New Zealand's indigenous land, freshwater and coastal birds.**

| Description of status | Indigenous species | | | Indigenous taxa (including subspecies) | | |
|---|---|---|---|---|---|---|
| | Endemic | Non-endemic | All | Endemic | Non-endemic | All |
| *Number of 'original ' land birds (i.e. those described from subfossils or living specimens)* | *93* | *38* | *131* | *156* | *24* | *180* |
| *Land bird extinctions that occurred prior to European settlement.* | *34** | *0* | *34* | *35* | *0* | *35* |
| *Land birds remaining when Europeans settled in New Zealand.* | *59* | *38* | *97* | *121* | *24* | *145* |
| *Land bird extinctions that occurred after the arrival of Europeans.* | *9* | *0* | *9* | *19* | *0* | *19* |
| *Total number of known land bird extinctions.* | *43* | *0* | *43* | *54* | *0* | *54* |
| *Percentage of 'original' land birds now extinct.* | *46%* | *0%* | *33%* | *35%* | *0%* | *30%* |
| *Land birds surviving in 1994 (with probable extinctions included as extinct).* | *50* | *38* | *88* | *102* | *24* | *126* |
| *Land birds threatened with extinction (i.e. those in categories A, B, and C in Department of Conservation Threatened Species publication: DOC 1994b).* | *37* | *0* | *37* | *66* | *0* | *66* |
| *Percentage of remaining land birds that are threatened with extinction.* | *74%* | *0%* | *42%* | *65%* | *0%* | *52%* |

*Source: Department of Conservation*
** All but 9 of these species have been found in middens.*

**Box 9.19**

### *The plight of the takahe*

The takahe (*Porphyrio mantelli*) is a flightless blue bird belonging to the rail family. It looks like a heavier version of its close cousin, the pukeko, or Purple Swamphen. In fact, the takahe is a descendant of stray pukekos which landed here from Australia several million years ago. In the placid New Zealand environment they lost the power of flight, put on weight, and prospered. Now they are in danger of dying out. The takahe were already rare when Europeans arrived and, for the first half of this century, were thought to be extinct. In 1948, however, about 500 survivors were found in the rugged and remote Murchison Mountains in Fiordland. Several pairs have been transferred to predator-free islands and have had some breeding success. But in the wild their plight is worsening. The Fiordland population is down to about 115 birds.

For a long time it was believed that the takahe's preferred habitat was the high tussock country where the survivors were found (Mills *et al*., 1984). Although takahe bones have been dug up in many parts of New Zealand, these were assumed to date from Ice Age times when tussock grasslands were more extensive. Today, however, the bones are believed to be more recent. Far from being tussock dwellers, it now seems that the takahe were most at home stepping and pecking their way along the edges of lowland streams and forests. The Murchison Mountains are merely their last inhospitable refuge from the onslaught of humans, rats and fire (Bunin and Jamieson, 1995).

Until recently, red deer (*Cervus elephus*) were blamed for steadily reducing takahe numbers by competing for what was assumed to be the birds' favorite food, snow tussock. However, after an intense deer eradication programme, the snow tussock has recovered, but not the takahe. The latest research suggests that the birds face the same problems as other small populations trapped in ecological 'islands'. The takahe are not prolific breeders and, faced with stoats and the harsh and changeable weather of the Murchison Mountains, the species is on a knife edge.

Having adapted to an environment free of mammalian predators, the takahe are not 'street wise' like their pukeko cousins. They appear to lack the know-how to recognise and avoid enemies. In contrast, the pukeko, which arrived here from Australia about 1,000 years ago, is one of our most common native birds, in spite of the best efforts of human hunters, rats, stoats and other predators. The pukeko has the advantage of being able to fly, albeit reluctantly and briefly, but another flightless New Zealand bird, the weka, has proved that you don't have to fly to survive. The knack may simply be in knowing when to run and what to run from.

Researchers recently tested this theory in a cross-fostering experiment with pukeko. Takahe eggs were slipped into a pukeko nest to find out whether the pukeko would be effective foster parents (thus freeing the takahe parents to produce more chicks) and also to see whether the takahe chicks may pick up a few survival skills from their foster family (Bunin and Jamieson, in press). The research was limited by a shortage of viable eggs. Over two breeding seasons, only 12 takahe eggs could be given to the pukeko, of which only eight hatched and only two produced chicks that survived. One of these chicks was used in a predator defence experiment with a model stoat. The chick appeared to respond more to the stoat than did another takahe chick reared by takahe parents. It was also more likely to leave the danger area.

With such a small sample, the behavioural experiment was far from conclusive, but the exercise did show that pukeko will hatch and raise takahe chicks, and that takahe will lay more eggs if the first clutch is removed. At the same time, it also confirmed that takahe eggs often fail to hatch, and that takahe chicks are often frail. Until scientists can find ways to solve these problems, the takahe will struggle to survive.

In the face of such pressures and limitations, the survival to date of some species is nothing short of remarkable. Among the threatened land birds are most of our flightless species, such as the takahe (see Box 9.19), the kiwi (see Box 9.20), the weka, the Auckland Island and Campbell Island teals, and the desperately endangered kakapo.

#### *Kakapo*

The kakapo (*Strigops habroptilus)* is a large flightless ground-dwelling parrot that managed to stay abundant in areas far away from Maori hunters and fires but declined dramatically after night-hunting mammals, such as cats, were introduced (Holdaway, 1989). A mere 50 survivors are known today. As part of the effort to save them from extinction, they have all been shifted from Stewart Island, where they were clinging to existence, onto three stoat- and cat-free island sanctuaries.

**Figure 9.7**

**The declining state of New Zealand's endemic land, freshwater and coastal birds.**

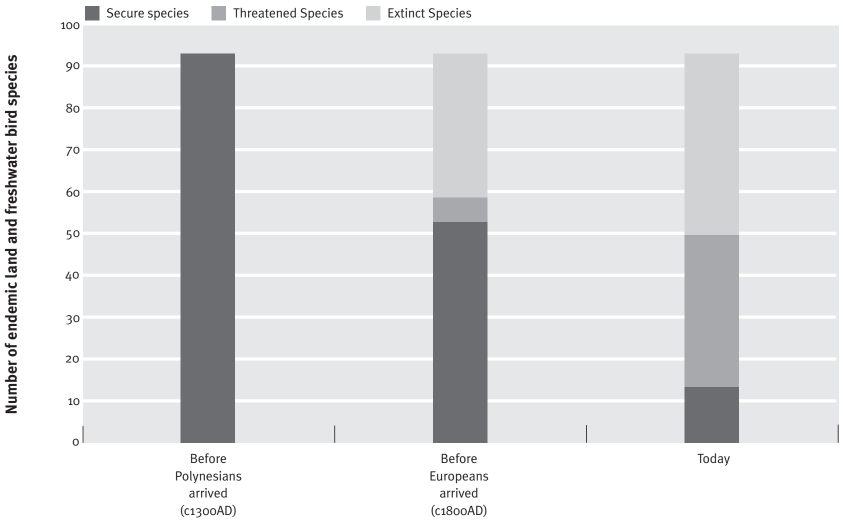



**Table 9.29**
**Some of New Zealand's extinct birds and the probable causes of their extinction.**

| | Vulnerable traits | | | | | Agents of extinction | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Flightless** | **Poor fliers** | **Ground-nesting** | **Small bodied** | **Small population** | **Rat** | **Dog** | **Human** | **Loss of habitat or prey** |
| *Moas* | *X* | | *X* | | | | *?* | *X* | *X h* |
| *Pelican* | | | *X* | | *X* | | | *X* | |
| *Swan* | *?* | *?* | *X* | | *X* | | *X* | *X* | |
| *Geese* | *X* | | *X* | | *X* | | *X* | *X* | *X h* |
| *Finsch's duck* | *?* | *X* | *X* | | | *X* | | | *X h* |
| *Blue-billed duck* | | | *X* | | *X* | *X* | | | |
| *Musk duck* | | | *X* | | *X* | *X* | | | |
| *Chatham Is. duck* | | *X* | *X* | | | | | *X* | |
| *Haast's Eagle* | | | | | *X* | | | | *X p* |
| *Goshawk* | | | | | *X?* | | | | *X h,p* |
| *Snipe-rail* | *X* | | *X* | *X* | | *X* | | | |
| *Giant coot* | *X* | | *X* | | | *X* | *X* | *X* | |
| *Hodgen's waterhen* | | | *X* | *X* | | *X* | | | |
| *Chatham Is. Giant rail* | *X* | | *X* | | | | | *X* | |
| *Adzebill* | *X* | | *X* | | | *X* | *X* | *X* | *X h,p* |
| *Snipe* | *X* | | *X* | *X* | | *X* | | | |
| *Giant owlet nightjar* | | *X* | *X* | *X* | | *X* | | | *X h,p* |
| *NZ wrens* | *X* | *X* | *X* | *X* | | *X* | | | |
| *NZ raven* | | | | | | | | *X* | *X h,p* |

*h = habitat loss*
*p = prey or carrion loss*
*Source: Anderson and McGlone (1992)*

**Box 9.20**

### *Beleaguered kiwis*

To Californians, a 'kiwi' is the fat brown Chinese gooseberry now marketed around the world as 'kiwifruit'. To Australians, it is the national nickname and marketing symbol of their New Zealand neighbours. To New Zealanders, it is both of these things but it is still, first and foremost, a bird. The question is, for how much longer? Introduced predators, loss of habitat and a measure of public complacency have reduced once flourishing populations to remnants. It is a strange way of repaying the bird that has helped put us and our products 'on the map'.

Kiwis are forest dwellers. At night they seek spiders, earthworms, and larger creatures such as frogs, fallen fruits and seeds. Kiwi couples tend to pair for life. Some are known to have been together for more than 30 years. Having evolved in a land without ground-dwelling mammals, the kiwi became a sort of pseudo-mammal. It is flightless and ground-burrowing. It has hair-like feathers and a body temperature closer to mammals than birds. It is the only bird known to have external nostrils at the end of its bill and a keen sense of smell to match. Even laying an egg is more like a mammalian birth. Only one egg is laid and it is an astounding 20 percent of the females' bodyweight—the largest egg-to-bodyweight ratio of any bird. With such a huge investment in just one offspring, both the male and female are devoted egg sitters and parents.

The kiwi genus (*Apteryx* spp.) is New Zealand's most ancient group of living birds, and one of Earth's oldest. The ancestral kiwi evolved shortly after the New Zealand landmass broke away from Gondwana about 80 million years ago. It belonged to the ancient ratite group of birds whose handful of large, flightless, species include Australian emus, Papuan cassowaries, South American rheas and tinamous, African ostriches and New Zealand's extinct moa. During New Zealand's Oligocene drowning, the early kiwi populations evolved into four separate species: the *great spotted*, the *little spotted*, the *northern brown*, and the recently identified *southern brown* or tokoeka.

The Department of Conservation further divides the northern brown into the North Island and the Okarito varieties, and the southern brown into the southern tokoeka (in Stewart Island and Fiordland), and the Haast tokoeka.

About 25,000 great spotted kiwis are thought to exist. Since European settlement their range has diminished by about one-third. They now occupy high rainfall areas in north Westland and Nelson where the surviving population may be stable because stoats are less prevalent in very wet habitats. The much rarer little spotted kiwi is lucky to be here at all. It would almost certainly be extinct were it not for island sanctuaries. Its population is now estimated to be about 1,500 birds, and growing. The most threatened kiwis are probably the northern browns, despite being the most numerous and widespread. Their population is declining at a rate of 5.8 percent per year but could be halted if predation on young kiwis by stoats and cats were cut by a third (McLennan *et al.,* 1996). In Northland the spread of ferrets and possums into the remaining pockets of lowland forest is placing them under extreme threat (Miller and Pierce, 1995). At the other end of the country, the southern browns appear to be holding their own on Stewart Island, probably because there are no stoats there, but the Haast population of about 200–300 birds is regarded as a remnant colony whose habitat is almost confined to the top of one range.

Efforts are being made, as resources permit, to slow the kiwis' decline in key areas and prevent their extinction. The Department of Conservation, the Royal Forest and Bird Protection Society, and the Bank of New Zealand, have joined forces in 'The Kiwi Recovery Programme'. Funds from the programme are being used to educate the public about the kiwis' plight and to support captive breeding programmes in which birds that face extinction in their natural environments are moved to predator-free 'museum environments' on offshore islands.

Since the intensive kakapo conservation programme began in 1989, only 13 chicks had hatched by 1995, and almost all had died as a result of predation or starvation. The Pacific rat, or *kiore*, is now generally accepted to be a major threat to nesting kakapo. Intensive research continues into the parrot's diet and how to improve it. On top of these concerns is the growing fear that the birds' biological clocks may be running out. Of the 50 surviving parrots, only 19 are females and most are more than 30 years old. They may be nearing, or at, the end of their reproductive lives.

*The threatened ducks*

The flightless Campbell Island teal (*Anas aucklandica nesiotis*) is our most threatened native duck. Only 50 to 100 of these small, almost cocoa-coloured, birds survive. After 10 years of trying to breed in captivity, four ducklings hatched in 1995. They, and any others bred by conservationists, will probably end up on another of New Zealand's island sanctuaries. Plans are under way to clear the rats from Centre Island in Foveaux Strait to make a teal refuge. The Campbell Island teal is a close relative of another highly threatened duck, the Auckland Island teal (*Anas aucklandica*). It, too, has lost the ability to fly and uses its small wings mainly to help it scramble out of the seaweed kelp forests where it feeds. It lives on coastal rocks in sheltered bays.

Not all our threatened ducks are flightless. The attractive blue duck (*Hymenolaimus malacorhynchos*), for instance, can fly but this has not prevented it from being reduced to a few small populations on remote fast-flowing rivers in the North and South Islands. Another teal, the brown teal (*Anas chlorotis*), can also fly but has experienced a similar reduction in numbers and range. Once common on swampy streams and tidal creeks shaded by overhanging trees, they were often killed for food by the early European settlers. As wetlands were turned into farmland, their numbers dropped dramatically. They now survive in the wild mainly in Northland.

***Endemic seabirds***

Of the 22 endemic seabird species (encompassing 39 taxa) which were here when people arrived, 18 survive (Turbott, 1990). Fifteen of the surviving species (83 percent), or 26 of the surviving 35 taxa (74 percent), are now listed as threatened (Department of Conservation, 1994b). These include 5 penguins (among them the world's rarest, the yellow-eyed penguin), 7 mollymawks, 4 albatrosses (including the royal albatross which nests at Taiaroa Head, near Dunedin), and 4 petrels. Threats include predation on nests and eggs by ferrets, stoats, rats, cats and humans, incidental capture by longlines and setnets, long-term changes to feeding grounds as sea temperatures rise, and localised pressures from pollution and toxic algal blooms.

The Chatham Islands are home to six of our most threatened seabirds. Several seabirds became extinct there following human settlement and today 24 seabird species still breed in the islands. Top of the threatened seabird list are the Chatham Islands taiko (*Pterodroma magentae*) and the Chatham petrel (*Pterodroma axillaris*). The other four threatened birds are the Northern royal albatross (*Diomeda epomophora sanfordi*), Northern Buller's albatross (*Diomeda bulleri platei*), Chatham Island albatross (*Diomeda cauta eremita*), and the Chatham Island shag (*Leucocarbo onslowi*) (Bell and Robertson, 1994).

The taiko or magenta petrel is a large bird, with a deep brownish-black head, neck and throat. It is one of the 'gadfly' group of petrels, named for their airy drifting flight punctuated by startlingly abrupt free-falls (Falla *et al.*, 1979). For more than a century the taiko was considered extinct. Breeding in burrows on the main island, it was easy prey for human hunters and the many bones found in middens indicate that it became a major food source for the Moriori people. The spread of predators such as rats and ferrets all but sealed the bird's fate.

The taiko was rediscovered on New Years Day 1978 and the population now has between 50 and 150 birds. Only four burrows are known to harbour breeding pairs, but the discovery of pairs of birds in another two burrows in 1993 has raised hopes that the number of breeding couples may rise to six. In 1994, the best breeding year so far, four known breeding pairs produced a chick each. All four died, however, even though intensive predation control was carried out.

**Table 9.30**
**The state of New Zealand's indigenous seabirds**

| Description of status | Indigenous species | | | Indigenous taxa (including subspecies) | | |
|---|---|---|---|---|---|---|
| | Endemic | Non-endemic | All | Endemic | Non-endemic | All |
| *Number of 'original' seabirds (i.e. those described from subfossils or living specimens)* | *22* | *43* | *65* | *39* | *37* | *76* |
| *Seabird extinctions that occurred before European settlement.* | *4** | *0* | *4* | *4* | *0* | *4* |
| *Seabird extinctions that occurred after the arrival of Europeans.* | *0* | *0* | *0* | *0* | *0* | *0* |
| *Seabirds surviving in 1994.* | *18* | *43* | *61* | *35* | *37* | *72* |
| *Seabirds threatened with extinction (i.e. those in categories A, B, and C in Department of Conservation Threatened Species publication: DOC 1994b).* | *15* | *3* | *18* | *26* | *3* | *29* |
| *Percentage of remaining seabirds that are threatened with extinction.* | *83%* | *7%* | *30%* | *74%* | *8%* | *40%* |

*Source: Department of Conservation*
** These, as yet unnamed species, have all been found in middens.*

Captive rearing of petrels has rarely been attempted and the rearing of seabirds in general without parental involvement is rare. To determine the requirements for captive rearing of the taiko, a trial is now in its second season at the Mount Bruce Reserve using eggs from the grey-faced petrel. One chick has survived, providing valuable information on such things as incubation temperature and feeding strategies. Predator numbers are still high, and twice-yearly trapping is carried out as part of the taiko conservation effort. The principal threats to the survival of the threatened birds are mammalian predation, destruction of ground nesting habitat by pastoral farming, occasional recreational and customary hunting, and possible climatic and oceanic changes or cycles (Bell and Robertson, 1994).

A significant threat to some seabird species is the risk of getting hooked on tuna longlines. Nearly 20 seabird taxa from 14 different species, 5 of them endemic, have been recorded among the longline bycatch. All these birds are legally protected and, under recent amendments to the Wildlife Act 1953, this protection now extends to the limit of New Zealand's Exclusive Economic Zone (EEZ). Among the victims are the wandering albatross, the snowy albatross, the southern black-browed albatross, the grey petrel and several threatened species, namely: the New Zealand black-browed albatross, the grey-headed albatross, the New Zealand white-capped albatross, the black petrel and the Westland black petrel.

Government observers on foreign tuna boats have recorded seabird bycatch since the late 1980s. However, the quality of the observer data is uneven, with marked fluctuations in some years (e.g. 16 observed captures in 1992 and 215 observed captures the following year). The observed catch rate per hundred sets has varied from 7 to 196 in the northern tuna fishery and from 4 to 80 in the southern fishery. While most of these fluctuations reflect uneven observer coverage, they may also reflect variations in fishing effort (e.g. the number of lines and hooks set in a given year); the use of mitigation measures by the boats carrying observers (e.g. the percentage of properly deployed tori lines); the choice of areas for setting longlines; and the degree of visibility during night sets (Duckworth, 1995).

Most seabirds are caught in the brief period between the longline being thrown overboard (setting) and it sinking out of diving reach (soaking). The baited longline provides a tempting meal and, once a bird has become hooked or entangled, it is dragged under and drowned. Observers are generally sleeping during this part of the operation, their main role being to record fish species during the 10–17 hour hauling-in phase. Most seabird deaths are therefore recorded hours after they occur, when the lines are pulled in, by which time an unknown number may have been eaten by sharks, become detached from the line, or died elsewhere from injuries sustained in tearing free (Brothers, 1991).

**Table 9.31**
**New Zealand seabird captures by Japanese tuna boats, 1988–95.**

| | Observed captures[1] | Estimated captures[2] | Best estimate | Total number of longline sets | Percentage of sets observed |
|---|---|---|---|---|---|
| ***1988***[3] | *15* | *234–1,406* | *820* | *2,231* | *2%* |
| ***1989*** | *123* | *1,697–6,261* | *3,979* | *3,310* | *3%* |
| ***1990*** | *129* | *1,197–3,595* | *2,396* | *2,918* | *5%* |
| ***1991*** | *37* | *266–1,092* | *629* | *4,452* | *3%* |
| ***1992*** | *16* | *16–371* | *185* | *3,148* | *8%* |
| ***1993*** | *215* | *310–1,146* | *728* | *1,499* | *28%* |
| ***1994*** | *108* | *108–176* | *132* | *320* | *76%* |
| ***1995*** | *90* | *90–252* | *167* | *463* | *54%* |
| ***Yearly average 1989–95*** | *103* | *526* | *1,174* | *2,301* | *10%* |

[1] *Seabird captures include live and dead birds recorded by MAF Fisheries observers.*
[2] *Estimates are based on observer data extrapolated over the whole fleet and have a 95% confidence interval.*
[3] *1988 data are for the northern tuna fishery only. All other years combine northern and southern tuna fisheries.*

*Adapted from Baird (1996)*

The scale of the seabird bycatch has been hotly debated. Estimates refer only to the Japanese tuna boats operating in New Zealand waters. Information from the domestic tuna fleet has been too limited to make estimates. In 1990, when the Japanese fleet was four or five times larger than it is today, one unofficial estimate put the seabird toll at 5,000–25,000 deaths (Tennyson, 1990). Official estimates for the same year, based on Government observer data, have ranged from more than 9,000 captures, with perhaps 5,000 deaths (Murray *et al.*, 1992, 1993) to 1,200–3,600 captures (Baird, 1996). The official estimate for 1995 is 90–252 seabird captures by Japanese longliners in New Zealand waters (Baird, 1996).

Bycatch estimates are dependent on both the level and quality of observer coverage and the level of fishing effort. Betweeen 1987 and 1992, Government observers witnessed only 1–7 percent of the Japanese longline sets. The percentage increased dramatically after 1992 as the Japanese tuna fleet was severely reduced. In New Zealand's southern bluefin tuna fishery, for example, the Japanese fishing effort fell from about 12 million hooks in 1990 to less than 3 million hooks by 1995, and the estimated number of seabird captures has declined accordingly (see Table 9.31). Conversely, the unrecorded bycatch of 10–15 years ago must have been much greater than it is today. In the period 1979–1983, nearly 22 million hooks were set each year in the southern bluefin fishery. This may have been a crucial factor in driving some species onto the threatened list.

As late as 1990, the 32 Japanese boats catching southern bluefin were accompanied by only 2 New Zealand longliners. By 1995, however, the number of Japanese vessels had declined to 9, while New Zealand longliners had multiplied to 25. The bycatch from these domestic vessels is not known, but conscientious efforts are being made by the local industry to reduce the problem. However, beyond New Zealand waters, other longline tuna fisheries encircle the Antarctic, both on the high seas and in other countries' exclusive economic zones. Together, these longline fleets may catch as many as 40,000 or more seabirds each year, including many New Zealand birds whose flight paths are not limited to New Zealand waters (Tennyson, 1990; Brothers, 1991; Close, 1994b).

