BASELINE ASSESSMENT REPORT

FISHERIES, AQUATIC ECOLOGY AND RIVER HEALTH

Strategic Environmental Assessment of the Hydropower Sector in Myanmar

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ABBREVIATIONS

ADB	Asian Development Bank
ADPA	Ayeyarwady Dolphin Protected Area
AIRBM	Ayeyarwady Integrated River Basin Management
ARC	Ayeyarwady River Corridor
AWP	Australian Water Partnership
DOF	Department of Fisheries
DOR	Degree of regulation
DWIR	Directorate of Water Resources and Improvement of River Systems
FFI	Fauna & Flora International
GIS	Geographic information system
GMS	Greater Mekong Sub-region
GoM	Government of Myanmar
HPP	Hydropower Project
IBAT	Integrated Biodiversity Assessment Tool
ICEM	International Centre for Environmental Management
IFC	International Finance Corporation
IWMI	International Water Management Institute
KBA	Key Biodiversity Area
MIMU	Myanmar information management unit
MOEE	Ministry of Electricity and energy
NGO	Non-government Organization
PA	Protected Area
PMU	Project Management Unit
SEA	Strategic Environmental Assessment
WCS	Wildlife Conservation Society
WLE	Water, Land and Ecosystem
WWF	World Wide Fund

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EXECUTIVE SUMMARY

The main rivers of Myanmar have been briefly described. The Ayeyarwady river system has been divided up into the Upper, Middle and Lower Ayeyarwady, leading into the Delta. The Chindwin is a large tributary of the Ayeyarwady and has been described separately, so that there are five main basins of the Ayeyarwady river system. The Thanlwin is described from the point of entry into Myanmar from China through to its estuary at Mawlamyine. It has a very different character to the Ayeyarwady system, being principally a narrow rock cut channel for most of its length. The Sittaung is a much smaller river system running from north to south between the two major river basins, before discharging into the Gulf of Mottama. The Myit Ma Hka and Bago river basins are two very small basins near Yangon between the Sittaung and Ayeyarwady. There are two coastal river basins, the Rakhine coastal basin consisting of a number of smaller rivers, including the Kaladan, Lemyo and Mayu rivers, with water arising in the Rakhine Yoma and flowing into the Bay of Bengal, and in the Tanintharyi coastal basin which contains the Tanintharyi and Lenya rivers, flowing into the Andaman Sea.

In the absence of strong data bases to describe the ecological value of the different river systems in Myanmar, the approach has been taken of attributing importance of different aspects to a standard dataset classifying all of the 36 different types of river reach found in Myanmar rivers. River reach rarity according to the total lengths of river reach is taken as an important ecological attribute, as are the areas around confluences and rivers flowing through limestone karst geology. Reaches lying within known areas where endemic fish species are found, including areas such as the Rakhine and Bago Yomas, headwaters of the Ayeyarwady and Chindwin, Indawgyi and Inle Lake areas and in the Tanintharyi coastal rivers. The important river and wetland areas have been noted including those identified from the Key Biodiversity Areas, Ramsar and potential Natural World Heritage Sites and wetlands surveyed during the 2004 Wetland Inventory of Myanmar. The IBAT and IUCN Redlist databases have been used to identify areas important for threatened species of turtles, molluscs, aquatic insects, crustacea and aquatic plants. Similarly, the likely presence of threatened fish species in different sub-basins has been used to identify importance of river reaches using the IBAT and Redlist databases. The importance of migratory fish such as Hilsa, eels, and Tor species are recognized and the mainstem reaches of each river receive recognition of the importance of ecosystem connectivity. Areas where aquatic mammals are found such as the Irrawady Dolphin and otter species have been described. The process provides an identification of the ecological sensitivity of the different river reaches in all the rivers in Myanmar, except for the Rakhine Coastal Basin, where the primary river reach database does not extend. These rivers are described qualitatively.