**Table 9.32**

**New Zealand's threatened birds**

| **Category X: Not seen for several years and possibly extinct** |
|---|
| *South Is. kokako (Callaeas cinerea cinerea)* |

| **Category A: Birds nearing extinction and having the highest conservation priority** | |
|---|---|
| *Campbell Is. teal (Anas aucklandica nesiotis)* | *Black stilt (Himantopus novaezealandiae)* |
| *Haast tokoeka (Apteryx 'Haast tokoeka')* | *Black robin (Petroica traversi)* |
| *North Is. brown kiwi (Apteryx 'North Is')* | *Takahe (Porphyrio mantelli hochstetteri)* |
| *Okarito brown kiwi (Apteryx 'Okarito brown')* | *Chatham Is. tui (Prosthemadera novaeseelandiae chathamensis)* |
| *NZ dotterel (southern) (Charadrius obscurus 'southern')* | *Chatham petrel (Pterodroma axillaris)* |
| *Orange-fronted parakeet (Cyanoramphus malherbi)* | *Taiko (Pterodroma magentae)* |
| *Chatham Is. oystercatcher (Haematopus chathamensis)* | *Fairy tern (Sterna nereis davisae)* |
| *Chatham Is. pigeon (Hemiphaga novaezeelandiae chathamensis)* | *Kakapo (Strigops habroptilus)* |

| **Category B: Seriously threatened birds with the second highest conservation priority** | |
|---|---|
| *Wrybill (Anarhynchus frontalis)* | *North Is. weka (Gallirallus australis greyi)* |
| *Great spotted kiwi (Apteryx haastii)* | *Stewart Is. weka (Gallirallus australis scotti)* |
| *Little spotted kiwi (Apteryx owenii)* | *NZ pigeon (Hemiphaga novaeseelandiae novaeseelandiae)* |
| *Southern tokoeka (Apteryx 'southern tokoeka')* | *Blue duck (Hymenolaimus malacorhynchos)* |
| *Stewart Is. fernbird (Bowdleria punctata stewartiana)* | *NZ king shag (Leucocarbo carunculatus)* |
| *Codfish Is. fernbird (Bowdleria punctata wilsoni)* | *Chatham Is. shag (Leucocarbo onslowi)* |
| *North Is. kokako (Callaeas cinerea wilsoni)* | *Yellow-eyed penguin (Megadyptes antipodes)* |
| *NZ dotterel (northern) (Charadrius obscurus 'northern')* | *Yellowhead (Mohoua ochrocephala)* |
| *Snares Is. snipe (Coenocorypha aucklandica huegeli)* | *South Is. kaka (Nestor meridionalis meridionalis)* |
| *Forbes' parakeet (Cyanoramphus auriceps forbesi)* | *North Is. kaka (Nestor meridionalis septentrionalis)* |
| *Chatham Is. red-crowned kakariki (Cyanoramphus novaezelandiae chathamensis)* | *Kea (Nestor notablis)* |
| *Stitchbird (Notiomystis cincta)* | *Northern Buller's mollymawk (Diomedea bulleri platei)* |
| *Chatham fulmar prion (Pachyptila crassirostris pyramidalis)* | *Chatham Is. mollymawk (Diomedea cauta eremita)* |
| *Kermadec white-faced storm petrel* | *Grey-headed mollymawk (Diomedea chrysostoma)* |
| *(Pelagodroma marina albiclunis)* | *Southern royal albatross (Diomedea epomophora epomophora)* |
| *South Georgian diving petrel (Codfish Is. population) (Pelecanoides georgicus 'Codfish Is')* | |
| *Northern royal albatross (Diomedea epomophora sanfordi)* | *Gibson's albatross (Diomedea exulans gibsoni)* |
| *South Is. saddleback (Philesturnus carunculatus carunculatus)* | *NZ black-browed mollymawk (Diomedea melanophrys impavida)* |
| *Black petrel (Procellaria parkinsoni)* | *Fiordland crested penguin (Eudyptes pachyrhynchus)* |
| *Westland petrel (Procellaria westlandica)* | *Erect-crested penguin (Eudyptes sclateri)* |
| *Buller's shearwater (Puffinus bulleri)* | *White-flippered penguin (Eudyptula minor albosignata)* |
| *Hutton's shearwater (Puffonis huttoni)* | *NZ falcon (Falco novaeseelandiae)* |
| *Black-fronted tern (Sterna albostriata)* | *Western weka (Gallirallus australis australis)* |
| *NZ shore plover (Thinornis novaeseelandiae)* | *Buff weka (Gallirallus australis hectori)* |

| **Group C: Threatened birds with the third highest conservation priority** | |
|---|---|
| *Brown teal (Anas aucklandica chlorotis)* | *Chatham Is. warbler (Gerygone albofrontata)* |
| *Three Kings bellbird (Anthornis melanura obscura)* | *Variable oystercatcher (Haematopus unicolor)* |
| *Poor Knights bellbird (Anthornis melanura oneho)* | *Campbell Is. shag (Leucocarbo campbelli)* |
| *Snares Is. fernbird (Bowdleria punctata caudata)* | *Stewart Is. shag (Leucarbo chalconotus)* |
| *Banded dotterel (Charadrius bicinctus bicinctus)* | *Auckland Is. shag (Leucocarbo colensoi)* |
| *Auckland Is. banded dotterel (Charadrius bicinctus exilis)* | *Bounty Is. shag (Leucocarbo ranfurlyi)* |
| *Auckland Is. snipe (Coenocorypha aucklandica aucklandica)* | *Northern giant petrel (Macronectes halli)* |
| *Antipodes Is. snipe (Coenocorypha aucklandica meinertzhagenae)* | *Stewart Is. robin (Petroica australis rakiura)* |
| *Chatham Is. tit (Petroica macrocephala chathamensis)* | *Chatham Is. snipe (Coenocorypha pusilla)* |
| *Snares Is. tit (Petroica macrocephala dannefaerdi)* | *Yellow-crowned parakeet (Cyanoramphus auriceps auriceps)* |
| *Auckland Is. tit (Petroica macrocephala marrineri)* | *Reischek's parakeet (Cyanoramphus novaezelandeae hochstetteri)* |
| *North Is. saddleback (Philesturnus carunculatus rufusater)* | *NZ dabchick (Poliocephalus rufopectus)* |
| *Antipodes Is. parakeet (Cyanoramphus unicolor)* | *White-naped petrel (Pterodroma cervicalis cervicalis)* |
| *Antipodes albatross (Diomedea exulans antipodensis)* | *Cook's petrel (Pterodroma cookii)* |
| *Southern Buller's mollymawk (Diomedea bulleri bulleri)* | *Chatham Is. fantail (Rhipidura fuliginosa penita)* |
| *Salvin's mollymawk (Diomedea cauta salvini)* | *White-fronted tern (Sterna striata)* |
| *NZ white-capped (shy) mollymawk (Diomedea cauta steadi)* | *Pitt Is. shag (Stictocarbo featherstoni)* |
| *Snares crested penguin (Eudyptes robustus)* | *Rock wren (Xenicus gilviventris)* |

| **Category O: Species which are threatened in New Zealand, but secure in other parts of their range outside New Zealand** | |
|---|---|
| *Common noddy (Anous stolidus pileatus)* | *White tern (gygus alba royana)* |
| *Australasian bittern (Botaurus poiciloptilus)* | *Royal spoonbill (Platalea regia)* |
| *White heron (Egretta alba modesdta)* | *Crested grebe (Podiceps cristatus australis)* |
| *Reef heron (Egretta sacra sacra)* | *Grey petrel (Procellaria cinerea)* |
| *Eastern rockhopper penguin (Eudyptes chrysocome filholi)* | *Caspian tern (Sterna caspia)* |
| *White-bellied storm petrel (Fregetta grallaria grallaria)* | |

*Source: Department of Conservation (1994b)*

## The State of Our Mammals

New Zealand has no native ground-dwelling mammals. Our few native mammals either fly or swim. The early ancestors of the mammals had not reached New Zealand when it split off from Gondwana about 80 million years ago. Before the ocean gap had become too wide, however, some bats flew or blew here and evolved into endemic species. The only other mammals to discover New Zealand without the aid of boats were marine ones—seals, sea lions, whales and dolphins.

### *The flying mammals*

Our native bats belong to two very different families. The comparatively normal long-tailed bat (*Chalinolobus tuberculatus*) is part of a worldwide family called the Vespertilionidae. It has close relatives in Australia. The short-tailed bat (*Mystacina tuberculata*) is so different from other bats that it belongs to a family of its own, the Mystacinidae, which exists only in New Zealand. The short-tailed bats are believed to have arrived here more than 35 million years ago, whereas long-tailed bats arrived about 3 million years ago.

In their isolation the short-tailed bats evolved some rather unbat-like ways. They rummage around on the ground for food, climb trees and have even been seen walking nimbly over boulders near the sea, wings tucked under forearms, hunting for insects and small marine invertebrates. They also eat fruit and nectar and are important pollinators of the threatened plant, *Dactylanthus taylorii* (Ecroyd, 1996).

Two species of short-tailed bat lived here but the larger of these was wiped out 30 years ago when rats invaded its last island refuge. The remaining species, the lesser short-tailed bat is listed as a 'high priority' threatened species. It is divided into northern, volcanic and southern subspecies, all of which are threatened. The long-tailed bat is also on the threatened list.

***The marine mammals***

Several times in the evolution of the mammals, different species took to the sea. In one case, about 50 million years ago, a wading relative of today's pigs, hippos and cattle evolved into a large otter-like animal, which gave rise to the world's whales and dolphins—the *cetaceans* (Thewissen *et al.*, 1994). Much later, between 20 and 25 million years ago, a population of wading bears also became otter-like and eventually evolved into today's seals and sea lions—the *pinnipeds* (Janis, 1994).

Some 34 species of cetaceans and 7 species of pinnipeds have been sighted in New Zealand waters, but only two are unique to New Zealand: Hector's dolphin (*Cephalorhynchus hectori*) and the New Zealand sea lion, also known as Hooker's sea lion (*Phocarctos hookeri*). The native New Zealand fur seal (*Arctocephalus forsteri*) is not endemic, being also found in southern Australia.

The massive elephant seals (*Mirounga leonina*), which live throughout the subantarctic region, were almost eliminated from New Zealand waters in previous centuries but re-colonised Campbell Island and the Antipodes Islands this century. Recently, however, unknown factors have drastically reduced elephant seal populations in parts of their range. The Campbell Island population has fallen by at least 95 percent and the Antipodes population is also small, having less than 100 pups.

The most commonly seen cetaceans in our waters are common dolphins (*Delphinus delphis*), dusky dolphins (*Lagenorhynchus obscurus*) and bottlenose dolphins (*Tursiops truncatus*). Several toothed whales are also common, such as long-finned pilot whales (*Globicephala melaena*), which normally live far out at sea but frequently strand on sloping beaches. Orcas, or killer whales (*Orcinus orca*) and pygmy sperm whales (*Kogia breviceps*) are also common and occasionally strand on New Zealand beaches.

A diverse but little-known group called the beaked whales is known mostly from strandings (Dawson, 1985). Nine species have been reported from New Zealand waters and they occasionally strand in ones and twos on our beaches. They seem rare in coastal waters but may be more common in the deep ocean. One of them, Shepherd's beaked whale (*Tamacetus shepherdi*), is rarely seen anywhere in the world, with only 30 or so specimens having been reported, most of them from strandings on New Zealand beaches.

The large whales which were most common around New Zealand were the southern right whale (*Eubalaena australis*), the humpback whale (*Megaptera novaeangliae*) and the sperm whale (*Physeter macrocephalus*). Right whales fed in the Antarctic during the summer and came north to breed in the winter. They bred close to the coast and were sometimes so abundant in places that ships had to avoid running into them. Their curiosity often drew them to ships and their protective instincts often led them to stay there after one of their number had been harpooned. They were easy prey and became almost extinct by about 1850, though a small remnant population still breeds in New Zealand's subantarctic waters.

Groups of 50–100 right whales have been seen in aerial surveys around the Auckland Islands and Campbell Island during the winter breeding season. Boat surveys have found an estimated 96 right whales around the Auckland Islands with 9 cow/calf pairs. New Zealand scientists are now studying genetic samples from the whales to identify their relationship to other right whale stocks.

Like the right whales, humpback and sperm whales were never permanent residents in New Zealand waters, but regularly passed through on their migrations between the tropical winter breeding grounds and the Antarctic summer feeding grounds. Though heavily depleted by whaling, a small humpback population still migrates past our coast. New Zealand scientists are investigating the relationship between this population, which breeds around Tonga, New Caledonia and Niue, and the rapidly recovering East Australian population.

Sperm whales are globally the most abundant of the large whales. The International Whaling Commission puts the total number of sperm whales at between 500,000 and 1,250,000. Although this is less than the pre-whaling population, they were not as heavily depleted as the other large whales. The main reason is that their breeding females are half the size of the males and were hunted less heavily. Because sperm whale society is polygynous, with one male having exclusive access to many females, most of the hunting impact fell on the reproductively 'surplus' bachelor males. In the other large whales, however, breeding females are bigger than males and so bore the brunt of the hunting.

Migrating bachelor sperm whales regularly stock up on squid and fish, including orange roughy, in the deep ocean trench off Kaikoura. In recent years a thriving whale-watch tourist industry has developed around them. Up to 20 or 30 whales may visit at a time, with some lingering for weeks or months. Several appear to be residents and are reasonably tolerant of the attention from the whale-watch boats.

Other large whales, such as the giant blue (*Balaenoptera musculus*), fin (*B. physalus*) and sei (*B. borealis*) whales, frequent polar oceans during summer months and are only rarely seen in New Zealand waters, but their smaller relatives, the 12 m Bryde's whale (*B. edeni*) and the 8 m minke whale (*B. acutorostrata*) are more common.

Unlike the cetaceans, pinnipeds spend a significant amount of their time on land. Before people arrived in New Zealand, fur seal colonies existed all around the coastline, from Northland to Bluff, though the largest populations were probably in the cooler southern regions and subantarctic islands. New Zealand sea lions (Hooker's sea lions) and elephant seals were less abundant than the fur seals but had a similar distribution (Smith, 1989). They were easy prey for the Maori settlers and their descendants and became the main meat source in many areas (Davidson, 1984). By 1600, pinnipeds had been eliminated from the North Island (Smith, 1989; Anderson and McGlone, 1992). By 1800, when the commercial sealers from Europe and America arrived, the fur and elephant seals and the sea lions had been eliminated from most of the South Island, too. Fur seal colonies survived only in the sparsely populated far south of the South Island. Sea lions had disappeared from the mainland, but still survived on Stewart Island. Elephant seals had gone completely (Smith, 1989). By 1820, the sealers had almost eradicated the remaining fur seals and sea lions and drastically depleted the large populations on the subantarctic islands (Taylor, 1982; Mattlin, 1987).

Whales and dolphins fared much better than the pinnipeds in the pre-European era. Maori hunting of whales appears to have been negligible. Stranded whales were eaten as they became available, but were rarely hunted as far as the archaeologists can tell. Dolphins, however, were hunted (Davidson, 1984; Smith, 1989). Harpoons have been recovered with dolphin remains in midden sites. Dolphins may also have been driven ashore or caught in large beach seine nets.

Apart from a few remains which have been identified as common dolphins (*Delphinus delphis*), most of the dolphin bones in Maori middens have not been identified at the species level. Some may belong to Hector's dolphin, which would have been relatively easy to catch and has more Maori names than any other cetacean. Today this dolphin is far more rare around the North Island than the South Island, but it is not known if this was always the case. Genetic analysis of bone samples may eventually shed light on this.

Whale hunting began with the arrival of American and European whalers in the late 1700s. Many coastal whaling stations were established and the remains of some are now historic places. Whales were hunted from these shore stations until the 1960s, though the greatest impact on whale numbers came from the visiting whaling fleets that killed vast numbers of whales in open waters. Each of the large species was devastated in turn, beginning with the right whales, then the blues, fins and humpbacks. The more resilient sperm whales were hunted throughout.

From the 1960s, the industry was dominated by Russian and Japanese factory fleets whose main prey were sei and minke whales, though it is now known that large quantities of other species were taken illegally or in larger quantities than reported (Yablokov, 1994; Baker and Palumbi, 1994). In 1986 the world regulatory body, the International Whaling Commission (IWC) imposed a moratorium on commercial whaling and, in 1994, created the Southern Ocean Whale Sanctuary as a permanent refuge, even if commercial whaling is resumed.

Today, only one nation commercially hunts whales. Norway kills about 300 minke whales each year in the north-east Atlantic (Motluk, 1995a; Abdulla, 1995). However, under IWC rules, 'scientific' whaling is still allowed, even within the Southern Ocean sanctuary. Japan is the only country which takes advantage of this, killing about 300 minke whales in the Antarctic each year. The meat from these frequently ends up in supermarkets rather than laboratories (Baker and Palumbi, 1994).

The whaling nations, some indigenous groups in the Arctic circle, and some pro-whaling lobby groups, continue to push for an expansion or resumption of whaling. However, most countries support the whaling moratorium and have opted for more benign forms of marine mammal commercialisation, such as whale-watching and dolphin-diving. This reflects the strong public sentiment in many of those countries that whales and dolphins are intelligent creatures deserving of special protection.

New Zealand's direct involvement in the whaling industry had dwindled by 1963 to just one shore-based station in the Marlborough Sounds. Following a sharp decline in the south-west Pacific population of humpbacks in 1960–61 the IWC banned the hunting of humpbacks in 1963. The station switched to sperm whaling but abandoned this in 1964 when the international price of sperm whale oil dropped from more than £90 per ton to about half that in one season.

With the closure of its last station, New Zealand withdrew from the IWC, but in 1976, in response to appeals from the public and the scientific community, the Government rejoined, this time to lobby for a global end to whaling. This was followed in 1978 by the passing of the Marine Mammal Protection Act, which banned the hunting and cruel treatment of marine mammals within New Zealand and its waters (with an allowance for accidental capture in fishing nets) and also banned the importation of whale products.

With hunting now largely removed, most cetacean populations appear to be recovering or, at least, holding their own, though many are still only a fraction of their former abundance (see Table 9.33). Whales in New Zealand waters now face few dangers other than becoming stranded on shallow beaches. Strandings are a problem for several deep water species (particularly pilot whales, beaked whales, and sometimes sperm whales) whose echolocation systems sometimes fail to detect gently sloping beaches. A whale rescue network is coordinated by the Department of Conservation. Each year about 200 callouts are attended and about 60 percent of the stranded whales (200–500 animals) are rescued (Department of Conservation, 1994d, 1995).

The main direct threat to fur seals and sea lions, and also some dolphins, is drowning in fishing nets, particularly the large trawl nets used in the hoki, southern blue whiting and squid fisheries (see Box 9.18 and Tables 9.33 and 9.34). Fur seal and sea lion deaths were first noted in the late 1970s and early 1980s by Government fishing observers who were placed on foreign trawlers. Since 1990, an average of almost 1,000 fur seals and nearly 70 sea lions are estimated to have been drowned each year in trawl nets.

#### *The State of the New Zealand Sea Lion (Phocarctos hookeri)*

The New Zealand sea lion was widely distributed before people arrived, though the population size is unknown. Bones found in Maori food middens reveal that sea lions once ranged the length of New Zealand right up to Houhora in the far North. They had been almost exterminated on

**Table 9.33**

**The state of cetaceans (whales and dolphins) found in New Zealand waters**

| Species | Distribution | Global Status[1] | Status in NZ Waters |
|---|---|---|---|
| *Southern Right Whale (Eubalaena australis)* | *Southern Hemisphere* | *Vulnerable. Current population probably below 5,000, but recovering. Originally more than 60,000.* | *Threatened. Population in the hundreds.* |
| *Pygmy Right Whale (Caperea marginata)* | *Southern Hemisphere* | *Insufficiently known. Never hunted* | *Apparently rare.* |
| *Humpback Whale (Megaptera novaeangliae)* | *All oceans—migratory* | *Vulnerable. Perhaps 25,000, but recovering. Originally around 150,000.* | *Rare. Small migrating population passes through NZ waters.* |
| *Blue Whale (Balaenoptera musculus intermedia)* | *All oceans* | *Endangered. Below 5,000 (less than 1,000 in the Southern Hemisphere). Originally more than 200,000.* | *Very rare. Occasionally seen, but mostly polar.* |
| *Pygmy Blue Whale (musculus subsp.)* | *Southern Hemisphere* | *Endangered. Severely depleted. Population less than 8,000.* | *Rare.* |
| *Fin Whale (Balaenoptera physalus)* | *All oceans* | *Vulnerable. Probably below 150,000. Originally probably 500,000 to 1 million.* | *Rare. Occasionally seen but mostly polar.* |
| *Sei Whale (Balaenoptera borealis)* | *All oceans* | *Vulnerable. Probably less than 60,000. Originally may have exceeded 250,000.* | *Regularly seen near NZ.* |
| *Bryde's Whale (Balaenoptera edenii)* | *Tropical and temperate seas* | *Insufficiently known. Maybe 80,000—100,000. Slightly below original numbers.* | *Frequently seen off the North-east coast of NZ.* |
| *Minke Whale (Balaenoptera acutorostrata)* | *Polar oceans* | *Insufficiently known. Maybe 800,000—900,000. Some northern stocks have been depleted, but Antarctic stocks may now exceed original size.* | *Occasionally seen around NZ, but aggregate on polar feeding ground in summer.* |
| *Sperm Whale (Physeter macrocephalus)* | *All oceans* | *Insufficiently known. At least several hundred thousand. Originally probably exceeded one million.* | *Common, but far out to sea except near Kaikoura.* |
| *Pygmy Sperm Whale (Kogia breviceps)* | *Warm and temperate seas* | *Insufficiently known. Apparently uncommon, though never hunted.* | *Relatively common in NZ waters, but population trends unknown.* |
| *Orca (Killer Whale) (Orcinus orca)* | *All oceans* | *Insufficiently known. Probably several hundred thousand.* | *Apparently common, but population trends unknown* |
| *False Killer Whale (Pseudorca crassidens)* | *Warmer oceans* | *Insufficiently known, but nowhere abundant.* | *Apparently common, but population trends unknown.* |
| *Pilot Whales (2 species) (Globicephala spp.)* | *All but North Pacific Ocean* | *Insufficiently known. Probably several hundred thousand.* | *Apparently common, but population trends unknown.* |
| *Beaked Whales (9 species)* | *Open ocean* | *All species insufficiently known. Apparently uncommon, though never hunted.* | *Regularly strand around NZ. Some species rare. Trends unknown.* |
| *Hector's Dolphin (Cephalorhynchus hectori)* | *Endemic to NZ waters, mostly South Island* | *Indeterminately threatened. Numbers about 3,000–4,000. World's rarest marine dolphin. Confined to New Zealand.* | *Threatened. Original population and current trends are unknown. May have been depleted by set nets.* |
| *Common Dolphin (Delphinus delphis)* | *Tropical and temperate seas* | *Insufficiently known, but probably in the millions.* | *Abundant, but population trends unknown.* |
| *Bottlenose Dolphin (Tursiops truncatus)* | *Tropical and temperate seas* | *Insufficiently known, but possibly in the millions.* | *Common, but population trends unknown.* |
| *Dusky Dolphin (Lagenorhyncus obscurus)* | *Southern Hemisphere* | *Insufficiently known, but common in cooler waters.* | *Common off the South Island. Rare north of Hawke's Bay. Population trends unknown.* |
| *Other cetaceans (6 dolphins, 1 porpoise, 1 melonhead whale)* | *Mostly tropical or polar waters* | *Insufficiently known, but most apparently not at risk.* | *Rarely stray into NZ waters.* |

1 *Global population estimates are highly uncertain, being based on sporadic sightings, limited surveys, and reported catch data. Many estimates have not been updated since commercial whaling was banned in the mid-1980s (IUCN, 1991).*

the mainland by 1500. When European sealers arrived, only the Stewart Island Maori were still able to hunt sea lions. The commercial sealers put a quick end to that. Although their main targets were fur seals, they killed large numbers of sea lions as well, leaving only remnant populations on several sub-antarctic islands.