The ecosystem services provided by Myanmar's rivers have been described qualitatively. In particular, detail has been provided on the fisheries provisioning services, which is one of the most important ecosystem services provided by the rivers. Information is provided on the freshwater and inshore fisheries and aquaculture and their contributions to livelihoods and nutrition of people living along the rivers. The distribution of the leasehold areas for commercial fishing by township is provided. Note is taken of the increasing recognition of the role of women in the fisheries sector. An analysis of the distribution of fish species which have different utilization is provided – commercial uses, subsistence and their potential as ornamental species. Other provisioning services include timber and textile materials from riparian vegetation, and the use of molluscs, crustacea and turtle species for food.

Regulating services include hydrological services such as the seasonal flows patterns, groundwater recharge, flood alleviation in the floodplains, sediment transport and sand and gravel extraction, and maintenance of water quality. Supporting services include nutrient transport from the upper reaches to the floodplains and delta, biodiversity support providing ecosystems and habitats for the different lifecycles of fish and other aquatic organisms, and the river connectivity, which is so important for migratory species. Cultural services include the cultural importance of the rivers of Myanmar to its peoples, and of specific features such as confluences e.g. at Myitsone, deep pools, rapids and water falls. Cultural services include navigation and tourism, especially on the Ayeyarwady.

There is a general recognition that the state of health of the rivers in Myanmar is deteriorating, coming both from government officials and from local villagers living by and using the rivers. There is a concern that conditions are changing quite rapidly. However, there are no comprehensive surveys or analyses of water quality or river health. An approach has been taken to complement the ecological value of the river with a mapping of the river reaches according to the intensity of human pressures upon the rivers. This includes the development of urban areas which affect downstream reaches through the addition of domestic and industrial waste waters, and solid wastes. The rural population density reflects a pressure of river and natural resource use - with increasing density it is possible that unsustainable uses are being reached. Similarly, deforestation in the watershed and clearance of riparian vegetation tends to increase the sediment erosion and transport by the rivers, and change their character. The intensity of agriculture has been mapped covering the areas of single and multiple cropping within each sub-basin. Mining activities, especially for jade and alluvial gold create very negative conditions within certain river reaches, and these have been mapped according to sub-basin. The construction of roads can create adverse conditions in the rivers, and increase access to the natural resources - the density of roads by sub-basin is used as an indicator of this human pressure on the river. Irrigation reservoirs store water for the consumptive use of water for agriculture. There are over 180 irrigation reservoirs in Myanmar covering just over 100,000 ha, which will have an impact upon seasonal flow patterns and reducing connectivity. There are 22 existing hydropower projects with reservoirs covering nearly 100,000 ha. These also affect seasonal and daily flow patterns, retain sediments and may affect water quality. The distribution of these human pressures upon the river systems has been mapped to identify those river reaches where the trends in deteriorating river health are expected to be high. The existing hydropower dams and reservoirs have been analysed for their impacts upon the rivers by estimating the degree of regulation and the degree of fragmentation of the river flows.

This baseline report looks forward to the next step of the SEA in which the ecological sensitivity of the river reaches described here will be analysed to give the inherent ecological value of each of 40 sub-basins. These sub-basins include those where hydropower projects are being proposed as well as other sub-basins where no hydropower is currently being proposed. The purpose of this process is to identify those sub-basins which have a high ecological value from an aquatic ecology perspective, and which can then be combined with their geomorphological and terrestrial ecology values. High value sub-basins identified will require additional safeguards and environmental management if they are to be developed for hydropower and irrigation dams and for other activities such as mining. All sub-basins will be described in terms of their characteristics and level of human pressures to indicate trends in river health. The impacts of the clusters of hydropower projects will then be assessed on those sub-basins in which hydropower is being proposed to identify the increased pressure upon those sub-basins.