Today, the species is still limited to those islands. The most recent population estimate is 10,000–15,000 (Cawthorn, 1993). Roughly 80 percent of all pup births occur on Dundas Island, a remote and almost inaccessible member of the Auckland Islands group. Another 10 percent are born on Enderby Island. Surveys on Enderby and Figure of Eight Islands have shown little population change in several decades. A small rookery exists on Campbell Island, and, until recently, a few pups were born at the Snares Islands each year.

New Zealand sea lions are now commonly sighted at Stewart Island, the Catlins coast and Otago Peninsula. Very rare sightings have been made at Banks Peninsula, and even the Kaikoura and Nelson coasts, with one sighting as far north as Plimmerton, near Wellington (Cawthorn, 1993). The Department of Conservation has recorded an influx of two-year-old males on the Otago Coast over the past 2 years. The presence of 3 females and a recent instance of breeding near Dunedin have led to speculation that the species may be re-establishing itself on the mainland after centuries in exile (Peat, 1993; Department of Conservation, 1995).

Squid trawling in the Auckland Islands began in the late 1970s and is a major fishery involving up to 40–50 boats during the summer and autumn. This is also the season when the sea lions are breeding and foraging for food on the Auckland Islands shelf. Each year squid trawl nets drown an estimated 20–140 sea lions (see Table 9.34). Sea lion bycatch data has only been systematically recorded since 1988. Although fishing industry observers have also recorded sea lion kills since 1993, official estimates use only Government observer records. Between 1988 and 1996, the percentage of trawlers carrying Government observers varied between 8 percent and 29 percent. In the 1995–1996 season the observers witnessed 557 trawl net tows and 13 sea lion kills. This represented 2.3 kills per hundred tows.

**Table 9.34**
**Reported and estimated New Zealand (Hooker's) sea lion bycatch in the southern squid fishery, 1988–95.**

| | Observed number of kills [1] | Estimated number of kills | Total number of squid trawl tows | Percentage of tows observed |
|---|---|---|---|---|
| ***1988*** | *8* | *26–33* | *1,790* | *24%* |
| ***1989*** | *27* | *120–140* | *3,766* | *19%* |
| ***1990*** | *14* | *103–116* | *5,218* | *12%* |
| ***1991*** | *2* | *21* | *3,252* | *10%* |
| ***1992*** | *8* | *82* | *2,168* | *10%* |
| ***1993*** | *5* [2] | *20* | *666* | *29%* |
| ***1994*** | *3* | *32* | *4,675* | *9%* |
| ***1995*** | *8* [3] | *95* | *3,909* | *8%* |
| ***1996*** [4] | *13* | *100* | *4,400* | *13%* |
| ***Yearly average 1988–96*** | *9* | *69* | *3,273* | *13%* |

*Sources: Baird (1996); Ministry of Fisheries; Fishing Industry Board*
1 *Kills witnessed under the Ministry of Fisheries Scientific Observer Programme.*
2 *A scampi trawler caught 3 of the observed kills in 1993.*
3 *A southern blue whiting vessel caught one of the observed kills in 1995.*
4 *Unpublished data.*

The number of sea lions killed before 1988 is not known, though concerns were expressed in the late 1970s by Government scientists on a large German research trawler. As a result, a 'no fishing' zone was designated around the Auckland Islands in 1982, extending out to the territorial sea limit of 12 nautical miles (22 kilometres). The zone became a marine mammal sanctuary in April 1993 but has been criticised as being too small in area (Bellingham, 1993a).

In 1992, the Ministers of Conservation and of Fisheries set a maximum allowable kill of 63 sea lions (including no more than 32 females). Meanwhile, the fishing industry decided to review the fishing operation of any vessel catching 3 or more sea lions and to voluntarily withdraw any vessel catching 4 or more. One boat was reviewed in 1993 when a freak incident led to three sea lions being caught in a badly deployed scampi net. Generally, the small nets used by scampi trawlers are far less of a threat to sea lions than the squid trawlers' huge pelagic nets (which can be larger than a 25-storey office block, stretching up to 80 m from top to bottom). Shortly before the end of the 1995 and 1996 seasons, the few remaining squid trawlers voluntarily withdrew from the fishing grounds after the Ministry of Fisheries estimated that the allowable sea lion kill had been exceeded.

***The State of the New Zealand Fur Seal (Arctocephalus forsteri)***

The New Zealand fur seal could just as easily have acquired an Australian name. Although it lives around the South Island, lower North Island and various subantarctic islands, it is also found along the coast of Tasmania and the southern Australian coast from Victoria to Albany. Though officially classified as a single species, recent genetic research by scientists at Wellington's Victoria University indicates that the fur seals may actually belong to two very divergent sub-species, one of which is much rarer than the other (Chambers *et al.*, 1996).

The original fur seal population in the New Zealand region is unknown. When the first European sealers arrived 200 years ago, the seals had already been eliminated from most of New Zealand's coastline, but were still abundant on the subantarctic islands. One estimate, based on historical sealing records, puts their population at this time at about 1.25 million (Richards, 1994). By the time the sealers were through, several decades later, the population may have been no more than 10,000. Fur seals began to be protected by the law from 1875 when the killing season was restricted to a short period every year. From 1894 hunters needed a permit to kill seals, except for a 3-month period in 1913 when there was an open season for anyone. Since then no fur seals have been killed legally, except on Campbell Island in 1922 and 1924, and in southern New Zealand in 1946 (Melrose, 1973).

The Australian population was recently estimated at about 27,000 and increasing (Shaughnessy *et al.*, 1994). In New Zealand, a planned national census of fur seals in 1995–96 was postponed by the Department of Conservation but is among the draft research suggestions put forward for 1997–98 by the Ministry of Fisheries' Nonfish Species and Fisheries Interactions Working Group (Baird, 1996).

Current population estimates for the New Zealand region are based on data collected in the early 1970s and summarised by Wilson (1981), who put the total population at 30,000–50,000. Studies since then have found marked population increases in Cook Strait, Nelson-Marlborough, Otago and on some subantarctic islands (Baird, 1995; Crawley, 1990; Dix, 1993; Lalas and Harcourt, 1995; R.H. Taylor, 1992; Taylor *et al.*, 1995). These studies suggest that the total population, though still just a fraction of its former size, may now exceed 50,000. As the population expands, new colonies are forming, and, for the first time in four centuries, the lower North Island is being recolonised.

An average of nearly 1,000 fur seals a year have been drowned by trawl nets in recent years (see Table 9.35). Most of the reported deaths occur in the southern blue whiting fishery on the Bounty Platform, the hoki fisheries off the South Island's West Coast and Puysegur Point, and the southern squid fishery (Baird, 1994a, 1996). Fur seal drownings began to be officially monitored in 1986 by Government observers on a sample of West Coast hoki trawlers. About 60–70 boats trawl for hoki off the West Coast during the winter and early spring, from June to September. In 1992 monitoring was extended to a sample of trawlers in other fisheries throughout the Exclusive Economic Zone.

Between 1990 and 1992, the estimated probability of catching one or more fur seals in one tow of the trawl net fell from 5.6 percent to 2 percent (Mattlin, 1994a). In 1994, the Fishing Industry Board estimated the encounter rate to be about 2–3 percent. However, even though the catch rate per tow has fallen, the actual number of deaths depends on other factors as well, such as the total number of tows in a season and their proximity to seal feeding grounds. As a result, annual bycatch figures continue to fluctuate (see Table 9.35).

Based on preliminary observer reports, the total fur seal bycatch for the Exclusive Economic Zone in 1994 was higher than in previous years, with 202 reported kills, 60 of them by hoki trawlers and 97 by southern blue whiting trawlers. If the ratio of observed to estimated kills was anything like previous years, this suggests approximately 1,600 kills, plus or minus 300 (see Table 9.35b). At present, NIWA scientists are reassessing fur seal bycatch estimates for 1992–95.

***The State of Hector's Dolphin (Cephalorhynchus hectori)***

Hector's dolphins are easily recognised in coastal waters by their paddle-shaped black dorsal fins. They are the world's smallest marine dolphins and live in small family groups of 2 to 12. They are found only in New Zealand waters and generally stay within 5 km of the coastline (Dawson and Slooten, 1994, 1996). Their population size and distribution before human settlement in New Zealand are unknown.

These days most Hector's dolphins occur around the South Island and their total population has been estimated at 3,000–4,000, making them one of the world's rarest dolphins (Dawson and Slooten, 1988). As yet unpublished research at Auckland University suggests that the population consists of two genetically distinct sub-populations, one on the east coast and one on the west coast, which have no contact with each other.

Modern pressures on Hector's dolphins include entanglement in fishing nets and pollution from river mouths and harbours. Between 1984 and 1988, setnets, or gill nets, removed 130–230 dolphins from the Banks Peninsula population of about 600 (Dawson, 1991). These deaths were additional to those resulting from other causes. Fears for the impact on the Banks Peninsula population led to the area being made a marine mammal sanctuary with a restriction on the use of gill nets (Dawson and Slooten, 1993).

Because they are at the top of the marine food chain and feed near river mouths, Hector's dolphins are also at risk from anything which may reduce the quantity or quality of their food supply, such as excessive inshore fishing, sediment washing down from rivers, or the accumulation of toxic chemicals in fish. Dead Hector's dolphins which

**Table 9.35**
**Reported and estimated fur seal bycatch, 1990–94.**

**(a) West Coast hoki fishery alone**

| | Observed kills[1] | Estimated kills[2] | Best estimate | Total number of towed nets | Percentage of tows observed |
|---|---|---|---|---|---|
| ***1990*** | *28* | *199–486* | *342* | *9,560* | *8%* |
| ***1991*** | *36* | *196–393* | *295* | *9,580* | *12%* |
| ***1992*** | *31* | *140–334* | *237* | *7,898* | *13%* |
| ***1993*** | *60* | *248–496* | *372* | *8,970* | *16%* |
| ***1994*** | *60*[3] | | | | |

**(b) Entire Exclusive Economic Zone (EEZ), including West Coast hoki fishery, southern blue whiting fishery and southern squid fishery.**

| | Observed kills[1] | Estimated kills[2] | Best estimate | Total number of towed nets | Percentage of tows observed |
|---|---|---|---|---|---|
| ***1990*** | *28* | *261–651* | *456* | *43,735* | *6%* |
| ***1991*** | *90* | *702–1,166* | *934* | *48,887* | *10%* |
| ***1992*** | *74* | *740–1,243* | *991* | *51,904* | *7%* |
| ***1993*** | *171* | *1,148–1,704* | *1,426* | *53,770* | *12%* |
| ***1994*** | *202*[3] | | | | |
| ***Yearly average 1990–93*** | *113*[4] | *713–1,191* | *952* | *49,574* | *9%* |

*Source: Ministry of Fisheries (unpublished provisional data).*

1 *Bycatch kills recorded by MAF Fisheries observers.*

2 *Estimates are based on MAF Fisheries observer data extrapolated over the whole fleet and have a 95% confidence interval.*

3 *Preliminary figures only. Data for 1994 and 1995 were not available when going to press because a reassessment of fur seal bycatch for the years 1992–95 was in progress (Baird, 1996).*

4 *Observed kill average is for 1990–94. Other averages are for 1990–93.*

**Table 9.36**

**Common and bottlenose dolphin kills by jack mackerel trawlers in the Taranaki Bight, 1990–95.**

| Season | Fishing ground | Observed kills[1] | Estimated kills[2] | Total number of trawl net tows | Percentage of tows observed |
|---|---|---|---|---|---|
| *1989–90* | *North Taranaki* | *0* | * | *1,433* | *4%* |
| | *South Taranaki* | *23* | * | *1,724* | *15%* |
| *1990–91* | *North Taranaki* | *0* | * | *794* | *<1%* |
| | *South Taranaki* | *0* | * | *1,053* | *23%* |
| *1991–92* | *North Taranaki* | *7* | * | *2,663* | *5%* |
| | *South Taranaki* | *22* | * | *1,010* | *10%* |
| *1992–93* | *North Taranaki* | *0* | * | *2,374* | *7%* |
| | *South Taranaki* | *9* | * | *992* | *15%* |
| *1993–94* | *North Taranaki* | *0* | * | *2,322* | *6%* |
| | *South Taranaki* | *8* | * | *1,079* | *24%* |
| *1994–95* | *North Taranaki* | *0* | * | *1,141* | *16%* |
| | *South Taranaki* | *21* | * | *600* | *34%* |

*Adapted from Baird (1996)*

1 *Dolphin kills witnessed by Ministry of Fisheries observers.*

2 *Official estimates of the total dolphin kill in the Taranaki Bight were unavailable on going to press, but a rough extrapolation from observed catches suggests that about 80–300 dolphins are caught each year (Slooten and Dawson, 1995).*

occasionally wash up on beaches or are drowned in setnets have had their blubber analysed for chemical residues. Although persistent organochlorines have been found, such as polychlorinated biphenyls (PCBs) and DDT residues, the concentrations are much lower than in Northern Hemisphere dolphins (Buckland *et al.*, 1990; Department of Conservation, 1992a; Jones, 1995).

PCB levels in Hector's dolphins are higher than in other cetaceans that live further from the coast (e.g. common dolphins, dusky dolphins, beaked whales) but are still below 5 parts per million (ppm). This compares to PCB concentrations of 37–80 ppm in US dolphins and 55 ppm in British harbour porpoises (Jones, 1995). Overseas research has linked high concentrations of organochlorines to reproductive abnormalities and immune deficiencies in a number of species, though the interpretation of such data is still controversial (Addison, 1989; Motluk, 1995b; Stone, 1994a, 1994b, 1995a; Sharpe, 1995; Tanabe, 1994). Even more controversial are claims that low organochlorine concentrations can interfere with reproduction and immunity through prolonged exposure or through a combined 'cocktail' effect (Colburn *et al.*, 1996; Wilkinson and Dawson, 1996).

Because no data were collected on New Zealand dolphin populations or their chemical residues during the years of high organochlorine use (1950–1980) it is not known whether Hector's dolphins were adversely affected during this period. It is likely that they had higher concentrations of organochlorine residues than are found in today's dolphins, but the effects on their population, if any, remain unknown.

Other dolphin species in New Zealand waters have even lower concentrations of organochlorines than the Hector's dolphins and their populations seem large enough to cope with the limited bycatch pressure from setnets and trawlers. Probably the largest dolphin bycatch is associated with jack mackerel trawlers in the Taranaki Bight (see Table 9.36). Most of the victims are common and bottlenose dolphins. More than 90 percent of the drownings occur during night trawls.

The fishing industry has developed a code of practice for trawlers catching jack mackerel in this Quota Management Area (JMA 7). The relatively small number of dolphins caught and the lack of a controlled comparison makes it difficult to draw any conclusions about the effectiveness of the code of practice (Baird, 1996). During the 1994–95 season, after several bycatch incidents with dolphins, the jack mackerel trawlers were voluntarily withdrawn from the Taranaki Bight and their operations reviewed.

## SOCIETY'S RESPONSES TO THE PRESSURES ON BIODIVERSITY

The first responses to New Zealand's biodiversity crisis were made by Maori tribes before Europeans came here. They included dietary changes, internal migration, territorial warfare, access restrictions based on *whakapapa* (genealogy) or *mana* (power, prestige) and conservation measures. These conservation measures varied from place to place and were driven by practical resource needs rather than the abstract principle of preserving biodiversity for its own sake (O'Regan, 1994).

The measures included the use of *tikanga* (ritualised methods) when harvesting important plants and animals, and the use of *tapu* (sacred prohibitions) and *rahui* (temporary prohibitions) to control the areas, seasons or species harvested. Because the measures were intended to maintain harvestable supplies of particular plants and animals, they focused on species which had resource value or were spiritually safe. Lizards, for example, were generally avoided because they were believed to have strong powers, while fish, food plants and edible invertebrates were readily eaten, with some being actively transferred from areas of plenty to areas of scarcity.

Following European settlement, nature conservation was far from most people's minds. The new settlers were intent on converting 'bush' into productive European-style farmland. European birds, domestic animals and game animals were introduced. Maori protests about the loss of native fisheries and the introduction of trout were ignored, as were the deforestation protests of a small number of European conservationists. Conservation measures were few and were limited to a small number of laws protecting individual species. In fact, the first laws were designed to protect introduced species.

The Protection of Certain Animals Act 1861 was a forerunner to the establishment of acclimatisation societies. It decreed that "no Deer of any kind, Hare, Swan, Partridge, English Plover, Rook, Starling, Thrush or Blackbird" could be shot for the rest of the decade. It was followed by the Trout and Salmon Protection Act 1867 which made provision for "the preservation and propagation of Salmon and Trout in this Colony". The other side of the acclimatisation coin soon followed with the Rabbit Nuisance Act 1876, the Small Birds Nuisance Act 1882 and the Noxious Weeds Act 1900.

The first legislation to protect indigenous species was the 1864 Wild Birds Protection Act which said: "No Wild Duck, Paradise Duck, or Pigeon indigenous in the colony shall be hunted, taken, or killed except during the months of April, May, June, and July in any year." In 1875 seal hunting was restricted to a short annual season, followed in 1894 by a requirement for sealing permits. In the 1890s, legal protection was also bestowed on such unique species as the tuatara and the doomed huia. Attitudes to indigenous species changed slowly. In 1907, legal protection was given to several more native birds (e.g. the tui, kaka, paradise shelduck and oystercatcher). The Animals Protection and Game Act 1921–22 extended protection to more species (including, however, the possum). Over the years, more native birds were given full protection (e.g. the Stewart Island diving petrel, or kuaka, in 1923, and the New Zealand pigeon, or kereru, in 1941).

Eventually, the protection of native animals was consolidated in the Wildlife Act 1953, which conferred protection on most native vertebrates (with some exceptions for sport hunting and pest control). In 1980, several dozen invertebrates were added to the list and in 1996 all of our lizards became protected species. Under these laws, most of the larger native land animals received some protection from harvesting, but were not protected from habitat decline and the encroachment of pests and weeds.

In 1908, the Fisheries Act empowered Ministers to use regulations if necessary to restrict the harvest of marine and freshwater species. These regulatory powers were later used to further limit seal hunting and to control the harvesting of toheroa, oysters, whitebait and some other fisheries. The original Fisheries Act and regulations have since been superseded by several new Acts, culminating in the Fisheries Act 1996 with its better safeguards for aquatic ecosystems and non-target species. Seals are now covered by separate marine mammal legislation. Non-commercial indigenous freshwater fish are managed under the Conservation Act 1987.

It was not until 1934 that protection measures were introduced for native plants outside of reserves and national parks. The Native Plants Protection Act makes it illegal to take most native plants without landowner consent. This Act is still in operation but provides little real protection for native plants.

Habitat protection was almost non-existent last century, except for a few small areas of lowland forest, which became scenic reserves, and extensive areas of high mountain forest, which were protected for flood control purposes. In 1887, Te Heuheu IV, paramount chief of the Tuwharetoa people of the central North Island, gifted their sacred mountains and surrounding land to the Government to protect them from encroaching farmers. Much of this land was tussock grassland which had been converted from forest by Maori fires centuries earlier. The land and its mountains, Ruapehu, Ngauruhoe and Tongariro, became New Zealand's first national park, the Tongariro National Park.

Over the next century, a dozen more national parks were established and about 4,000 smaller reserves, but only a few of these had biodiversity as a central consideration. Most were preserved for their scenery. A Scenery Preservation Commission was established in 1904, but provided little protection for the lowland forests, wetlands, dunelands, South Island tussock lands or river ecosystems. The concept of protecting marine areas was not recognised until the late 1960s. As a result of lobbying by marine scientists, the Marine Reserves Act was passed in 1971 and the first marine reserve was established in 1975.

Attitudes to biodiversity still vary widely in New Zealand. To some people, indigenous species are fellow beings with intrinsic value and a fundamental right to exist. To others they are resources whose value depends on their economic, recreational or cultural usefulness. These philosophical differences have an important bearing on how conservation priorities are set, which species and ecosystems are protected, and the degree of protection given. Despite the different perspectives, however, more than three-quarters of those surveyed in a 1992 Heylen poll believed that protecting endangered species is a very important issue, whether for ethical, economic or cultural reasons (Department of Conservation, 1993). This general sentiment is reflected in our key conservation laws.

The Government has listed the protection of indigenous habitats and biological diversity as one of its 11 most important environmental issues (Ministry for the Environment, 1995). To help it achieve its objective in this area, and to lay the groundwork for a more constructive and coordinated approach to sustaining biodiversity, the Government is developing the New Zealand Biodiversity Strategy (see Box 9.21).

**Box 9.21**

***The New Zealand Biodiversity Strategy***

Under the global Convention on Biological Diversity (CBD), which was signed at the 1992 Earth Summit in Rio de Janeiro, New Zealand joined with many other governments in agreeing to a range of measures for the conservation and sustainable use of biological diversity. In Article 6 of the Convention they agreed to develop national strategies, plans or programmes and to integrate these into relevant sectoral (social and economic) plans, programmes and policies.

The New Zealand Biodiversity Strategy is now being developed by the Department of Conservation and the Ministry for the Environment. An outline strategy document based on discussions with a range of interested parties is expected to be released in mid 1997. The document will outline various issues affecting the management of biodiversity and potential responses to these issues. It will invite submissions from the public. The submissions will be reviewed and the New Zealand Biodiversity Strategy will then be released. Some of the issues likely to come within the scope of the Strategy include:

- the conservation and sustainable management of indigenous biodiversity;
- threats to indigenous biodiversity from habitat destruction and fragmentation, introduced plant pests and animal predators, over-exploitation by recreational and commercial activities, and global environmental change;
- the sustainable management of introduced biodiversity—in terms of the threats it poses to our indigenous biodiversity;
- biosecurity—protecting both indigenous and productive ecosystems from further foreign plant and animal pests.

The Biodiversity Strategy will not be just a statement of good intentions. It will be action-oriented with a focus on how best to sustain our biodiversity. It will help to coordinate the different biodiversity initiatives up and down the country and ensure they are better integrated.

### Key conservation laws

The **Conservation Act 1987**, and amendments to it, have established the Department of Conservation, the New Zealand Conservation Authority and Boards, and the New Zealand and Regional Fish and Game Councils with the aim of promoting the conservation of natural and historic resources. It defines conservation as the preservation and protection of natural and historic resources (which include plants and animals of all kinds as well as fungi, algae and bacteria) for the purpose of maintaining their intrinsic values, providing for their appreciation and recreational enjoyment by the public, and safeguarding the options of future generations.

The **Wildlife Act 1953** provides for the protection of wildlife, except for certain species named in Schedules to the Act, and also provides for the control of wildlife. It allows game(birds) to be hunted or killed, subject to restrictions. Recent amendments to this Act include the protection of several marine groups, namely black corals (Antipatharia), red corals (Stylasterids) and spotted black groper (*Epinephalus daemelii*).

The **Reserves Act 1977** allows the classification of different types of public reserves. The Act contains provisions for their acquisition, control, management, maintenance, preservation, development and use.

The **Marine Reserves Act 1971** makes the Department of Conservation responsible for the management and protection of marine reserves. Management functions include marking marine reserve boundaries, law enforcement, the issuing of permits for scientific studies, and monitoring environmental changes. The legislation has scientific study and preservation of marine life as its primary focus and is the key legislation for protection of marine biodiversity.

The **Marine Mammals Protection Act 1978**, administered by the Department of Conservation, provides for the conservation, protection and management of marine mammals. Under the Act, a permit is required for anyone to 'take' a marine mammal. (The definition of 'take' includes actions that harm, harass, injure, and attract.) The Act does not prevent the accidental (or incidental) catching of marine mammals (bycatch) during fishing operations.

The **National Parks Act 1980** provides for the establishment, administration, control and management of national parks. National parks comprise land with scenery of such distinctive quality, ecological systems or natural features so beautiful, unique or scientifically important that their preservation is in the national interest. National parks are preserved for their intrinsic worth and for the benefit, use and enjoyment of the public.

The **Resource Management Act 1991,** which sets out the environmental management responsibilities of local authorities, aims to promote the sustainable management of natural and physical resources (which are defined as including all forms of plants and animals). The authorities must provide for "matters of national importance" which include, among other things, the protection of areas of significant indigenous vegetation, significant habitats of indigenous fauna, and wetlands.

They are also required, among other things, to have particular regard for any finite characteristics of natural and physical resources, the protection of trout and salmon habitat, and, most significantly, the intrinsic values of ecosystems, which are defined as those aspects and parts of an ecosystem "which have value in their own right", including (a) their biological and genetic diversity; and (b) the essential characteristics that determine the integrity, form, functioning and resilience of the ecosystem.

**The Environment Act 1986**, which reformed the Commission for the Environment and established the Ministry for the Environment, aims to ensure that, in the management of natural and physical resources (which are defined to include, among other things, all forms of flora and fauna), full and balanced account is taken of, among other things, their sustainability, the intrinsic values of ecosystems (which are defined as systems of interacting organisms within their natural environment) and the needs of future generations.

The 1993 amendment to the **Forests Act 1949** requires that the milling of indigenous timber from most privately owned indigenous forests in New Zealand be subject to a sustainable forest management regime that maintains the forest's ability to provide products and amenities in perpetuity while also retaining its natural values.

The **Fisheries Act 1996** aims to use fisheries resources while "ensuring sustainability". This is defined as both maintaining their potential to meet the needs of future generations, and avoiding, remedying or mitigating any adverse effects of fishing on the aquatic environment. In pursuing these objectives, the Act requires that the following environmental principles be taken into account: (a) associated or dependent species should be maintained above a level that ensures their long-term viability; (b) biological diversity of the aquatic environment should be maintained; (c) habitat of particular significance for fisheries management should be protected. In addition, the Act's information principles require that decisions be based on the best possible information, be cautious when information is uncertain, unreliable or inadequate, and not be deferred because of inadequate information.

Besides these main laws, a range of more specific laws operate to promote conservation at the national and local levels. Some of these have already been mentioned. They include the Native Plants Protection Act 1934; the Marine Reserves Act 1971; the Wild Animal Control Act 1977; the Queen Elizabeth II National Trust Act 1977; the Marine Mammal Protection Act 1978; the National Parks Act 1980; the Trade in Endangered Species Act 1989; the Local Government Amendment Act 1989; the Maori Fisheries Act 1989; the Treaty of Waitangi (Fisheries Claim) Settlement Act 1992; the Biosecurity Act 1993; and the Hazardous Substances and New Organisms Act 1996. Some of these are discussed below or in earlier chapters.

Rules in regional and district plans have the status of law under the Resource Management Act as do Heritage Protection Orders and Water Conservation Orders issued by central Government under that Act. A range of funding mechanisms also exist to purchase land for conservation purposes or to pay landowners for reserving land through legally binding protection covenants.

#### International conservation obligations

The need to protect biodiversity is not just a national or local concern. It has also become an international obligation. Because New Zealand's endemic species are found nowhere else on Earth, their loss is a world loss. Conversely, because New Zealanders are part of the global community, the extinction of any overseas species is also our loss. New Zealand is therefore an active member of the international conservation network and a party to many international agreements related to biodiversity.

Three of the most significant biodiversity conventions are: the Convention on Biological Diversity; the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); and the International Convention for the Regulation of Whaling.

Of these, the **Convention on Biological Diversity** is the most all-embracing. It was opened for signing at the United Nations Earth Summit in Rio de Janeiro on 5 June 1992 and came into force on 29 December 1993. The Convention spells out principles and obligations for the conservation, sustainable use and fair and equitable exploitation of other species. It notes that the fundamental requirement for maintaining biological diversity is the *in-situ* conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings. The Convention also notes that lack of full scientific certainty should not be used as a reason for postponing measures that may avoid or minimize threats to biodiversity.

Although the Convention does not prescribe any particular methods for conserving biological diversity, it does require member countries to develop national biodiversity strategies and to integrate these with other forms of planning. It also requires countries to monitor their biodiversity, establish a system of protected areas, introduce procedures to assess, and avoid or minimise the impact on biodiversity of proposed projects, and promote public education and awareness. Where compatible with conservation or sustainable use requirements, Convention members are also to encourage customary use of biodiversity in accordance with traditional practices and facilitate access for other resource users.

The **Convention on the International Trade in Endangered Species (CITES)** aims to limit the threat posed by trade through a system of import and export controls. The Convention came into force on 1 July 1975, but New Zealand only ratified it in 1989 when the Trade in Endangered Species Act was passed. Under the Act, species are listed in three categories: endangered; threatened; and exploited. Endangered species may only be traded when accompanied by an export permit, issued by the country of origin, and an import permit, issued by the country of import. Threatened species may only be traded if accompanied by an export permit from their country of origin stating that the transaction is not harmful to the species. The CITES appendices are periodically revised and member countries are required to amend their import and export controls accordingly. Of prime concern are species targeted by international collectors (such as parrots, rare reptiles, corals, turtle shells, elephant ivory, rare animal skins) and those targeted by the Asian medicaments industry (such as tigers, bears and rhinoceroses).

The **International Convention for the Regulation of Whaling** was signed in 1946 and established the International Whaling Commission (IWC). New Zealand was an IWC member until our whaling industry ceased in the 1960s. In 1978, however, in response to growing public pressure for an end to whaling worldwide, New Zealand rejoined the Commission to support other non-whaling countries in their bid for a global ban on commercial whaling.

New Zealand has taken a consistently conservationist and humanitarian position at the IWC, reflecting most New Zealanders' opposition to both the ecological destructiveness of whaling and its cruelty. In 1986, the IWC imposed a moratorium on whaling, with exceptions for 'traditional' and 'scientific' whaling. In 1994, the IWC voted to establish a southern ocean whale sanctuary surrounding the South Pole. Together with the existing Indian Ocean sanctuary, this means that almost one-third of the world's oceans will be off-limits to whalers if the moratorium were ever lifted.

Other significant biodiversity conventions to which New Zealand is a party are: the Convention on Wetlands of International Importance Especially as Waterfowl Habitats (Ramsar Convention) (see Chapter 7 for discussion); the Convention on the Conservation of

Nature in the South Pacific (Apia Convention); the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention); the Convention on the Conservation of Antarctic Marine Living Resources; the Convention on the Prohibition of Fishing with Long Drift Nets in the South Pacific (Wellington Convention); and the Convention for the Conservation of Southern Bluefin Tuna. New Zealand is also participating in United Nations-sponsored talks to regulate the fishing of migratory fish stocks in open seas.

Finally, Chapter 17 of the Rio Summit's *Agenda 21* document (see Chapter 7) calls on nations to work towards protecting marine ecosystems within their Economic Exclusion Zones by identifying ecosystems with high levels of productivity and biodiversity or with critical habitat areas and, where necessary, limiting use in these areas through, among other things, the designation of protected areas.

**New Zealand's conservation network**

A large number of organisations and individuals are involved in efforts to maintain New Zealand's biological diversity. They include Government departments, other statutory agencies and a wide range of voluntary organisations, professional groups and biodiversity resource users.

The **Department of Conservation** is the main Government agency responsible for protecting and sustaining biodiversity. Established in 1987 under the Conservation Act, it undertakes the day-to-day management of New Zealand's protected areas and unallocated public lands. In addition to advising the Government and other agencies on conservation and biodiversity matters, the Department advocates, promotes and encourages the conservation of all natural and historical resources. It can voice its opinions on any issues of natural resource management (including statutory advocacy through the Resource Management Act, commenting on marine fisheries, indigenous forestry management, freshwater fish habitats etc.).

The Department consists of a Wellington-based head office, 3 regional offices (at Hamilton, Wellington and Christchurch) and 14 conservancy offices distributed throughout the country. Its main functions include:

- managing nearly one-third of New Zealand's land in the form of national parks, reserves and stewardship land;
- managing species protected under the Wildlife Act 1953 both on and off the 'conservation estate';
- managing indigenous and recreational freshwater fisheries, and protecting freshwater fish habitat;
- protecting marine mammals;
- controlling designated wild animals;
- carrying out weed and pest control, and fire control, on the conservation estate and unallocated Crown land;
- managing the Crown foreshore and seabed, developing the New Zealand Coastal Policy Statement and approving regional coastal plans;
- creating and managing marine protected areas;
- acting as an advocate for the Crown to achieve protection for indigenous species through local authority plans and polices, voluntary agreements with land owners, land purchases and legislation; and
- meeting New Zealand's international conservation commitments.

The Department also has a consultative voice in the management of marine fisheries and in sustainable forest management plans for indigenous timber production. Apart from sustaining biodiversity, the Department is also responsible for providing recreational, tourist and visitor services on conservation land, a role which consumes more than a third of the Department's $127 million annual budget (Department of Conservation, 1995).

Several other statutory organisations also play important roles in New Zealand's conservation network. Among these are the **New Zealand Conservation Authority** and its 17 **Regional Conservation Boards** which act as bridges between the Department of Conservation and the public. The Authority and boards are housed within the Department and serviced by its staff but are quite independent in their advice and functions.

Its members are drawn from organisations representing Maori interests, the tourism sector, recreational users of conservation land and environmentalists.

Their role is to ensure that the Department manages its lands in accordance with public wishes, subject to the Conservation Act's requirement that protected species and indigenous habitats and other sites be maintained. The Authority produces discussion documents and invites public feedback on contentious issues, such as the cultural harvesting of indigenous species, and they provide independent advice to both the Department and the Minister on conservation issues of national importance. Authority approval is also required before the Department can implement its policies and plans for national parks or its conservation management strategies and plans.

The **Forest Heritage Fund** and **Nga Whenua Rahui** are also independent of the Department of Conservation, though they are housed within it and serviced by Department staff. These special-purpose committees were set up in 1990 to pay for the protection of indigenous forests of high conservation value on private land either through legally binding protection covenants or direct purchase. Each year these funds are allocated a total of $6.8 million for this purpose, with the Forest Heritage Fund receiving $4.5 million and Nga Whenua Rahui $2.3 million. About 130,000 hectares were protected or earmarked for protection by mid-1996.

Another statutory organisation which has the role of funding voluntary protection of 'open spaces' on private land is the **Queen Elizabeth II National Trust,** which was established under its own Act in 1977. Nearly 100,000 hectares of forest, wetland and other 'open spaces' were protected or earmarked for protection by mid-1996. The Trust receives funding from Government grants, the Forest Heritage Fund and public donations. The Conservation Department also has a small, self-generated fund for buying land that has high biodiversity. This is financed from the sale of less important conservation land and has amounted to about $1.5 million a year.

The **New Zealand Fish and Game Council** and its 12 **Regional Fish and Game Councils** are modern descendants of the old acclimatisation societies which brought so many pest species into New Zealand. Today these organisations are charged with managing, maintaining and enhancing populations of introduced sports fish (e.g. trout and salmon) and native and introduced game birds (e.g. ducks, geese, pheasants). As some of the sports fish have negative impacts on native fish, and some of the game birds are declining indigenous species (e.g. grey and shoveler ducks), the game councils' activities have important implications for biodiversity. The councils and the Department of Conservation are required to coordinate their management plans wherever sports fish and game birds are involved.

The **Ministry of Fisheries** (formerly a part of the Ministry of Agriculture and Fisheries) is responsible for the management of marine and commercial freshwater fisheries. Under the Fisheries Act, the Minister is required to sustain not only the target species of a fishery, but also any associated or dependent species, the biological diversity of the marine environment, and any habitat of particular significance to fisheries.

The Ministry provides the expert advice for this, drawing on data from the fisheries scientists at the Crown Research Institute, NIWA, and on consultations with fishing companies, Maori interests, recreational fishers, environmental groups and Government agencies such as the Department of Conservation and the Ministry of Maori Affairs (Te Puni Kokiri).

The **regional and unitary councils** and **district councils** enforce resource management policies and plans in consultation with the community and Maori interests. In doing this, they are required, among other things, to sustain ecosystems and have regard for their intrinsic values and for the protection of significant habitat of indigenous species as well as the habitat of trout and salmon.

The **Ministry for the Environment** has an oversight role in the planning and policy-making process and also furnishes advice to the Government and the councils on a range of environmental issues, including some relating to biodiversity.

The **Ministry of Forestry** has an Indigenous Forestry Unit whose role is to ensure that sustainable management permits and plans for the milling of native timber follow the requirements of Part III of the Forests Act 1949, which was amended in 1993 to ensure that the forest's natural values are retained while the forest is being harvested.

Several **Crown Research Institutes**, particularly Landcare Research and NIWA, maintain biodiversity and pest databases and undertake research on species and ecosystems.

Conservation activities, policies or research are also pursued by a number of non-governmental organisations (NGOs) such as ECO, Friends of the Earth, Greenpeace, the Maruia Society, the New Zealand Ecological Society, the Royal Forest and Bird Protection Society and the Worldwide Fund for Nature (NZ). Some are special-purpose organisations, such as the Botanical Society of New Zealand, Ducks Unlimited, the Federated Mountain Clubs, the Native Forests Restoration Trust, the Ornithological Society of New Zealand, Project Jonah, the Rainforest Coalition and the Yellow Eyed Penguin Trust. Groups such as these have been instrumental in bringing conservation issues to the attention of national and local government, lobbying for effective solutions and initiating practical biodiversity conservation projects.

Several companies have also become involved in conservation activities by making financial contributions to conservation projects. Their sponsorships are managed through partnerships with the Department of Conservation, the Royal Forest and Bird Protection Society and the New Zealand Conservation Authority under the Threatened Species Trust Programme. The Bank of New Zealand contributes to the Kiwi Recovery Programme; Comalco provides funds to help save the kakapo; State Insurance helps support the kokako; Flightcentre New Zealand is sponsoring the Takahe Recovery Programme; and Ace Dynaco Magicdoors has pledged $30,000 to saving threatened native frogs.

Other corporate conservation sponsors who work in conjunction with the Department of Conservation are Hannahs (walkways), Corbans Wines (wetlands), Carter Holt Harvey (Project Crimson—pohutukawa planting), Westpac (Project Crimson and other tree projects), Software Education (various bird support projects) and McDonald's (tree planting programme). Some companies support conservation by donating to voluntary organisations or conservation trusts. Mainland Cheese, for example, supports the Yellow-eyed Penguin Trust, a private organisation which purchases coastal sites for penguin habitat. Besides these big companies whose conservation sponsorship is widely known, many small firms and businesses support conservation projects at the local level.

Over the years, a significant number of landowners have chosen to retain small areas of indigenous forest or wetland on their properties. These have not been formal arrangements sealed by covenants but simply personal decisions to hold on to patches of "bush" and wetland for aesthetic or conservation reasons, or because the land owners have no other use for the land. Often the preserved forest is in gullies and alongside streams. Such strips are important refuges for indigenous biodiversity, but unfortunately many are too small or isolated to sustain viable populations of rare or threatened species for very long. However, the forest remnants can provide temporary footholds, and could provide more permanent habitat if they were modestly expanded and, where possible, connected up.

**Maori tribes** or **iwi** have a strong interest in the management of activities which affect our biodiversity, both as traditional users of some species and as significant land owners and commercial fishers. Maori interests own 40 percent of the commercial fishing quota and a considerable amount of biodiversity habitat is on Maori land (i.e. more than half a million hectares of native forest). Conversely, many species traditionally harvested by Maori communities are now protected by law, with some species restricted to conservation land or subject to harvesting prohibitions or restrictions.

Most of the claims before the Treaty of Waitangi Tribunal include areas of conservation land. Often these areas include mahinga kai (traditional food-gathering areas), waahi tapu (sacred sites), and urupa (burial sites). One claim (Wai-262), which was submitted in

1991 and was still being considered in 1996, seeks iwi control of all New Zealand's biodiversity; its use, study, conservation, and sale (Murray *et al.*, 1991).

Maori interest in biodiversity and resource management is recognised in the Conservation Act 1987 and the Resource Management Act 1991, which require resource managers to consult with Maori. Maori interests and claims have also been recognised in the Maori Fisheries Act 1989 and the Treaty of Waitangi (Fisheries Claims) Settlement Act 1992. In some areas the Minister of Fisheries has established taiapure or traditional fishery zones managed by the local Maori runanga. Separate legislation to provide for customary Maori fisheries is currently being drafted.

**Resources for biodiversity conservation**

In the 8 years from 1987/88 and 1994/95 the Crown contribution to the Department of Conservation's budget was reduced by about 20 percent in real terms and staff numbers fell from a peak of 2,300 in March 1988 to approximately 1,500 full-time equivalent positions (Department of Conservation, 1993). Current DOC staffing is approximately 1,300 full-time equivalent positions. The Department had a total budget of $123 million in 1994/95, of which almost $95 million came from the Crown and $28 million came from other sources.

In 1995/96, the Department received a $5 million increase in Government funding, most of which was earmarked for possum control and threatened species work. This boosted the Department's budget for threatened species and island habitat programmes from nearly $16 million in 1994/95 to nearly $19 million in 1995/96 (Department of Conservation, 1995). On 20 May 1996, the Government announced a further increase of $68.4 million in funding for the Department of Conservation to be spread over the following three years.

The new financial allocation came as part of the Government's Budget strategy in what has been called a 'Green Package.' The increase will take the Department's total funding to $181 million a year by 1998/99. Of the new funding, $20 million will be used to combat pests and weeds, $18 million will go toward the protection of threatened species, and $6.25 million will be allocated to research to find new and cost-effective ways of controlling possums.

**Responses to the pressures on biodiversity**

The combination of laws, statutory organisations and interest groups has produced a wide range of responses to the main pressures on our biodiversity. Most of these responses have focused on reducing human predation but, increasingly, measures are being developed to deal more effectively with the pressures of habitat decline and pests and weeds.

***Responding to human predation***

The Conservation Act 1987 and other Acts covering reserves and national parks prohibit the taking of indigenous species on protected land without the Department of Conservation's consent. Several other laws prohibit or regulate the taking of indigenous plants and animals anywhere in New Zealand.

The ***Native Plants Protection Act 1934*** is generally acknowledged to provide little real protection for native plants. It appears to have been written to limit the collection by gardeners of small herbaceous plants (Bellingham, 1993b). Fines are very small (not exceeding $40 for the third offence) and in the only test case a pohutukawa tree was found not to be a 'plant' under the Act. The Act prohibits the taking of significant quantities of most native plants without landowner permission. On public land, that permission must come from Government or local authorities.

Exceptions are made for medicinal, research or horticultural plant uses and for the following plant taxa: hutiwai or piripiri (*Acaena* spp.), tutu (*Coriaria* spp.), tauhinu (*Cassinia* spp.), fireweed (*Erechtitoid* spp.), waterfern (*Histiopteris incisa*), kanuka (*Kunzea ericoides*), manuka (*Leptospermum scoparium*), hard fern (*Paesia scaberula*), tauhinu (*Pomaderris phylicifolia*), bracken (*Pteridium esculentum*), nettles (*Urtica* spp.), thallose liverworts (*Marchantia* spp.) and all mosses. The Act also does not apply to lichens, other fungi or algae.

The ***Wildlife Act 1953*** gives varying levels of protection to native and introduced animals which live in a wild state in New Zealand.

The definition of 'animal' is legal rather than scientific. It includes most wild mammals (but not rabbits, hares or marine mammals), all wild birds, all reptiles and native frogs, but very few fish and invertebrates. The protected invertebrates include the giant wetas, all the large land snails, some weevils and other beetles, a grasshopper and the cave spider.

The Act was recently amended to include some marine species (e.g. black and red corals, and black spotted groper) that were formerly protected under fisheries regulations, and to extend its coverage out to the 200 mile limit of the Exclusive Economic Zone. Most fish, however, are covered separately by the Conservation Act 1987 (in the case of freshwater native and sports fish) and the Fisheries Acts 1996 (in the case of commercially harvested freshwater fish and all marine fish). The vast majority of invertebrates are also excluded from the Act's definition of animal. Most of the species covered by the Act are totally protected from being killed, moved, liberated, held or disturbed. Several species, however, are in the following special protection categories:

*Game birds* may be hunted in season, but are protected at other times. They include the native grey duck, shoveller and paradise ducks and pukeko, as well as a number of introduced species.

*Partially protected* species may be killed as pests by landowners, but are otherwise protected. They include the southern skua, white-eye, harrier hawk, black shag and little owl.

*Publicly notifiable* species may be killed subject to conditions set by the Minister of Conservation in a *Gazette* notice. They include the sooty shearwater and grey-faced petrel (which may be killed by Maori customary hunters), peafowl, little shag and pied shag. They also include (in the Chatham Islands only) grey ducks, pukeko and South Island wekas, plus introduced black swans and mallard ducks, and (on islands in Foveaux Strait and off Stewart Island) the Stewart Island weka.

*Unprotected* species may be killed at any time. They include introduced mammals (cat, dog, cattle, sheep, horse, weasel, stoat, ferret, polecat, rat, mouse, hedgehog), birds (black-backed gull, blackbird, red-vented bulbul, cirl bunting, Cape Barren goose, Malay dove, feral goose, chaffinch, goldfinch, greenfinch, guinea-fowl, kookaburra, magpie, mynah, budgerigar, eastern rosella, sulphur-crested cockatoo, rock pigeon, redpoll, skylark, hedge sparrow, house sparrow, starling, thrush, turkey, yellowhammer) and frogs (green frog and whistling frog).

The Wildlife Act also prohibits the export of any bat, bird (other than farmed fowl, duck, turkey or pheasant), reptile, amphibian, *Paryphanta* land snail, or any parts thereof, without the consent of the Director-General of Conservation.

The ***Fisheries Act 1996*** requires all commercial fishing to be authorised by a fishing permit. It empowers the Minister of Fisheries to impose sustainability measures on any fishery by setting limits on catches (annual quotas, daily bag limits), minimum sizes, prohibited areas, fishing methods and seasons. More than 50 fish and invertebrate species are currently managed this way, most of them through the Quota Management System (QMS). About 120 more species will eventually be added to the QMS, bringing about 15 percent of our marine fish species under quota management.

The Minister may also impose a three-month moratorium on any fishery if the stock, associated species, or environment are being depleted by fishing activity. However, the Minister can no longer impose absolute protection through fisheries regulations. A small number of marine species which were protected in this way are now protected under an amendment to the Wildlife Act 1953.

The Fisheries Act also sets out a process for dealing with bycatch, or 'fishing related mortality' where it affects any of the species covered by the Wildlife Act 1953 or the Marine Mammals Protection Act 1978. Both of these Acts were amended to allow the Minister of Conservation to produce Population Management Plans which establish allowable bycatch limits for protected species. The Fisheries Minister is required to manage the fishery in accordance with these plans, or, in the absence of a plan, to consult with the Minister of Conservation on measures to be taken.

The ***Marine Mammals Protection Act 1978*** combines conservation and animal welfare objectives by prohibiting people from injuring, killing or molesting marine mammals around New Zealand's coasts and throughout the Exclusive Economic Zone (EEZ). The Minister is also empowered to establish marine mammal sanctuaries in which fishing or other disturbances to marine mammals can be restricted or prohibited. At present, two such sanctuaries exist, around Banks Peninsula and the Auckland Islands. The Act allows the accidental killing of marine mammals in fishing nets but empowers the Minister of Conservation to impose limits on this through Population Management Plans.

The ***Trade in Endangered Species Act 1989*** and the Trade in Endangered Species Order 1991 fulfil New Zealand's obligations under the Convention on Trade in Endangered Species (CITES). The CITES list is periodically revised and includes the following New Zealand species: Campbell and Auckland Island teals, brown teal, parakeets (Forbes', Antipodes Island, orange-fronted, yellow-crowned and red-crowned), kakapo, kaka, kea, falcon, Australasian harrier, buff weka, tuatara, all *Paryphanta* snails, black coral, Cyathea and Dicksonia tree ferns, and all orchids. It is illegal to export these species or to import other CITES-listed plants, animals or body parts without a country of origin permit. Fines range up to $100,000 for an individual and $200,000 for a corporation.

New Zealand has a more liberal interpretation of export permits than some other CITES members, such as Australia. Since 1988, export permits for both native and imported species have only been withheld where it can be shown that the species have been illegally imported, captured or killed (Ansley, 1995). Imports are closely policed, however, with the Department of Conservation, the Customs Department and the Ministry of Agriculture jointly operating the National Flora and Fauna Investigations Unit (NFFIU). More than 6,000 illegally imported CITES-listed specimens are apprehended each year.

### *Responding to habitat decline and alien species*

#### *Legal protection*

The responses to habitat decline occur at two levels: legal protection, which is effectively protection from encroachment by people; and ecological protection, which is protection from introduced species and the effects of previous environmental destruction. The main legal protection measures have already been described in chapters 4 and 5. In brief, nearly 8 million hectares of land and about 1 million hectares of sea have been set aside in parks, reserves, or other protected areas, and are administered by the Department of Conservation (see Tables 9.37 and 9.38).

Despite their size, however, these protected areas are not representative of the habitats where much of our indigenous biodiversity is found. The bulk of the protected land is in the mountains, and most of the protected marine area is around the Kermadec Islands and in marine mammal sanctuaries, leaving barely 15,000 hectares of protected marine habitat in our coastal waters (see Figure 9.8). While the Kermadec Marine Reserve boosts the protected portion of our marine environment to nearly 7 percent of the territorial sea (i.e. waters within 12 nautical miles of the coast), the remaining marine reserves cover less than 2 percent of our coastal mainland waters (i.e. waters within a kilometre of the coast). All marine protected areas combined cover barely a fraction of 1 percent of our Exclusive Economic Zone. In fact, New Zealand's parks and reserves have made a surprisingly small contribution to species conservation. Only a few reserves were set aside to protect native species. They include the island sanctuaries of Little Barrier, Kapiti and the subantarctic islands, a few mainland sanctuaries, such as Waipoua Forest, and a scattering of small scientific reserves.

In most places, protected areas were chosen more because they were available and not wanted for anything else than because they had high biodiversity value (Towns and Williams, 1993). Almost all the national parks were established for their landscape features. Some were amalgamations of scenic reserves which were developed for aesthetic reasons and to service a tourist industry. Forested areas were not routinely set aside for their scientific value until the Forests Act was amended in 1976. As a result, the lowland forests, which made up about 50 percent of the original forest area, and supported a wider variety of species than the mountain forests, now comprise only about 16 percent of the protected forest area, and less than 7 percent of the original lowland forest area.

The Department of Conservation is attempting to improve the representativeness of our protected areas. Through the Protected Natural Areas Programme (PNAP) it is identifying under-represented habitats, many of which are on private land in lowland areas or on high-country leasehold land. Legal protection for these is achieved in various ways (e.g. through local authority plans, covenants and other contractual arrangements with landowners, land purchases, leases and exchanges). The Department can also take action under the statutory advocacy functions provided by Section 6 of the Conservation Act and through the processes contained in the Resource Management Act 1991.

**Table 9.37**

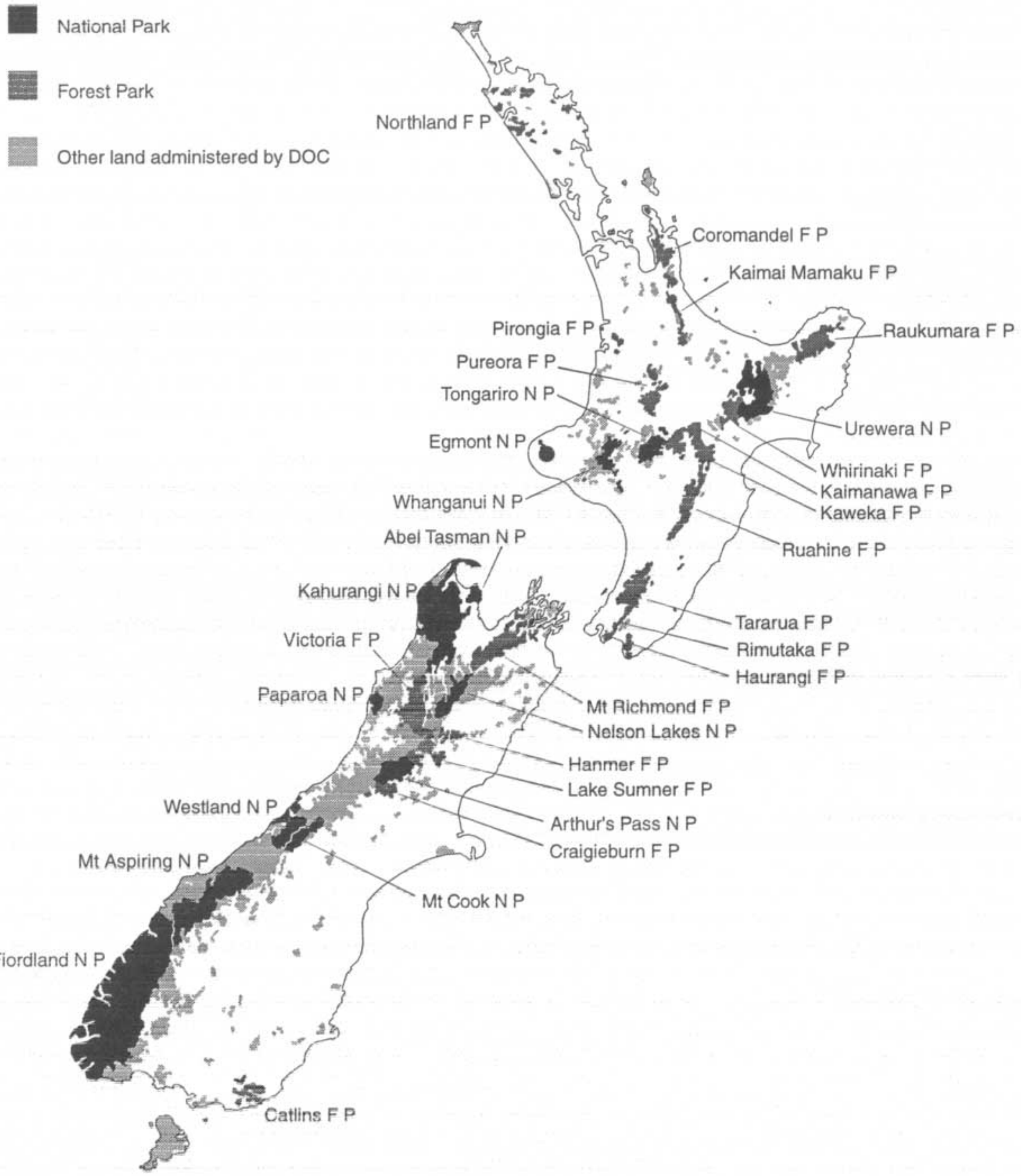
**Parks and reserves administered by the Department of Conservation in 1996**

| Protected areas | North Island | South Island |
|---|---|---|
| ***13 National Parks***<br>*(Total area approximately 2.8 million hectares)* | *Tongariro*<br>*Urewera*<br>*Egmont*<br>*Whanganui* | *Abel Tasman*<br>*Kahurangi*<br>*Nelson Lakes*<br>*Paparoa*<br>*Arthur's Pass*<br>*Westland*<br>*Mount Cook*<br>*Mount Aspiring*<br>*Fiordland* |
| ***19 Forest Parks***<br>*(Total area approximately 1.4 million hectares)* | *Northland*<br>*Coromandel*<br>*Kaimai-Mamaku*<br>*Raukumara*<br>*Pirongia*<br>*Whirinaki*<br>*Pureora*<br>*Kaimanawa*<br>*Kaweka*<br>*Ruahine*<br>*Tararua*<br>*Rimutaka*<br>*Haurangi* | *Mount Richmond*<br>*Victoria*<br>*Hanmer*<br>*Lake Sumner*<br>*Craigieburn*<br>*Catlins* |
| ***4000 Reserves*** *(approximately)* | *Dispersed throughout New Zealand* | |
| ***2 Marine Parks*** | *Mimiwhangata (near Whangarei)*<br>*Tauharanui (near Auckland)* | |
| ***1 Marine Protected Area*** | *Sugar Loaf Islands (near New Plymouth)* | |
| ***13 Marine Reserves*** | *Kermadec Islands*<br>*Cape Rodney-Okakari Point*<br>*Poor Knights Islands*<br>*Whanganui-A-Hei*<br>*Tuhua/Mayor Island*<br>*Motu Manawa-Pollen Island* | *Long Bay-Okura*<br>*Kapiti*<br>*Long Island - Kokomohua*<br>*Westhaven Te Tai Tapu*<br>*Tonga Island (Abel Tasman National Park)*<br>*Piopiotahi*<br>*Te Awaatu Channel*<br>*(The Gut, Doubtful Sound, Fiordland)* |
| ***2 Marine Mammal Sanctuaries*** | *Banks Peninsula (for Hector's Dolphin)*<br>*Auckland Islands (for New Zealand Sea Lion)* | |
| ***2 World Heritage Natural Sites*** | *Te Wahipounamu (south-west New Zealand)*<br>*Tongariro National Park* | |
| ***1 World Heritage Cultural Site*** | *Tongariro National Park* | |

*Source: Department of Conservation*

**Figure 9.8**

**Land administered by the Department of Conservation in 1996**




*Source: Department of Conservation*

**Table 9.38**

**Area of parks and reserves administered by Department of Conservation in 1996.**

| Protected Area Categories | IUCN Category[1] | Area (hectares) |
|---|---|---|
| ***Public land subject to the National Parks Act 1980*** | | ***2,425,884*** |
| *specially protected areas* | *Ia* | *55,176* |
| *wilderness areas* | *Ib* | *205,260* |
| *national parks (balance)* | *II* | *2,165,448* |
| ***Public land subject to the Conservation Act 1987*** | | ***4,668,440*** |
| *conservation parks* | *II* | *1,815,026*[2] |
| *ecological areas* | *Ia* | *215,116* |
| *sanctuary areas* | *Ia* | *16,420* |
| *wilderness areas* | *Ib* | *167,597* |
| *stewardship areas* | *IV* | *2,769,683* |
| ***Public Land subject to the Reserves Act 1977*** | | ***809,570*** |
| *national reserves* | *II* | *96,361*[3] |
| *nature reserves* | *Ia* | *189,472* |
| *historic reserves* | *III* | *3,279* |
| *scenic reserves* | *III* | *518,501* |
| *scientific reserves* | *Ia* | *10,368* |
| *wildlife purpose reserves* | *III* | *18,621* |
| *recreation and other reserves* | *V* | *68,969* |
| ***Public land subject to the Wildlife Act 1953*** | | ***10,821*** |
| *wildlife refuges and management areas* | *IV* | *10,226* |
| *wildlife sanctuaries* | *Ia* | *595* |
| ***Private land subject to the Conservation Act 1987 and the Reserves Act 1977*** | | ***61,760*** |
| *reserved under conservation covenants or private agreements* | *IV* | *61,760*[4] |
| ***Total land conservation area*** | | ***7,976,475*** |
| ***Marine reserves subject to the Marine Reserves Act 1971*** | *Ia* | ***760,513*** |
| ***Marine mammal sanctuaries subject to the Marine Mammal Protection Act 1978*** | *Ia* | ***335,111*** |
| ***Marine parks subject to the Fisheries Act 1983 and the Harbours Act 1950*** | *Ia* | ***2,350***[5] |
| ***Marine protected area subject to the Sugar Loaf Islands Marine Protected Area Act 1991*** | *Ia* | ***800***[6] |
| ***Total marine conservation area*** | | ***1,098,774*** |

[1] *As defined by the International Union for the Conservation of Nature and Natural Resources.*

[2] *The total area figure for 'conservation parks' also includes many ecological and sanctuary areas, as well as two wilderness areas. The 'double counts' are excluded from the net total area.*

[3] *The total areas figure for 'national reserves' also includes units of nature, scenic and historic reserves. These 'double counts' are excluded from the net total area.*

[4] *Further areas of private land, totalling at least 70,000 hectares, were committed for protection as of mid-1996, but not yet gazetted.*

[5] *The lead administrative agency is the Ministry of Fisheries which shares responsibilities with the Department of Conservation (at Mimiwhangata) and the Auckland Regional Council (at Tauharanui).*

[6] *Fisheries matters within this reserve are administered by the Ministry of Fisheries.*

**Figure 9.9**
**Marine reserves, proposals and investigations in 1996**


*Source: Department of Conservation*

**Box 9.22**

***Marine reserves as rock lobster nurseries***

New Zealand's oldest marine reserve is the 518-hectare Cape Rodney-Okakari Point Marine Reserve at Leigh north of Auckland which extends about 800 metres out from the shoreline for a length of some 7 kilometres. Since 1975 it has offered full protection to all the species within its boundaries, including much sought-after species such as snapper and rock lobster. Surveys of the reserve's rock lobsters found that, while commercially-harvested populations elsewhere were declining, those at the Leigh reserve and also the Tawharanui Marine Park further south, were becoming denser and their adult lobsters were reaching larger sizes (Ayling, 1978; MacDiarmid, 1991).

In the mid-1980s, as rock lobsters became rarer everywhere else, fishing boats began targeting the boundaries of the reserve and marine park. From 1990, the reserve's male lobsters, but not its females, went into a steep decline. Investigations found that the male lobsters were being caught outside the reserve area during their summer "vacations" (MacDiarmid, 1991; Kelly, 1997 in press). The lobsters like to holiday at deep offshore reef patches up to two kilometres from their dens where they forage on shellfish on the sandy sea floor. Males are caught much more than females because they spend more time out of the reserve. In any case, egg-bearing females that are caught must be thrown back.

The irony is that the reserve which was designed to protect the lobsters from commercial pressures has actually benefited the local lobster fishery. The spillover of adult males from the protected areas makes up a significant part of the local commercial catch. Catch rates on the reserve boundaries are substantially higher than in other areas where the lobsters and their nursery environments have been over-exploited. While this one small reserve makes an insignificant contribution to the national rock lobster catch, it shows that reserves can have commercial as well as environmental benefits. However, for marine reserves to play a more significant role in the nation's rock lobster fishery, there would need to be many more of them than there are at present (MacDiarmid, 1991).

An increasing amount of habitat protection is being achieved on private land through the Forest Heritage Fund, Nga Whenua Rahui, the Queen Elizabeth II National Trust, and private organisations such as Ducks Unlimited, the Native Forests Restoration Trust and the Yellow-eyed Penguin Trust. The Department is also considering proposals for about 24 new marine reserves (see Figure 9.9) and has begun a process similar to that followed by the Protected Natural Areas Programme (PNAP) for the nearshore marine area, to ensure that protected marine areas are representative. The Department aims to establish a network of marine reserves that will include key ecological communities in each biogeographic region.

Even with legal protection, however, most of our terrestrial and freshwater habitats are in ecological decline as a result of previous or surrounding land use (e.g. forestry, agriculture) and the impacts of introduced pests and weeds. Legal protection, therefore, has to be accompanied by ecological protection (i.e. controlling pests and enhancing native habitat) in many cases.

*Ecological protection*

The Department undertakes about 70 ecosystem restoration programmes each year, ranging from pingao planting in sand dunes to artificial restoration of water tables in drained wetlands (e.g. Whangamarino wetland). This sort of work can require extensive maintenance. In other cases, restoration may involve intensive pest and weed control or nothing more complex than the erection of a fence to keep stock out.

One of the most successful mainland restorations is at Mapara wildlife management reserve, 35 km south of Te Kuiti in the North Island, where a comprehensive programme controlled rats and possums. The nesting success rate for native birds rose from less than 30 percent to nearly 60 percent, with kokako, New Zealand falcons, fernbirds and native pigeons all showing population increases. Similarly, at Kaharoa, near Rotorua, three years of intensive possum and rat control raised the kokako population from 7 to 13 pairs and lifted the rate of breeding success from 14 percent to 85 percent.

**Box 9.23**

### *Island sanctuaries*

Only a handful of islands in the world are still relatively free of human influence and introduced animals. New Zealand has some of these among the 330 islands with areas greater than 5 hectares which lie off-shore and beyond. Many islands have become sanctuaries for threatened species, either as last outposts for plants or animals which occur nowhere else, or as rehabilitation centres for species transferred from the mainland or other islands. These island sanctuaries include most of the subantarctic outlying islands, such as the pristine Snares Islands, as well as the smaller islands in the Chathams group, the Three Kings (where Great Island became naturally reforested within 40 years of the eradication of goats), Whakaari (White Island), the Poor Knights, the Kermadec group, and Little Barrier Island (Towns *et al., 1990*).

The big advantage of islands is their isolation which makes it relatively easy to keep them free of weeds, browsing animals and predators. Their main disadvantage is their small size, which limits the population levels and species diversity they can support. Many islands also have a history as death traps because, once invaded by mammals or noxious plants, the vulnerable indigenous species have nowhere to run. When ship rats invaded Big South Cape Island in 1964, for example, robins, fernbirds, bush wrens, snipe, saddlebacks and the larger short-tailed bat were wiped out.

Ecological restoration is possible, however, even though extinct species cannot be brought back. Little Barrier Island is probably the most celebrated example. This 3,083 hectare island near Auckland was logged for kauri last century, but was made a Nature Reserve in 1894. Although it took some time, all mammals were removed from the island, except the Pacific rat (kiore). Today it has a rich regenerating lowland forest with an abundance of native birds and invertebrates. More recently, the eradication of possums from Kapiti Island, near Wellington, has resulted in a resurgence of flowering trees and bird populations. Rat eradication is now under way on the island. In Fiordland, the elimination of rats from Breaksea Island has allowed the return of the Fiordland skink (*Oligosoma acrinasum*), threatened weevils and the South Island saddleback, a forest bird which is now extinct on its namesake island (Taylor and Thomas, 1993). It has also created an opportunity to rehabilitate several other species. A restoration programme has also begun on denuded Motutapu Island near Auckland. It involves environmental groups, local Maori and the wider Auckland public. Two-thirds of the island will be replanted in indigenous species during the next 50 years, including plants which have traditional cultural uses. A wetland will be restored and archaeological and traditional sites will be protected.

One of the most critical island restorations is occurring on 11,216 hectare Campbell Island, New Zealand's southernmost subantarctic island. It is the breeding ground for 95 percent of the world's royal albatrosses as well as elephant seals, yellow-eyed penguins, and many other species. In 1984 cattle were removed and, in 1991, the last sheep, allowing the island's original vegetation to start recovering. The eradication of cats and rats is being considered as an option over the next 5 to 10 years, as these have wiped out many of the islands' insects and all the smaller ground-dwelling birds, such as pipits and storm petrels. The Campbell Island teal is now a refugee on nearby Dent Island. Getting rid of the introduced species may not be enough, however. The numbers of large animals on the island have been dwindling for decades, perhaps because their food supplies are changing in response to changing sea temperatures. The waters around New Zealand have risen more than half a degree this century (Thwaites, 1994). The crustaceans on which the island's penguins usually feed have apparently migrated south, forcing the penguins to rely wholly on fish, in competition with marine mammals and fishing boats. Rockhopper penguin numbers have fallen from about 1 million pairs in the 1940s to about 50,000 pairs. Yellow-eyed penguin numbers have also declined and elephant seal numbers have decreased by more than 95 percent.

**Box 9.24**

### *The legacy of 'Old Blue'*

Through the ages, animal heroes, real and imaginary, have been immortalised in legend: Black Beauty (horse), Tarka (otter), Elsa (lioness), Didget (gorilla), Smokey (bear), Tex (whooping crane), Martha (the last passenger pigeon) and, closer to home, Pelorus Jack and Opo (dolphins), Z12 (yellow-eyed penguin) and Grandma (royal albatross). Each of these animal heroes has, in one way or another, advanced the causes of animal welfare or conservation. Not one, however, has matched the achievement of Old Blue, a female black robin in the Chatham Islands. Besides winning hearts and minds, she also won the race against extinction. Her story must surely be unique—a true tale of an individual who, with a little help from mate, rescued her kind from oblivion (Merton, 1992).

Old Blue came into the world about 1970 on Little Mangere Island. This speck in the sea, with its seven hectares of scrub-forest, had become the last refuge for her species. Although black robins had once been widespread throughout the Chatham Islands, by 1871, rats, cats and habitat disturbance by humans had exterminated them on all but two small islands. One hundred years later, the black robins were down to 18 individuals eking out a precarious existence on the smaller of these islands. By 1976, their numbers had slipped to just 7 individuals—5 males and 2 females. One of the females was Old Blue. She was lucky to survive because even this tiny pocket of forest was shrinking fast, strangled by encroaching noxious plants. In 1976, all 7 robins were captured by Government wildlife experts in an audacious rescue operation, and transported down the 200 metre cliffs of Little Mangere and across the rough sea to Big Mangere Island. The following year a massive avalanche obliterated a third of their new forest refuge and the population fell to 5. Old Blue and her infertile mate were among the charmed survivors. By now she had already passed the average life span of her species, 5–6 years, and showed little sign of becoming the saviour of her kind. She had not produced a single chick.

In 1978, however, Old Blue did an unusual thing. Defying black robin custom, she changed mates, taking up with the only other male on the island, dubbed Old Yellow by the scientists. At age 9, robin dotage, she became a mother for the first time and, from then, until her death at age 13, she and Old Yellow produced 11 healthy offspring. Even this late effort would have been futile, however, were it not for the resourcefulness of her scientist midwives who knew the risks of putting all one's eggs in one basket. They fostered some of Old Blue's eggs to birds of other species in a bid to keep her eggs coming. It worked. By mid-1996, the black robin population had grown to 200 birds on two islands, all descendants of Old Blue and Old Yellow. This makes the black robin the most inbred wild bird species on Earth, and the only one for which the parentage and lineage of every individual is known and traceable to a single ancestral couple. Without that couple, and the scientists who watched over them, the black robins would be gone. The only question now, is whether the limited genetic variability in the surviving population will be sufficient to cope with the environmental conditions of the future. Only time will tell the answer to this, but, in the meantime, conservation scientists are attempting to spread the risk by establishing colonies of the species on several different islands.

#### Species conservation

Much of the ecological restoration work is undertaken as part of species conservation programmes. New Zealand's programmes have been described as the most imaginative and cost-effective in the world (Diamond, 1990). Innovative techniques pioneered here include the restoration and use of off-shore islands as refuges for threatened species and the use of cross-species fostering to increase chick production (see Boxes 9.23 and 9.24). In 1995/96 the Department ran 490 species conservation programmes, comprising 132 for birds, 171 for plants, 49 for reptiles, frogs, and bats, 40 for fish, 34 for invertebrates, and 78 multi-species programmes. Marine mammals are also the subject of ongoing programmes. The Banks Peninsula Hector's dolphins and the New Zealand sea lions on the Otago coast are being monitored, fur seal populations and bycatch are being studied, and about 200–500 stranded whales are rescued each year.

Among the conservation programmes are about 40 species recovery programmes which target highly threatened species. These include bats, birds, reptiles, amphibians, fish, invertebrates and plants. The programmes include research and monitoring, habitat restoration, predator control, captive breeding and transfers to new or underpopulated areas. Recovery programmes with high priority are those for kakapo, kiwi, black stilt, parea (Chatham Island pigeon) and taiko (Chatham Island seabird). Other birds receiving special attention are the yellow-eyed penguin, the New Zealand shore plover, the Chatham Island oystercatcher, the blue duck, brown teal, stitchbirds and the New Zealand dotterel.

### Island restorations

Island restorations have been particularly successful (see Box 9.23). Each year the Department undertakes about 110 restoration programmes on off-shore islands. These involve pest eradications, revegetation and the introduction or reintroduction of threatened species. The Department's Pest Eradication Database shows that by April 1994, Norway rats had been eliminated from 20 islands and were in the process of being eliminated from 5 more. Ship rats had been eradicated from 6 islands and were still being eradicated from 12 more. Pacific rats had been eradicated from 14 islands and were being eradicated from 5 more. Mice had been eradicated from 5 islands and were being removed from 4 more.

The Department also has island eradication programmes for possums (3 complete, 8 in process, 1 failure); rabbits (12 complete, 4 in process), stoats (3 complete, 1 failure), ferrets (1 complete), cats (8 complete, 1 stopped), pigs (8 complete, 1 failed), goats (15 complete, 2 in process), cattle (4 complete), sheep (4 complete) and wekas (9 complete, 2 in process, 2 stopped, 2 failed). In 1996, an eradication programme for Norway and Pacific rats was initiated on Kapiti Island.

### Pest control

Pest control is a central element of all ecological protection programmes in New Zealand, on both islands and mainland reserves. Under the Wildlife Act 1953, the Wild Animals Control Act 1977 and the Conservation Act 1987, the Department of Conservation is responsible for controlling 'wild animals' (ecologically destructive mammals) and other pests and weeds on the conservation estate and unallocated Crown lands. These responsibilities are separate from those covered by the Biosecurity Act 1993 (which deals with pests and weeds in agricultural and urban areas, but not on conservation or forestry land) and by the Hazardous Substances and New Organisms Act (which covers the importation of potentially harmful foreign organisms and the creation of new ones through genetic manipulation).

In 1994/95, 328 animal pest control operations were carried out over 1.2 million hectares of conservation land, rising to 1.3 million hectares in 1995/96. Because of the size of the conservation estate, pest control is limited to selected high priority areas. The top priority pest is the Australian brushtail possum (see Box 9.25). Funding for possum control has increased in recent years. In 1994/95 the Department's control operations aimed to reduce possum numbers by at least 80 percent over some 200,000 hectares of forest. Increased funding in 1995/96 enabled the Department to expand these operations to about 380,000 hectares and more funding increases announced in the 1996 'Green Package' should enable further expansions in possum control during the next three years.

Feral goats are also major targets. In 1994/95 the Department ran more than 100 goat control operations covering about 760,000 hectares. It planned to do the same in 1995/96 and also to begin 8 tahr control operations to reduce numbers below the critical 10,000 mark. Besides animal pests, about 136 weed species have been identified as needing management on the conservation estate. Each year the Department carries out about 300 weed control operations for ecosystem restoration, targeting everything from old man's beard in forests, to wilding pines in tussock lands and spartina grass in waterways.

**Box 9.25**

### *Possum control as a way of life*

Few overseas tourists realise the extent to which conserving our beautiful forests requires the poisoning and trapping of millions of small furry mammals every year. Increasing efforts are being made to develop methods which are cost-effective, humane and harmless to other species, and improvements are slowly being made in each of these areas. Of the 60–70 million Australian possums estimated to infest our forests and shrublands, two-thirds are in the North Island. Numbers appear to have peaked in most areas between 1930 and the late 1960s (i.e. about 30–40 years after local colonisation). By 1980, possums were estimated to cover more than 90 percent of the country. They are still spreading into remote areas of South Westland, south-east Fiordland, Coromandel and Northland (Parliamentary Commission for the Environment, 1994; Department of Conservation, 1994c).

From 1951 to 1961, a bounty was offered for dead possums, but this had little effect on their numbers. Since then, widespread poisoning has been the main control method, augmented by trapping methods which range from the inhumane and non-lethal leg-hold or gin traps, to the more humane but lethal-to-kiwis kill-traps. The main poison used is a natural plant toxin called sodium fluoroacetate, which is more widely known as 'ten-eighty' (or 1080) after the sample label by which it was first identified. The poison occurs naturally in Africa, South America and Australia. In New Zealand, it is applied to diced carrot or pollard baits. Like the more humane sodium cyanide, which is also used for possum control, 1080 is fast-acting and biodegradable, leaving no residues in soil or water (Parliamentary Commission for the Environment, 1994).

However, considerable debate has occurred about its effect on non-target species which eat poisoned bait or carcasses. Invertebrates, birds and native bats are all susceptible though, on balance, their populations are thought to be more at risk from possum damage than from 1080. Dogs which eat freshly poisoned carcasses are highly sensitive to it, though not so cats and mustelids. No effects on human health have been demonstrated from environmental exposure to 1080, though a suicide and several cases of illness have resulted from drinking large quantities. Two other widely used poisons are: phosphorus and brodifacoum (Talon). Phosphorus causes painful death, but leaves little toxic residue. Talon is not painful and is usually broken down in the soil by bacteria and fungi, but it can leave toxic residue for up to a year in dry environments (Parliamentary Commission for the Environment, 1994).

The Department of Conservation is responsible for possum control on protected land, but possums are also a threat on farmland where they can pass bovine tuberculosis (Tb) on to cattle. As a result, possum control involves an intricate network of Government agencies, regional councils, research organisations and land users, all coordinated by the Animal Health Board through a national possum management strategy which was formulated under the Biosecurity Act 1993. Possums are not the only Tb carriers, but they are the most numerous. Deer, pigs, goats, cats, ferrets and stoats can also pass on the bacterium. The cattle's innate curiosity is partly to blame. When very ill possums stagger into fields they are often surrounded and closely inspected by curious cattle who then pick up the disease from the dying animals' breath.

The amount of money spent on possum control has risen considerably in recent years. At $20–$30 per hectare, control operations are costly. Total funding rose from $34 million in 1992–93 to $58 million in 1993–94. Most of this was to protect cattle from Tb, but one-third of it was also to protect indigenous ecosystems from possums. Government funding for the control of possums in natural areas rose from $7.3 million (with the Department of Conservation's share totalling $3.4 million) to $19.7 million (with Conservation's share rising to $8.4 million) (Parliamentary Commission for the Environment, 1994). The 1995 Budget further increased this sum, with the Department receiving an extra $5 million to help combat the 'furry chainsaws' and the 1996 'Green Package' increased funding again, providing an extra $20 million over three years for the Department's pest control operations and $6.25 million for research on better possum control methods.

Complete eradication is not feasible, so control measures have to be continual, with the focus constantly shifting to areas that are most vulnerable. While 1080 remains the control method of choice at present, researchers are striving to find methods which are more cost-effective, more humane and even less threatening to native wildlife. Biological controls have been suggested, but their development appears to be a long way off and carries biodiversity risks of its own. At present, poisons and traps are the price that we and the possums have to pay for the privilege of living in this unique but biologically ravaged part of the world.

## CONCLUSIONS

New Zealand's environment has been substantively changed in a time span that is very short in evolutionary terms. Though, from today's perspectives, we may wonder whether it was necessary to remove quite so much forest, drain quite so many wetlands, introduce quite so many alien species, create quite so much pasture, and extinguish quite so many native species, New Zealand's economic and social progress was based on these changes . We are what we are today because of our past. We cannot undo history - we can only learn from it.

In recent decades, New Zealanders have become less complacent about their natural environment. There is a growing awareness of what has been irrevocably lost. New Zealanders are also seeing how people from other parts of the world admire what does remain, which is reflected in the ecotourism boom and in the success of our 'clean and green' export promotions. A large majority of New Zealanders now support efforts to save our threatened species and their habitats.

Their sentiments are reflected in our key environmental laws which require that native species, habitats or ecosystems, including fisheries, be protected from use or sustainably managed during use, not just for resource purposes but also for their intrinsic value. More specific laws provide varying degrees of harvesting protection to most of our native vertebrates and vascular plants. These laws and the success of the Department of Conservation's species management and habitat protection programmes have markedly improved the survival prospects of some threatened and declining species.

Despite this, however, many species remain threatened and more appear to be joining them. New Zealand has lost a third of its native land and freshwater birds, and now has a greater percentage of threatened endemic birds than almost any other country. Two thirds of our land is now a biodiversity desert in which 1,000 known taxa of plants, animals and fungi are struggling to survive. Some may not even reach the next century. The threat is greatest for our endemic vertebrates and for plants, fungi and invertebrates with restricted populations.

The reasons for the continuing pressure on our threatened species are partly perceptual and partly historical. The perceptual problem is shared by most New Zealanders. It rests on the belief that the remaining area of natural habitat, in the mountains and isolated reserves, is sufficient to support our surviving indigenous species, provided it is protected or properly managed. In fact, the remaining area is not sufficient. For many of our threatened species, the existing habitat is in the wrong location or in reserves which are too small.

The historical problem is a dual legacy: habitat loss and introduced species. The massive habitat change wrought by previous generations has incurred an 'extinction debt' which is still being paid by our indigenous species. With each generation, the vulnerable populations shrink further. If the damage is to be undone, native forests will need to be restored to at least 10–20 percent of the lowlands and foothills, particularly along streams and rivers. Other native habitats, such as wetlands, will also have to be expanded. Because of the slow regrowth of native forest, some of the habitat-deprived species will need intensive conservation programmes for several generations while this restoration is occurring.

The remnant areas of forest and wetland that have been deliberately spared by private landowners provide an opportunity to make some biodiversity gains in lowland areas without large changes in area. Significant recovery and rehabilitation of the indigenous biodiversity in these habitats could be achieved by landowners modestly increasing the width of some forest strips and working together, voluntarily or with community support, to form larger forest areas by joining up some of the existing forest remnants.

Our second historical legacy is the army of predatory and browsing animals and aggressive weeds which were introduced by previous generations and which now threaten our remaining natural habitats. They have turned many reserve areas into war zones where ceasefires are temporary and the pressure is constant. Costly though it is, pest and weed control is now a necessary component of the modified New Zealand ecosystem.

Faced with these pressures and problems, the future seems bleak for many of our indigenous species unless current rescue and restoration efforts can be expanded. To meet this huge challenge, land uses will need to become more accommodating to native species, effective pest control will need to be maintained over large areas, systematic monitoring of biodiversity will need to be undertaken in all regions and fishery areas. In addition, our recently increased rescue and restoration efforts for vulnerable species and habitats on the protected estate will need to be consistently maintained or increased to ensure success. More effort will also need to go into public awareness and education programmes.

Even our marine species are increasingly vulnerable, despite being substantially removed from the pressures affecting the land and freshwater species. They, too, are experiencing environmental changes as a result of increasing harvesting pressures from commercial fishing, rising sea temperatures and sediment entering coastal waters from land-based activities.

Although New Zealand's fisheries are now managed on a strong scientific footing, the principle of Maximum Sustainable Yield on which quotas are based, has a single-species focus which is largely blind to the ecological impacts of stock reductions. New fisheries legislation now makes the tension between single species management and ecosystem management explicit by requiring the impacts of fishing on ecosystems and non-target species to be minimised. This will require wider monitoring and a more precautionary approach to fisheries management.

New Zealanders are slowly beginning to realise that indigenous species have been the main victims and the silent cost-bearers of our impacts on the environment. Sacrificing them on the march toward economic progress was once seen as a small price to pay. But a small price in human terms converted to a massive cost for the species concerned. Now that commitments have been made to safeguard our remaining species, the true cost of our environmental destruction is becoming more apparent as we seek affordable methods of halting and reversing the damage.

If lasting solutions are to be found, they will be based, in part, on new attitudes to the species which were once sovereign here—and to those which have displaced them. Vilifying introduced pests has become a part of the New Zealand psyche, but these innocent killers did not come here of their own volition. In making scapegoats of them, we lose sight of our own role. Our historical hunger for land and often poor self-control when harvesting indigenous plants and animals are significant causes of the nation's biodiversity crisis. Likewise, our earlier careless importation of pests and weeds has compounded the problem.

Ultimately, the fate of New Zealand's biodiversity will depend on our ability to better manage the exotic species we have brought here, including ourselves, and on our willingness to share more of the nation's land and water resources with the depleted species which have nowhere left to run. It may also depend on our willingness to accept a simple ethical proposition: that the species which evolved here have a basic right to be here, whether we need them or not.

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THE STATE OF NEW ZEALAND'S ENVIRONMENT

CHAPTER TEN

# CONCLUSIONS ON THE STATE OF NEW ZEALAND'S ENVIRONMENT

In many respects New Zealand is a picture postcard country. Lest we forget it, the nation is awash with coffee table books, calendars and evocative television advertisements that showcase our spectacular scenery. The images, photographed through crisp, clean air, are of green and productive farmland, dazzling white mountain peaks, blue glacial lakes, swift mountain streams, yacht-bespeckled bays and harbours, tall pine plantations, and remote native forest tracks. These images show the environment as it really is in many parts of New Zealand, and most of us take considerable pride in that fact.

But, of course, they are not the full story. To focus exclusively on the pretty pictures is to be lulled into a false sense of security about our environment. This first comprehensive report on the state of New Zealand's environment adds to the pictures with words and figures and identifies the environmental problems we face and our remedial actions. In some cases (e.g. air, soil and water contamination) the problems appear to be less severe than in more densely populated parts of the world, but they are still serious enough to merit our concern and they have the potential to worsen if we are complacent. In other cases (e.g. habitat decline and threatened species) the problems are severe and widespread and appear to be getting worse, even as our wildlife documentaries prosper on world television.

Evidence of our environmental impacts is not hard to find. Because humans have been here for only 700–800 years, our first impacts are still detectable in sediment layers that show past erosion, buried charcoal, the pollen of incinerated plants, and the bones of more than 30 extinct birds. The more recent impacts are all around us: in our still declining populations of native animals, plants and fungi; in the pests and pastures that have displaced them; in localised instances of flash floods, erosion, pollution and other soil and water problems; in the haze of car fumes and chimney smoke that forms in some urban areas; and in the burning February sunlight that intensifies as the thinning ozone layer reaches its annual low point.

The fundamental source of most of these problems is the dramatic ecological change that occurred when a land of forests and shade was turned into a land of open pastures and towns. This big change reduced, fragmented and destabilised ancient ecosystems, altered water tables and run-off patterns, accelerated erosion in some areas, and set the scene for a raft of human activities that have sometimes led to air and water pollution, soil contamination and an influx of exotic pests and weeds.

While there are some exceptions, most of today's large environmental problems are either the legacy of past changes still taking their toll (e.g. flooding, habitat and species decline, contaminated sites), or the combined effect of many small impacts that are not quite in balance with the environment's ability to absorb them (e.g. water pollution from diffuse sources and local air pollution from motor vehicle emissions and household chimneys). Cumulatively, over time these small impacts can add up to much larger impacts on the environment and on our quality of life.

Using the information in previous chapters, we can now draw some conclusions about the state of New Zealand's environment, as far as present data allow us. We will do this by considering what they tell us about some of the important environmental issues facing New Zealand. The Government's *Environment 2010 Strategy* identifies eleven priority issues that need to be addressed over the next decade (see Chapter 4). Six of these issues are concerned with sustaining valued aspects of the environment (i.e. biodiversity, fisheries, soil, water resources, air quality and the ozone layer). Five are concerned with controlling pressures on the environment from various sources (i.e. pests and weeds, waste and hazardous substances, energy use, transport, and greenhouse gas emissions). Although the issues are listed as if they are independent, they are, in fact, all interconnected to some degree (Ministry for the Environment, 1995). For example, water quality is affected by, among other things, land use, pests and weeds, and pollution from wastes and transport leaks and residues.

Atmospheric and air quality are also affected by land use, transport, and other forms of energy use. Soil quality is affected by land use, pests and weeds and waste disposal. And biodiversity is affected, to some extent, by all of these things.

So, rather than see the issues as separate, it is more accurate to think of them as facets of the same picture or interconnected strands in a web. Some strands are relatively short and connected to only a few others. Some are long and connected to many others. In all cases, none can be changed independently without affecting some of the other strands. Addressing the issues effectively, then, requires an integrated approach to environmental management, such as that envisaged in the Resource Management Act.

It also requires something else—good information. One of the key goals of the *Environment 2010 Strategy* is for New Zealand to develop a sound information base through well coordinated research and a nationally standardised approach to monitoring. The OECD's 1996 performance review of New Zealand considered our current information base to be very limited and stressed the need for better environmental information (OECD, 1996). This lack of good environmental information and data is not confined to the public sector. In a recent survey of company environmental reporting in thirteen countries, New Zealand companies came bottom, with only 39 percent of those surveyed mentioning the environment in their annual reports and none producing a separate environmental report (Wennberg and Larsson, 1996).

The need for better environmental information is highlighted by the chapters of this report. While they show that New Zealand has a lot of environmental information and some very good analysis, they also show that much of this is too limited in place, time or topic to depict national trends or even provide a national snapshot (see Table 10.1). To ensure that environmental management is well focused, we need to have a coherent, consistent picture—and this picture should help integrate our responses to issues. Our first, and strongest, conclusion then is that New Zealand's environmental information, including the collection and integration of data, needs to be improved. Many of the other conclusions in this chapter should be read with the caveat that they are often based on limited information.

*Conclusion 1:*
***New Zealand's environmental information needs considerable upgrading if the state of the nation's environment is to be accurately described and trends detected.***

With the passing of the Resource Management Act and the increasing involvement of New Zealand in international environmental agreements and information exchanges, the need for better environmental information is now widely recognised. The improvements are needed in three areas: national indicators, basic research and applied research.

Indicators are important because they enable us to detect environmental changes through regular monitoring of a few symptoms or signs of change. To be useful nationally, indicators need to be measured using standardised methods and protocols. The Ministry for the Environment's National Environmental Indicators Programme is now addressing this need (see Chapter 1). The programme focuses on eleven sets of core indicators, corresponding to each of the priority issues identified in the *Environment 2010 Strategy*. Rather than duplicating or cutting across the monitoring programmes of councils and other resource management agencies, the indicators programme encourages collaboration so that common techniques can be developed and research and planning can be better targeted and coordinated. The information from the national indicators programme will also form the basis of future national reports on the state of the environment.

**Table 10.1**

**The state of our environmental data: a summary**

| Environmental issue | State of the data |
|---|---|
| *Biodiversity* | *Only 30,000 of perhaps 80,000 multicellular species have been identified. Most of the undescribed species are insects and fungi. Wildlife habitat sites and a number of ecologically representative areas have been surveyed and recorded over the past two decades, but relatively few have been monitored since the initial survey. The status of most species and ecosystems is not known.* |
| *Pests and weeds* | *Considerable data exist on vertebrate pests, economic pests and a range of ecological and economic weeds, though we still lack population estimates and distribution maps for many of them. Very little is known about invertebrate pests in natural ecosystems.* |
| *Fisheries* | *Considerable raw data have been collected on marine fish and invertebrates, but analysis has largely been confined to the commercially important target species. Catch data are the main monitoring method. Status estimates are available for about half the commercial quota stocks. The status of marine ecosystems and non-target species is unknown.* |
| *Soil quality and quantity* | *No current information exists on the national state of our soils, though the land use capabilities of our soils are known. Erosion data are 20 years old, except in some areas which have been more recently updated. Other indicators of soil quality (e.g. nutrient loss, carbon loss, compaction, acidification, site contamination) have not been surveyed at the national level, though variable data exist at regional and local levels.* |
| *Water quality and quantity* | *Considerable information exists on rainfall and river flows. National survey data exist on river quality, and lake and groundwater quality are now being monitored through a national network. Coastal waters are monitored for toxic algae. More than a third of drinking water supplies are of unknown quality because of inadequate monitoring. Most water quality monitoring focuses on chemical and physical indicators. Ecosystem monitoring is just in the developmental stage. A lot of information is held by regional councils, but not in forms that can be easily aggregated nationally.* |
| *Air quality* | *Very little air monitoring has been done in most parts of New Zealand. The data which do exist come from just a few cities, most notably Christchurch and Auckland. A national air quality monitoring network is now being developed.* |
| *Waste and hazardous substances* | *The collection of national data on sewage waste was discontinued in the mid-1980s and has only recently been revived with the development of a national waste treatment plant database. There is little information and monitoring of other liquid wastes. Except for the national litter survey which has been run since 1987, national data on solid waste were non-existent until the mid-1990s. With the development of the Waste Analysis Protocol to systematise waste data collection, and the completion of our first landfill census in 1995, national estimates of solid waste are now possible. However, gaps still remain in identifying the particular sources of waste, the amount and sources of hazardous waste and the extent of recycling.* |
| *Environmental impacts of energy* | *A considerable amount of information exists on the economic uses of energy but little national data exists on the environmental impacts of energy use (e.g. waterways transformed, land areas flooded, sites contaminated, air pollution from fires, greenhouse gas emissions). Statistics on oil spills at major ports are now being kept and estimates of greenhouse gas emissions are calculated from economic data.* |
| *Environmental impacts of transport* | *National data on the environmental impacts of transport are virtually non-existent though local studies of the impacts on stormwater and air quality have been conducted in some cities (e.g. Auckland). Estimates of some transport impacts may be inferred from existing data on vehicle fleet size and composition, kilometres travelled, size of roading network and petrol and diesel consumption.* |
| *Greenhouse gases and potential climate change* | *National data on weather patterns, temperature, rainfall etc. are generally of high quality and go back many decades. Data on greenhouse gas concentrations in the atmosphere are also of high quality and go back two decades. Data on some greenhouse gas emissions are still limited and uncertain, but estimates of carbon dioxide emissions from energy and industrial processes can be accurately calculated from economic data. Good data on carbon storage in pine plantations are available, but are lacking for indigenous forests and soils* |
| *Ozone depletion* | *Data on ozone concentrations are of high quality and go back about a decade. National data on imports of some ozone-depleting substances exist, but no data exist on the use and emission of ozone-depleting substances.* |

While indicators alert us to the signs of environmental change, basic research provides a deeper understanding of the processes of cause and effect that underlie it. However, both indicators and basic research have limited value if the information they provide cannot be used to influence the change process. For this, applied research is vital because it translates the findings of basic research into useful methods of environmental management, such as new technologies or clear guidelines and codes of practice. The Ministry of Research Science and Technology has the prime responsibility for identifying research priorities and national science strategies.

The funding for research in priority areas comes largely from the Public Good Science Fund which is managed by the Foundation for Research, Science and Technology. Some basic and applied research is also funded by the Ministry of Fisheries (in part through user-pays levies on the fishing industry), the Department of Conservation, the Ministry of Agriculture, the Crown Research Institutes themselves, and the Minister for the Environment's Sustainable Management Fund. Most of the public good funding is for basic research while responsibility for commissioning applied research falls mainly to local authorities or to government departments whose role is to set environmental guidelines and standards or advise on fishery quotas.

***Issue:***
***Protecting indigenous habitats and biological diversity.***

If the scale of an issue is in any way reflected by the sheer amount of paper needed to describe it, then the chapters of this report would indicate that biodiversity decline is our most extensive and multi-faceted environmental issue. It is big because of the range of species and ecosystems encompassed by it, and also because it is linked to most of our other environmental issues, particularly those affecting land and water. These extensive links mean that tackling the biodiversity issue will inevitably lead to wider environmental benefits, particularly in land and water management.

The arrival of humans established two distinct biological communities in New Zealand. The first community consists of species that evolved here or adapted after arriving by wind or water during the past 80 million years (including such recent self-introductions as the swallow, waxeye and reef heron). The second community consists of humans and the species that came with us, particularly those that have arrived within the past two centuries.

For both economic and recreational reasons, we have managed the country's resources largely for the benefit of the second community (including unintended beneficiaries, such as rabbits) while leaving the native species to survive as best they could, often in habitat remnants and protected areas. Only in recent decades have the efforts of, first, the Wildlife Service and then the Department of Conservation begun to successfully turn the tide in some parts of the protected estate.

At present, the scale of the problem and the degree of threat facing most species and ecosystems is only approximately known. Ignorance of species and ecological processes is particularly acute for invertebrate animals, fungi and micro-organisms, though even many large animals and plants are only poorly known.

About 30,000 of our estimated 80,000 indigenous animals, fungi and plants have been formally identified, and only a fraction of these are known well enough to have their conservation status assessed. National vegetation maps describing our ecosystems at the landscape level have not been updated for more than a decade. Only a few of the habitat areas in the Department of Conservation's nationwide SSWI database (Sites of Special Wildlife Interest) have had their status updated since 1985, and most of the representative ecological areas surveyed to date by the Protected Natural Areas Programme are not monitored for trends and changing conditions. Water ecosystems have tended to be monitored for physical and chemical contaminants rather than for biodiversity, though moves are now underway to survey marine ecological areas around the coast. There has been little research and little monitoring of our marine ecosystems except in a few small reserves.

Of the species whose condition is known, a larger number than previously thought appear to be threatened. At least 800 species and 200 subspecies, virtually all of them endemic, are considered threatened. They include both of our endemic marine mammals, two-thirds of our endemic birds, 20 percent of our coastal rockpool fish, and 10 percent of our native plants. These threatened species may be the growing swell of a third extinction wave. The first and second extinction waves followed the two main periods of human colonisation, and wiped out 32 percent of our endemic land and freshwater birds, 18 percent of our endemic seabirds, 1 of our 3 native bats, at least 3 out of 64 reptiles, and at least 12 invertebrates.

*Conclusion 2:*
***Biodiversity decline is New Zealand's most pervasive environmental issue, with 85 percent of lowland forests and wetlands now gone, and at least 800 species and 200 subspecies of animals, fungi and plants considered threatened.***

The main pressure on most species is insufficient natural habitat caused by past land development and water management practices. The areas of greatest habitat loss have been in lower-lying, developed parts of the country where habitat destruction and fragmentation has been extensive. Around 85 percent of the original lowland forests and wetlands have been removed since human settlement. Complex and diverse ecosystems have been replaced by monocultures and built-up areas. Large areas of land and freshwater are now dominated by a small number of exotic species and sustain relatively few native species.

Although ongoing deforestation and drainage have now largely ceased, their legacy is an 'extinction debt' that has forced the decline of many threatened species. Surviving indigenous habitat areas continue to decline in biodiversity through the impacts of pests and weeds and the inability of small isolated populations to indefinitely withstand external pressures. Human predation, particularly fishing activities, can also still have an impact on some species.

*Conclusion 3:*
***The main pressures on indigenous biodiversity today are insufficient habitat in lowland areas, declining quality of many of the remaining land and freshwater habitats, the impacts of pests and weeds and, for some marine species and ecosystems, human fishing activities.***

Around 30 percent of the national land area is now in a protected conservation estate. Although this is among the highest percentages of protected land in the OECD, most of it is steep and mountainous, containing relatively few areas of lowland forest, wetland, duneland or even sub-alpine grassland. Within the protected estate the Government has provided significant additional funding in recent budgets to carry out extensive pest control programmes on areas at severe risk from habitat collapse and also to implement highly successful species recovery programmes both on offshore islands and for some mainland 'islands'. The Government also funds voluntary protection of existing forest and open-space remnants, but, as yet, there is no broad strategy for enhancing native biodiversity in lowland areas.

Among our protected areas, coastal ecosystems are under-represented. Active protection applies to 1–2 percent of the coastal waters within a kilometre of the main islands. The vast bulk of New Zealand's protected marine areas are located around the Kermadec and Auckland islands. Because of their size, they make up about 7 percent of our territorial waters, well under 1 percent of our Exclusive Economic Zone.

The Fisheries Act 1996 now requires that fisheries be managed in a way that sustains biodiversity and marine ecosystems, but tensions may arise between management of fishstock for sustainable yield and ecosystem management. New Zealand has ratified the Convention on Biodiversity. One of its responsibilities under that convention is to develop a National Biodiversity Strategy and these issues are likely to be addressed in the development of that strategy.

*Conclusion 4:*
***The main responses to biodiversity decline have focused on ecosystem and species recovery programmes on offshore islands and extensive pest control operations on the mainland, but the need for partial restoration of representative indigenous lowland and coastal ecosystems and for wider protection of marine ecosystems has yet to be addressed.***

The loss of any endemic native species is a loss not only for the nation but for the world. Once they have gone from New Zealand, they have left the planet forever. However, biodiversity loss is not confined to endemic species. Beneficial exotic species are vital to the New Zealand economy, but most high yield strains and varieties have limited genetic diversity. In the event of disease, significant climate change, or new market preferences, such crops and livestock have a limited ability to adapt without genetic input from their lower yield and wild type relatives. It is therefore important to maintain the genetic diversity of beneficial exotic species.

At present, many minority crop and livestock strains and varieties may be disappearing from New Zealand because of poor storage facilities and limited knowledge of their existence or importance. While many of these strains can be imported or recreated from overseas gene pools, some are specifically adapted to New Zealand conditions and would be difficult to recreate quickly.

*Conclusion 5:*
***Many strains and varieties of beneficial exotic species may be disappearing and this may have significant economic impacts on New Zealand's agriculture, horticulture and forestry.***

***Issue:***

***Managing pests, weeds, and diseases***

Introduced pests, weeds and diseases pose a serious risk to biodiversity, agriculture, forestry and aquaculture. The nation's estimated 70 million possums are currently considered to be the nation's most destructive pests. Every night they eat about 21,000 tonnes of vegetation, kill native birds and invertebrates, and help spread tuberculosis to domestic cattle. Rabbits are another high profile pest, though their greatest impact is limited to the 'tussock predominant' grasslands of the South Island where their pressure has combined with that of invasive weeds and grazing sheep to degrade an area of about 1 million hectares. Less obvious, but more widespread, is the combined pressure from many smaller invaders, such as insects, parasitic worms, weeds and fungi. These threaten native species, exotic crops, forests or livestock and their pressure grows with each new arrival (e.g. the white spotted tussock moth).

Air and ship travel has allowed many exotic organisms to leapfrog the ocean barrier that once protected New Zealand from biological invaders. With the success of our economy based largely on the sale of high quality primary produce in distant markets, it is vital to control the entry or subsequent spread of new organisms. We also need to assure buyers and governments that our quality standards will not allow the inadvertent export of any pests.

Careful management is needed to contain these risks. Measures employed to date include: border controls (i.e. the monitoring of incoming passengers and freight and the incineration of aircraft rubbish); technological controls (e.g. pesticides, animal traps, the release of biocontrol organisms, the breeding of pest-resistant crop and livestock strains, careful husbandry practices); and ecological controls (i.e. spreading the risk by increasing crop, stock or ecosystem diversity). The most cost-effective approach in the longer term, integrated pest management (IPM), combines all or several of the technological methods.

The sheer numbers of some species (e.g. possums and rabbits) together with public concern about some technological control methods (e.g. pesticides, gin-traps, biocontrols, and genetically engineered crop and livestock strains) means that the pest control war is likely to be a never-ending one—for some species at least. For the foreseeable future, vigilant pest and border control in concert with comprehensive species recovery and ecosystem restoration programmes are our only means of ensuring ecological and economic security. Because of its scale, continuous pest control will only be sustainable economically and socially if it continues to become safer, more humane and more cost-effective.

*Conclusion 6:*

*Pest control, especially of possums, is now a vital means of protecting our environment as well as being important for our economy. Pest control will need to become increasingly safe, humane and cost-effective to remain economically and socially sustainable.*

***Issue:***
***Sustainably managing our soil quantity and quality***

Two-thirds of our soils are on mountains and hills, most of which consist of soft sedimentary rocks that have been fractured and raised by frequent earthquakes. These young erosion-prone mountains have produced a land that is rich in sand and gravel but has relatively few metal deposits other than gold and ironsands. The mountains also create a rain-shadow effect in eastern and northerly parts of the country, occasionally subjecting the soils to drought conditions.

The New Zealand climate is ideal for growing pasture grass and exotic pine forests, but the soils that nourish these plants are often less than ideal. The general characteristics of our soils are well known, thanks to comprehensive soil maps and assessments of land use capability made several decades ago. Having evolved under forests, most of our soils tend to be thin and acidic and generally have low levels of nitrogen, phosphorus and sulphur. They are not well suited to agriculture and so need to be modified and managed in order to support farming and cropping regimes.

Only about 30 percent of the land can sustain pastoral farming without risk of significant erosion problems. A further 28 percent can support limited livestock grazing but this must be accompanied by erosion management measures such as tree planting, farm forestry and, importantly from a biodiversity viewpoint, encouraging native plant regrowth and expansion.

However, while the general soil characteristics are known, national data on the current quality and condition of the soil are non-existent. Local occurrences of soil degradation and erosion are known to land owners and regional council officers, but a national overview of the extent of these is not available. Current estimates of erosion are based on the New Zealand Land Resource Inventory of the 1970s. However, in some parts of the country this information has been updated, and in some cases to a finer scale than the original work.

The challenge of maintaining production from soils that are prone to erosion, nutrient loss, or episodic drought has been met in New Zealand by extensive grazing systems rather than intensive ones, heavy use of fertilisers and lime, and heavy use of irrigation water where required. In addition, the need to control native and introduced pasture pests has required widespread use of pesticides. Each of these land management measures has environmental impacts. In many cases, too, impacts have resulted from a lack of management, such as failing to provide adequate tree cover on erodible slopes and river banks.

A large area of New Zealand has been converted from natural forests, wetlands or dunelands to farm or forestry land (52 percent compared to the world average of 37 percent). This has accelerated erosion of some soils by exposing them to the impacts of wind and rain. In moister, high fertility areas, some soils are exposed to the risk of nutrient loss, compaction and carbon loss from over-cultivation and stock treading. In some areas, too, soil has been contaminated by the careless storage, use or disposal of chemical products from various industries and urban landfills, and in a few rural areas, from the past heavy use of organochlorine pesticides.

Over half of New Zealand is affected by slight to moderate soil erosion, mostly on hill pastures and drought-prone pasture land. Two decades ago, nearly 10 percent of New Zealand suffered from severe to extreme erosion. This was mostly concentrated in a few high risk areas along the east coast of the North Island from Gisborne to Wairarapa, in parts of Taranaki and the South Island High Country.

*Conclusion 7:*
***The main pressures on soil are from past deforestation of erodible land, localised accumulations of harmful chemicals or waste products, and the impacts of over-cultivation or overstocking on erosion-prone and compaction-prone land.***

As early as the 1870s, people realised that impacts on land were serious and needed resolution. From this era on, there was a progressive development of laws and institutions to enable controls to be put on land use to reduce the effects of erosion and, more recently, its causes.

Regulating land use to sustain soils is difficult except where significant adverse effects would occur from that land use. Previous policies of subsidising agricultural production often encouraged land use practices such as the clearance of steep land for pasture that led to environmental problems such as erosion and subsequent siltation of streams and rivers. Today all production subsidies have been abolished and native trees are returning to some slopes.

Current responses to land use problems tend to emphasise providing land users with accessible, usable and relevant information, backed by effective science. Through community-based approaches, such as landcare groups, it is intended that land use problems will be tackled continuously and at their source. This information focused approach is, nevertheless, supported by background regulation and controls available through the Resource Management Act.

Responses to soil problems are increasingly the land users' responsibility. This has led to some positive environmental effects (e.g. reduced sheep numbers and the increase of native scrub or plantation forests on former erosion-prone pasture land) as well as negative ones (e.g. the downturn in fertiliser and lime use in the late 1980s, the economically-motivated deferral of soil conservation measures by some farmers, and the inadequate use of conservation measures by others).

*Conclusion 8:*
*Soil conservation is increasingly the land users' responsibility. Forest planting, regeneration of native vegetation on some erosion-prone land, and the formation of landcare groups are the main response trends.*

***Issue:***
***Managing the quantity and quality of our water resources***

Many parts of New Zealand are prone to problems of either too much or too little water. The uneven distribution of our rainfall means that the mountains and the West Coast are very wet by world standards while the eastern and northerly rainshadow areas are sometimes relatively dry. Most of the population and many of our livestock live in these rainshadow areas.

With expanding urban demand and expanding dairy herds, some water supplies are vulnerable to pressure during occasional summer droughts. This has the potential to significantly reduce river flows and put stress on freshwater animals and ecosystems. Many water supplies rely heavily on groundwater and also on large reservoirs. However, water supplies cannot be indefinitely expanded, and the wisdom of water conservation measures is now beginning to be recognised.

*Conclusion 9:*
*The main pressures on water flows have been from drainage and channelisation (which have reduced wetlands and altered the natural character of rivers including lowland aquatic habitats), deforestation (which has intensified flooding and sedimentation in steep catchments), and increasing demand for urban water supplies, livestock and irrigation.*

All areas are subject to intense flooding from time to time. For most of this century, the main responses to water problems focused on managing water flows, principally through engineering channel straightening and flood protection stop banks. These modifications reduced the frequency of small floods but also encouraged settlement in flood-prone areas, exposing more people and property to risks from large floods. Flood control and land use modifications, together with hydroelectricity schemes, also rechannelled and redistributed many river flows. Through such changes, together with the removal of riparian vegetation and the draining of 85 percent of the original wetlands, the natural character and habitat quality of many freshwater and estuarine ecosystems has been lost or degraded.

As it became evident that floods were directly related to upper catchment deforestation, responses have gradually shifted from flood control to flood reduction through preventative measures such as conservation of mountain forests and reafforestation in parts of some catchments.

*Conclusion 10:*
***Responses to water flow problems that historically focused on flood control and drainage works downstream and on increasing the supply of drinking and irrigation water are now looking more to whole catchment approaches involving afforestation and water conservation.***

Although Maori communities have a long developed respect for water quality and have applied customary rules to it, water quality only became subject to legislation in the mid-1960s. Since then, New Zealand has made significant progress in reducing point source pollution such as piped discharges from factories and sewage treatment plants. Relative to other countries, New Zealand has a small industrial base and little significant heavy industry. This means that large discharges from industrial processes can be relatively easily identified, though many smaller discharges are harder to detect and manage.

With the advent of the Resource Management Act and the Hazardous Substances and New Organisms Act, point sources of pollution are likely to improve further. Under the Resource Management Act existing discharge consents are progressively being renewed and, where necessary, tighter standards will be applied to new consents. However, this will not happen quickly unless major problems are found in a water body. Where no serious problems are apparent, the discharge standards will reflect current knowledge and community requirements.

As point source pollution continues to improve, attention is now switching to New Zealand's most difficult water quality problem—the diffuse runoff of pollutants from land into water. Some of this pollution comes from sediment runoff caused by erosion from extensive pastoral use. But there is increasing pollution from intensive agriculture, particularly dairying, where both animal wastes and nitrogenous fertilisers wash into surface water or leach into ground water.

The scale of the potential problem is large: the total amount of excreta from our livestock equals that of 150 million people. Only a fraction of this enters waterways but that is still a significant amount when concentrated in the lower parts of many catchments. Non-point source pollution is also a major problem in stormwater from urban areas. Large paved surfaces such as roads, carparks and areas around houses and factories contribute considerable amounts of pollution to nearby waterways.

*Conclusion 11:*
***The main sources of pressure on water quality are non-point source pollution (from diffuse pasture runoff of animal wastes, fertiliser and sediments as well as runoff of pollutants from paved surfaces in urban areas) and point source discharges (e.g. from factories and sewage outfalls).***

Because most of the pressures on water quality tend to accumulate downstream, water quality is highest in mountain streams and in the upper reaches of rivers in sparsely developed areas. Such high quality waters are widespread in the South Island and in the upper catchments of most North Island rivers. However, water quality declines measurably in some lowland streams and rivers. Nutrients from run off and animal wastes make some waters unsuitable for swimming, and water quality in some intensive dairying areas is badly polluted from these sources.

Nearly 60 percent of the population receives drinking water from supply and reticulation systems that are safe from contamination. However, a further 40 percent receive water that is either unsafe or of unknown quality. This includes 15 percent of the population who are not connected to water supply systems, 8 percent whose water supply systems are vulnerable to contamination, and a further 8 percent whose water supply systems are too small to be formally graded.

*Conclusion 12:*
*The quality of our water is high by international standards, except in some low-lying rural streams and small lakes, some shallow groundwaters, and some piped water supplies.*

New Zealand has a well developed history of water management and expertise, most of which now resides with its catchment-based regional councils. These organisations are well placed to identify and manage future water issues. As with other environmental issues, developing integrated and standardised indicators and monitoring systems are vital tools with which to identify and analyse problems.

*Conclusion 13:*
*Responses to water quality problems have successfully focused on improving point source discharges (from sewage, factory and dairyshed outfalls) but the more difficult and pervasive problem of non-point source discharges has yet to be addressed and will require changes in land management.*

***Issue:***
***Sustainable fisheries***

The Fisheries Act 1996 requires that fishstocks are utilised in a sustainable manner. This means sustaining target fish stocks while also sustaining marine ecosystems and non-target species. Most target stocks are harvested at rates that aim to maintain them at or near the level that produces the maximum sustainable yield (MSY). Maximum sustainable yield represents the optimum yield level for the fishery and is generally 25–60 percent of the biomass of the unfished stock. Catch limits are the main method of stock management.

Most stocks are thought to be at or near the level that produces the maximum sustainable yield. Some stocks of snapper, orange roughy and rock lobster, however, are currently estimated to be below this level. For these stocks, catch limits and other measures have been set to rebuild them to levels that can produce the maximum sustainable yield.

A total of 42 marine fish species are currently harvested under the Quota Management System (QMS)—about 4 percent of our marine fish species. For management purposes they are lumped into 30 'species groups' and then divided into 179 QMS stocks. Only 74 of these stocks are of known status and only 7 of these were considered to be below the MSY level in 1995-96.

*Conclusion 14:*
*The status of more than half the commercially exploited fish stocks is unknown but, of the stocks whose status is known, about 10 percent are considered to be below the level of Maximum Sustainable Yield and measures have been set to rebuild these stocks.*

Fishing puts direct pressure on target species and indirect pressure on other species, not only of fish but also marine mammals, birds, and marine invertebrates such as corals. Although measures designed to reduce bycatch of these species have been implemented, incidental captures and mortalities occur. It is estimated that as many as 1000 marine mammals, predominantly fur seals, may be caught each year. However reported seabird bycatches, once in the thousands, appear to have declined as the foreign tuna fleet in our waters has been reduced. An estimated 167 seabirds were caught in 1995 as incidental bycatch in tuna longline fishing operations.

*Conclusion 15:*
***Pressures on marine life from fishing include direct harvesting pressure as well as indirect pressures from trawling and dumping of offal on nursery ecosystems (e.g. coral communities, seamounts, bryozoan mats), and bycatch of non-target species (e.g. 1,000 marine mammals, several hundred seabirds, and many non-target fish per year).***

The marine environment is also subject to risk from exotic organisms, especially ones which are unintentionally introduced into New Zealand. Sources such as ballast water from ships or organisms which arrive on the hulls of ships pose potential and quite expensive risks. Toxic algal blooms have become a recurring problem for shellfish fisheries along parts of the east coast of both the North and South Islands.

The Fisheries Act 1996, is based on sustainability and requires this to be achieved in a way that not only with sustains fish species but also associated species and the ecosystems of which they are a part. It recognises that decisions must be based on the best available information, using a precautionary approach when information is uncertain, unreliable or inadequate. The successful implementation of the Act holds the key to ensuring a major economic and ecological resource is both maintained and sustained into the future.

*Conclusion 16:*
***The new Fisheries Act 1996 recognises that environmental sustainability requires more that just sustaining the yield from target stocks but also requires the maintenance of marine biodiversity and ecosystems.***

In addition to fisheries management controls, responses to marine and fisheries issues include preservation of some marine ecological areas through marine reserves and parks. Research on rock lobsters has shown that some reserves can act as both reservoirs of biodiversity and nurseries for some commercial fisheries. To date more than 90 percent of our protected marine areas are confined to two distant island groups (the Kermadecs and Auckland Islands). Less than 2 percent of the coastal ecosystems around the New Zealand mainland islands are protected.

*Conclusion 17:*
***Protected marine areas can act as both reservoirs of biodiversity and nurseries for some commercial fisheries yet, apart from the Kermadec and Auckland Islands, protected marine areas are under-represented in both our coastal waters and our deep water ecosystems, e.g. seamounts.***

***Issue:***
***Maintaining clear, clean, breatheable air***

Thanks to our location, geography, small population and economy, New Zealand generally has very good air quality. Indeed, many visitors are taken with the visual clarity of our air. Compared to more populated and industrialised countries, New Zealand seems like a place where one can 'see forever'.

However, this pristine picture has its blemishes. Recent monitoring has uncovered air pollution levels in some urban areas that, at times, exceed *New Zealand Ambient Air Guideline* values. These guideline values are based on agreed international human health standards. In particular, carbon monoxide levels in some inner city locations show exceedances at times during the year.

Lead levels in the air have been dropping since 1986 when the lead content of petrol was reduced. The production or importation of leaded petrol has been banned in New Zealand since 31 December 1995. Other pollutants such as particulate matter from dust and smoke have also been decreasing. Sulphur dioxide levels have been dropping over the past 20 years and are generally now fairly low.

*Conclusion 18*
*New Zealand is thought to have good air quality by world standards but this judgement is based on little, but increasing, monitoring. In some locations in our larger urban centres, however, there is evidence of ambient air quality at times exceeding New Zealand guideline limits for protecting human health.*

The significant sources of New Zealand's air pollution are industrial sources, multiple small discharges, such as domestic fires, and the motor vehicle fleet. The highest levels of pollution have been recorded in urban centres in winter months when all these sources are contributing. Vehicle use is growing substantially in a number of urban areas.

*Conclusion 19*
*Instances of significant air pollution are caused by the combined effect of discharges from industry, small businesses and homes and the growing use of our vehicle fleet.*

Generally, air emissions from industry can be managed more easily than the diffuse and dispersed emissions from homes and vehicles. Under the Resource Management Act, all discharges to air from industrial and trade premises can be controlled to the extent deemed necessary by regional councils, with some discharges currently uncontrolled while the Act is still in its transitional phase. Regional councils can set ambient standards and require that specific discharge controls be applied to point source discharges from chimneys. This new system is currently evolving but it has the potential to effectively manage all industrial and trade discharges. It also has the ability to impose controls on domestic fires (such as banning open fires and only allowing certain low emission burners) where their unrestrained use would otherwise result in a cumulative problem. Where cumulative problems occur, action is needed to appropriately address all sources.

At present there is limited control of motor vehicle emissions. Use of the Resource Management Act by regional councils may not be the most cost effective way to manage emissions from mobile sources and other measures are being investigated to control these emission sources. These will need to address a number of air pollutants including problems with small particles ($PM_{10}$).

Establishing ambient standards for air quality, and the quantity and concentration limits on the discharge of air emissions is new, as is comprehensive monitoring of air quality. Further work is needed to establish the magnitude of potential problems such as the discharge of small particles which impact on health as well as long term issues affecting air clarity and visibility and ecosystem protection, particularly from toxic air emissions. Development of national air quality indicators, together with a national monitoring programme, is a vital ingredient in discovering and helping eliminate unacceptable blemishes in our air quality picture.

*Conclusion 20*
*Regional councils have mechanisms available under the Resource Management Act to deal satisfactorily with the point source discharges, both large and small, but these mechanisms are unlikely to be as effective on vehicle emissions.*

***Issue:***
***Managing waste, contaminated sites and hazardous substances***

Waste is principally an urban problem. A high proportion of New Zealanders live in urban areas. These urban concentrations, though small by world standards, impose intense pressures on the environment. Urban pollution problems generally come from the combination of big industry, small industry and manufacturing, and importantly from diffuse non-point source run-off from a generally spread out, low density development pattern. This is exacerbated by land and water pollution from extensive use of motor vehicles, especially cars used for commuting to work.

The problem of stormwater runoff from hard surfaces has already been mentioned. This is added to by the activities that occur in urban areas, from motor vehicles which drop contaminants onto surfaces, through to manufacturing and other activities from which contaminants escape or from which they have escaped historically. In some areas, such as Auckland's Tamaki Estuary and its Manukau Harbour, the combined effect of pollutants, including some hazardous pollutants, is evident in the marine ecosystem.

The impacts from New Zealand's industry have been mainly from direct, point source discharges into water or the air. While in total these still represent a significant load on the environment, they are now being controlled and can be expected to keep improving. New Zealand has little tradition of heavy industry and the major contaminated sites associated with it. However, there are widespread low risk sites from landfills, service stations and various industrial activities. These perhaps exceed 7,000 in total although only 1,500 are thought likely to present a high risk to human health or the environment.

New Zealanders produce considerable quantities of solid waste. In 1995 we sent over 3 million tonnes of waste to landfills—about 900kg per person. Approximately 55 percent of this was from industrial sources and 45 percent 'residential', though the latter also included some wastes from small businesses and commercial activities while excluding some from households collected by private contractors. Though not strictly comparable, New Zealand's 400kg of 'residential' waste per person compares with the OECD average of 500kg of 'municipal' waste per person.

The composition of the waste going to New Zealand's landfills falls about half way between the waste profiles of typical rich and poor countries with 39 percent organic matter, paper 19 percent, construction and demolition waste 17 percent, potentially hazardous material 8 percent, plastic 7 percent, metal 6 percent, glass 2 percent and other 5 percent. This varies significantly from area to area and is seasonal with the majority of organic matter coming during the summer. Based on Auckland figures, however, the amount of landfilled solid waste is apparently increasing, although littering has stabilised after a decrease. Other waste trends are unknown.

Effective waste management, with its emphasis on reducing, reusing and recycling waste is an increasingly important environmental management issue in New Zealand, particularly in urban areas. Although landfill capacity is generally available, suitable sites are not always easy to obtain. In large urban areas it is increasingly difficult for landfill sites to gain the necessary approvals and they are expensive to build and operate. Poorly managed landfills can have significant adverse effects in the long term. Stringent standards were introduced by the Resource Management Act resulting in more pressure on landfill performance with consequent reduction in the quantity of landfills available. Guidelines have been developed for the management of landfills but the recent landfill census found significant gaps between the guideline recommendations and practices in the field, with key issues being open burning and lack of operator training.

*Conclusion 21:*
*In many cities the amount of recycling has increased, in some places landfill fees have been raised, and cleaner production is being attempted by some organisations.*

There is a growing awareness of the benefits of cleaner production, not just for big business, but also for small and medium sized business. Cleaner production is based on the goal of reducing the adverse impacts of production and service activities on the environment. In short, it means:

- Avoiding or reducing the amount of waste produced;
- Using energy and resources more efficiently;
- Producing environmentally sound products and services; and
- Achieving less waste, lower costs and higher profits.

Many of these improvements result from simple 'good housekeeping' changes. A number of enterprises are implementing cleaner production and, in doing so, helping the environment and themselves with significant reductions in waste, emissions and costs.

However the evidence suggests that these companies are still the exception rather than the rule. Auckland data indicate that solid waste appears to have increased in recent years in line with economic activity, while the volume of hazardous waste (98 percent of which is disposed in liquid form and is generally not monitored) appears to be greater than previously thought. The Auckland Hazardous Waste Study has concluded that there is still widespread indifference to the dangers of generating, handling and disposing of hazardous waste.

*Conclusion 22:*
*While waste management responses increasingly include recycling, cleaner production systems and higher landfill fees, total waste has increased, our landfill management practices are generally poor, as are our practices and attitudes towards managing hazardous waste.*

***Issue:***
***Managing the environmental impacts of energy services***

Towns and cities and food and fibre processing require energy and we are continuing to demand more of it to provide for our lifestyles. New Zealand's energy consumption has grown by more than six times since the Second World War. Since the 1960s there has been a big increase in gas use and a decline in coal use. Use of oil fuels has declined since the 1970s but is approaching the 70s levels again. Oil provides around 32 percent of our total primary energy, gas 27 percent and coal 7 percent. Since the 1950s oil and electricity have been the dominant consumer energy forms. The greatest energy consumption and growth is in the transport sector, which has increased its proportion of total energy consumed to some 39 percent. By contrast, agriculture's consumption of energy is only 5 percent of the total, although some of the transport use is agriculture related.

New Zealand makes greater use of renewable water based energy for its electricity supply than most other nations—we get up to 79 percent of our electricity energy from hydroelectric stations and up to a further 6 percent from geothermal stations. But there are limits to the ability to economically dam more lakes and rivers. There are also increasing environmental limits as communities seek to protect the ecological and recreational features of many of the wild and scenic rivers that remain. For these reasons, electricity generation has been moving to other sources of fuel, notably gas. However, New Zealand's principal gas reserve, the Maui field, is expected to reach the end of its economic life around 2006. New reserves that have been discovered so far will not be able to sustain Maui's rates of supply.

*Conclusion 23:*
*Most of our electricity is of hydro origin (with impacts on river flows and lake levels) but around two-thirds of our total primary energy is from fossil fuels (with pollutant impacts on atmosphere, water and soil).*

The environmental impacts of energy use vary according to the energy source and the scale of use. Impacts include altered waterways and aquatic ecosystems, loss of geothermal features, air pollution, greenhouse gas emissions, and contamination of soil and water from oil leaks and spills. Though our energy use continues to increase, little data has been collated on the national extent of these impacts so it is difficult to say whether they are increasing or decreasing as a result of more efficient and environmentally responsible technologies, such as wind farms, and co-generation industrial plants.

There has been increasing investment in recent years in relatively high efficiency co-generation industrial plants which burn fossil fuels to generate electricity and use the waste heat in the production processes in the industrial plants. There is also considerable potential for use of more renewable fuels, particularly wind and solar power, together with gains from energy efficiency. The Government is promoting energy efficiency as one of the main responses to the economic and environmental costs of energy use. Other responses include the Maritime Safety Authority's marine oil spill monitoring and contingency plan, and planned measures to reduce greenhouse gas emissions. Like all other sectors, the energy sector is subject to environmental controls under the Resource Management Act. This Act deals effectively with most impacts from stationary point sources (though not some greenhouse gases), but not from mobile sources.

*Conclusion 24:*
*Responses to the environmental impacts of energy services include the requirement to obtain consents under the Resource Management Act, moves toward greater use of renewable energy forms (including the development of wind power) and the encouragement of energy efficiency.*

***Issue:***
***Managing the environmental effects of transport services***

New Zealand has a relatively low density population, so New Zealanders tend to travel a lot, mostly by private vehicle. Between 1987 and 1992 the number of licensed vehicles fell but since then vehicle numbers have increased to their highest level ever. Vehicle use is growing substantially in a number of urban areas.

The low density of our cities multiplies the demand for travel and makes some public transport hardly viable without additional financial support. Encouraged by the availability of private vehicles, New Zealand cities have expanded dramatically in the last 40 years and, in some cases, their expansion has put pressure on surrounding air, land and water resources. New Zealand's relatively low population growth rate and the fact that most of its growth is concentrated in a small number of large urban areas, means that the problems caused by urban expansion do not directly affect the whole country.

Our high level of motor vehicle use produces some significant effects, again principally in large urban areas. Here, travel frequencies and patterns result in adverse effects on air quality particularly along traffic corridors, noise effects and amenity effects such as the intrusion into urban space caused by expanding roading and motorway systems.

There have been few studies of the environmental impacts of transport services, whether on land, sea or air. For land transport, there has been some monitoring of air quality within the traffic corridors in some large urban areas and short term surveys elsewhere. These studies show that at times, air pollutants in these corridors exceed *New Zealand Ambient Air Guideline* values. These guideline values are based on agreed international human health standards. In particular, carbon monoxide levels in high traffic density locations show exceedances at times during the year.

Transport contributes 40 percent of New Zealand's $CO_2$ emissions and these emissions increased by 7 percent in 1995. This is occurring even though vehicles have become more fuel efficient. The lead content of petrol was reduced from 1986 and from 1 January 1996, the production or importation of leaded petrol was banned in New Zealand.

Some 2600 petrol stations are listed among the nation's potentially contaminated sites though data on the extent of any contamination is still very limited. A guideline has been produced for the installation and operation of new underground storage tanks and many old fuel tanks have been removed and replaced.

Stormwater studies, particularly in the Auckland area, have identified extensive contamination of some harbours and estuarine areas with heavy metal and poly-aromatic hydrocarbons. Transport runoff is the major source of these pollutants along with other runoff, trade waste and sewage.

*Conclusion 25:*
*Limited air and stormwater studies show that at times, carbon monoxide levels in some urban traffic corridors exceed the New Zealand Ambient Air Guidelines, and transport is also responsible for some of the extensive heavy metal contamination of some harbours and estuarine areas. Transport also contributes 40 percent of New Zealand's $CO_2$ emissions.*

Many of the environmental effects of transport services are diffuse and this makes them difficult to deal with. At present the only control of motor vehicle emissions is Traffic Regulation No. 28 in which it is an offence if the smoke emitted from a vehicle limits visibility so much to be a safety hazard. There are no controls for environmental purposes. Use of the Resource Management Act by regional councils is unlikely to be the most cost-effective way to manage vehicle emissions. Other possible management options are under study in the Vehicle Fleet Emissions Control Strategy that is first examining emissions to air, then going on to examine and recommend measures to appropriately control emissions to water and noise.

*Conclusion 26:*
*Apart from banning lead in petrol, systematic measures do not currently exist to deal with the environmental impacts of transport services. The Vehicle Fleet Emissions Control Strategy is investigating appropriate measures to control transport noise and emissions to air and water.*

***Issue:***
***Reducing the risk of climate change***

On a per capita basis, New Zealand emissions of the human-induced greenhouse gas carbon dioxide are 25 percent lower than the OECD average, but about 50 percent higher than the global average. Half of these emissions are currently absorbed by forests which act as carbon 'sinks'. Commercial plantation forest growth should increase the $CO_2$ sinks over the medium term. This may be partially offset by biomass loss from indigenous forests caused by pests or be assisted by the regeneration of native vegetation on some marginal land where production subsidies formerly applied. Work is underway to quantify changes in carbon stored in indigenous forests and scrublands. While sinks provide an opportunity for increased absorption of $CO_2$, absorption is not expected to offset the increase in gross emissions this decade and New Zealand will have to seriously address reducing its growth in gross emissions.

New Zealand's per capita emissions of methane, another greenhouse gas, are almost six times the OECD average and ten times the global average. New Zealand's ruminant animals are a major source of methane. The decline in sheep numbers has reduced this source, but cattle and deer numbers are increasing. Overall these changes have reduced New Zealand's emissions by 4 percent between 1990 and 1995.

*Conclusion 27:*
***New Zealand contributes an above-average share to the world total of human induced carbon dioxide gas emissions but less than the average for developed countries.***

Globally and locally, greenhouse gases have increased rapidly in the past century while global climate has warmed by about 0.5°C, and may increase by 1–3°C over the next century if current models of the relationship between greenhouse gases and global temperature prove correct.

There is a common misconception that climate change, if it occurs on the scale predicted by climate models, will be a gradual warming that will enhance New Zealand's economy and society. A temperature rise would lengthen our growing seasons and thereby extend the subtropical and temperate growing areas further south. However some of the other effects of this are uncertain and it is likely that it would also usher in a raft of problems such as more storms and droughts, and greater risks from subtropical pests, weeds and diseases whose range would be extended. Climate change will exacerbate the pressure on ecosystems where they are already under stress.

New Zealand is a signatory to the Framework Convention on Climate Change and is an active participant in the negotiation of a new international agreement for greenhouse gas emission reductions through the Berlin Mandate process. New Zealand recognises that it will only be through joint action, across a substantial number of states, that effective responses will be possible. New Zealand has a programme of measures in place to reduce carbon dioxide emissions—these have achieved some reduction below a 'business as usual' projection. New Zealand is not, however, on track to achieve its current commitment under the FCCC of stabilising net $CO_2$ at 1990 levels by the year 2000, largely because the anticipated increase in absorption through new forest plantings has been lower than expected. New measures are under active consideration and New Zealand will decide on the form and extent of these additional measures following the conclusion of the Berlin mandate process in December 1997 when commitments and options for multilateral action are much clearer. Targets and possible actions for other non-$CO_2$ greenhouse gases are also being addressed.

*Conclusion 28:*
***Although existing measures have achieved some reduction below a 'business as usual' projection, New Zealand is not on track to achieve its current commitment under the Framework Convention on Climate Change of stabilising $CO_2$ at 1990 levels by the year 2000.***

***Issue:***
***Sustaining the ozone layer***

New Zealand's windy climate, small population and maritime location makes for clean air much of the time. Perversely, this clean air exposes us to risks caused by depletion of the ozone layer. The levels of ultraviolet radiation in New Zealand appear to be increasing. An 8 percent decrease in ozone since the 1960s has produced a 10–12 percent increase in ultraviolet-B radiation and will continue to worsen for several decades before slowly rebuilding throughout the next century. The potential impacts on New Zealand of increased UV-B radiation are rising skin cancer rates in people and unsheltered stock animals, property and crop damage, and ecological changes caused by plant and algal damage. International action to address ozone depletion is clearly of significance to New Zealand.

The pressures on atmospheric ozone come from many gases emitted by modern appliances and economic activities. The main gases appear to be halocarbons, such as the CFCs, whose manufacture and import in developed countries such as New Zealand was banned at the end of 1995. Another ozone-depleting substance, methyl bromide, is used as a fumigant in agriculture to kill pests in soils and for quarantine purposes to kill pests in products being imported and exported. With the decline in CFC imports, it appears to have become the dominant ozone-depleting gas released in New Zealand.

Globally, CFCs and halons use is now declining rapidly as a result of swift international actions under the Montreal Protocol. New Zealand is a signatory to the Protocol and takes its obligations seriously. It played a significant role in the development of the Montreal Protocol and has consistently taken actions to achieve the targets set for Parties to the Protocol. Wherever possible, we have accelerated the elimination of imports of substances such as halons and HCFCs. Methyl bromide imports have been partially restricted to 1991 levels but like many other countries New Zealand currently has no phase-out schedule for this in its legislation.

*Conclusion 29:*
*Depletion of the ozone layer will continue for many decades and requires international action. New Zealand has been, and remains, an active participant in the responses to ozone loss including the signing of the Montreal Protocol and the banning of CFC imports in their raw form. We have moved to phase out the use of ozone-depleting substances faster than internationally required but do not yet have a phase-out schedule for methyl bromide.*

***Embracing the sustainability ethic***

While this report conveys a sense of what has been lost and what is under threat, it also shows that much is being done to halt and reverse the adverse environmental impacts. These days New Zealanders value their environment very highly. In a national poll conducted in 1993, two-thirds of the 70 percent who responded said that, if necessary, they would accept a drop in economic growth in order to protect the environment (Gendall *et al.*, 1994). In the same survey, 17 percent reported belonging to an environmental group, a third said they would accept much higher taxes and cuts in their standard of living to protect the environment, and half said they had given money to an environmental campaign in the past five years.

In such a climate of high environmental awareness, fewer people and industries these days are prepared to knowingly impose major impacts on the environment. The Christchurch Press reported that a survey of 380 manufacturers in 1994, for instance, found that three-quarters thought it was in their interest to preserve New Zealand's high environmental reputation.

There is a keen and growing social and economic sense of the value of sustainable environmental management. The ethic of ecological sustainability is enshrined in key pieces of environmental legislation such as the Resource Management Act, the Conservation Act, the Forests Act and the Fisheries Act. Accompanying this sustainability emphasis is a developing environmental management practice which includes the increasing use of the precautionary principle, of polluter pays and economic instruments that identify and transfer the costs of environmental damage to those who cause it.

Both central and local government have been and are setting sustainable environmental improvement targets through formal statutory and policy frameworks and strategies. Systematic monitoring and evaluation systems are being developed. National, regional and local environmental indicators are evolving and in some cases are in place. Work is underway to address the problems of unsustainable land use and to direct science funding toward research on sustainability problems.

Business increasingly values the attributes of a cleaner, more sustainable environment and are themselves busy developing and applying quality and environmental management systems to benchmark and improve their performance. New Zealand's competitive advantage lies in a diverse range of quality products from a quality environment. There is money to be saved from undertaking environmental audits of manufacturing, distribution and service systems and implementing cleaner production and waste reduction practices. There is also a future for nature-based tourism, provided the carrying capacity of the environment is carefully measured and respected.

The sustainability ethic is also helped by a growing awareness of the importance and utility of Maori views and values. These have developed over 700–800 years of sometimes hard-earned experience in living with the indigenous environment and they are most effectively expressed when Maori participate actively in environmental decision making and have the ability to make decisions for their own resources.

***Environmental improvement: a challenge for everyone***

Environmental impacts come from many sources and are often the result of a large number of small, diffuse impacts accumulating over time to produce a significant effect. Managing day to day impacts can help considerably. Individual and household behaviour is very important. Awareness of and active measures to manage the use of energy and water and of the generation and disposal of domestic waste can help considerably over time. Energy efficiency is a direct substitute for more power generation and provides the benefits of energy services at less overall cost to the user and the environment. If motor vehicles are driven carefully and conservatively, less fuel is used and fewer emissions generated. Again the user benefits economically and the environment benefits through cumulative reduction of adverse impacts.

In the primary production arena, small cumulative improvements can also deliver progressive gains. If every land user aimed to maximise diversity of plants and animals, enormous gains could be reaped. If remnant forest areas were left and fenced, wetlands protected or even recreated, riparian strips left free from use, steep erosion prone land retired, diverse tree species including natives planted, and more mixed crop and crop/ animal combinations used, then production would be more economically and environmentally resilient and, over time, more sustainable. The less a farmer has to rely on importing agrichemicals to sustain farming, the better the result for the local and wider environment. Further, over time, such farming should cost less, too.

***Where to from here?***

This report provides a first comprehensive stocktake of the state of New Zealand's environment. Whilst much of its message may seem surprisingly grim to those who are not aware of the nature of environmental impacts in these temperate, wind-blown islands, there is much to be proud of, too. The pendulum of introduced change seems to have completed its swing and to be returning to a state of better balance. New Zealand is conquering its problems of point source pollution. A large amount of the country is now permanently protected. More than ever before people are aware of and value our heritage and are starting to use it constructively and sustainably. More diverse, quality managed and value added primary production offers a path to a richer and more environmentally beneficial future. Measures to define environmental quality and, from this, to identify problems, contain damage and reverse adverse trends are developing. And, finally, the challenge of protecting indigenous biodiversity has been accepted and work is underway to develop a New Zealand Biodiversity Strategy.

A lot has been done to recognise our environmental problems. Core institutions have been put in place to deal with them and legislative frameworks such as the Resource Management Act are based on the notion of ecological sustainability. Work is underway to deal with the big issue of managing the risks to the environment including developing an understanding of the comparative risks that different issues pose. New Zealanders are well placed to develop a constructive and beneficial relationship between the indigenous and human-induced environments.

There are clearly many environmental quality problems ahead and, with them, challenges for all New Zealanders—rural land users and urban dwellers alike. Encouraging the re-establishment of indigenous biodiversity back through and alongside the monocultures of modified New Zealand remains the biggest challenge of all. Measures to reduce non-point source (diffuse) pollution and to increase the sustainable use of land are also very important. With the support and action of those who produce our fibre, food and fish, we should improve the state of our environment. Hopefully, the path from here on will keep the pendulum of change swinging back to a better and more sustainable balance between the indigenous and the modified, between the old and the new.

A key to all these actions, however, will be better, timely and systematic information that increases our awareness of the environment, shows us the improved environmental results we are achieving using our environmental legislation and helps us focus on areas where we need greater collaborative effort to achieve our goals.

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