1 INTRODUCTION AND SUMMARY OF THE AQUATIC ECOLOGY AND FISHERIES THEME

The aquatic ecology and fisheries theme considers the rivers of Myanmar and the natural resources they contain or support and their importance, especially the biodiversity and fisheries. In this baseline report, each of the major river basins is described briefly in terms of its ecological character, and then the ecological sensitivity of the different river reaches is assessed, using several different parameters. The objective of this approach is to identify those parts of the river systems that have high importance and which may need specific safeguards to protect and maintain them, with or without the development of hydropower.

The baseline report also has an analysis of the different human pressures on these river systems. Hydropower development will be an additional human activity putting pressure on the river reaches, and it is important to understand where the existing pressures and degradation of the river systems is occurring. While it is difficult to directly map the historical trends in river system health e.g. in water quality, it is possible to map the pressures from activities such as urban development, loss of riparian and catchment forest cover, mining and existing irrigation and hydropower dams. Many of these trends have been described in the other theme reports for example:

- **Geomorphology and sediment transport -** this theme provides the essential understanding of the structure and form of the rivers upon which the aquatic ecology depends. The geology, soils, elevation and slope of the rivers defines the character of each section.
- **Biodiversity -** covers the terrestrial habitats and biodiversity. The separation of aquatic from terrestrial ecosystems is essentially artificial, since all rivers are flowing through terrestrial ecoregions and landscapes. The diversity of the aquatic habitats is largely determined by the surrounding ecology, and pressures upon the terrestrial habitats, e.g. from loss of forest cover and mining will determine the status and health of the aquatic ecosystems.
- **Social and livelihoods -** this theme provides information about the people using the rivers and their natural resources, their dependence upon the aquatic ecosystems. Population growth, development of urban centres represent pressures upon the aquatic ecosystems leading towards current declines in river health, emphasized by consultations with riparian communities.
- **Economic development and Land use -** this theme describes the trends in some of the pressures upon river ecosystems, notably changes in agriculture and increasing intensity of cultivation and use of agrochemicals, increasing mining, especially alluvial gold and sand mining which directly affects the river channels.
- **Hydropower -** this theme describes the existing dams and reservoirs, including irrigation dams, which can change the hydrology of rivers, the degree of regulation and which can also cause fragmentation and loss of connectivity.

The description of the baseline situation for the river ecosystems in Myanmar has to be done with a fairly broad brush at this scale, allowing more detailed focus when the positions of proposed hydropower are identified later in the SEA process. Several globally available databases of the rivers are used to highlight the importance of ecological features in different parts of the country. These include the WWF River Reach classification for the Greater Mekong Sub-region, and IBAT/Redlist assessments for freshwater biodiversity.

One of the most important conclusions that emerges from application of these databases is how limited the information is. Large proportions of the species are listed as Data Deficient in the IUCN Redlist. Many parts of the country remain to be surveyed, and the focus for recent surveys has been upon recognized biodiversity hotspots, which illustrate how many new records, new species to science and extensions of ranges of both threatened Least Concern species may be expected from other parts of the river system. Even without further stages of the SEA process, it is possible to recommend surveys to fill the data gaps for further definition of ecologically important river reaches and the biodiversity they contain.

The fish and fisheries are a key natural resource associated with the rivers and wetlands. Aquatic biodiversity information and analysis features mainly in the first section. Fisheries is treated as a human pressure and features in the second section and includes discussion on the contribution that Myanmar's freshwater fisheries sector makes to productivity and nutrition in the country. It also includes their importance for different forms of utilization - commercial fish species, subsistence fish species and fish species with ornamental potential.

2 METHODOLOGY

2.1 River reach classification

The first data set for building up the description of the rivers and identification of areas of ecological importance is the WWF river reach classification scheme which has been developed for the whole of the Greater Mekong Sub-region, except for the Rakhine region (Lehner, 2014). This classification forms the basis for further steps in identifying the reaches of ecological importance, i.e. the sections of the rivers which are important for the biodiversity and ecosystem functions and services. The same classification system is used later in illustrating the trends in human pressures on the river system.

2.2 Identifying ecologically sensitive river reaches

Using a methodology originally developed by the Mekong River Commission (Mekong River Commission, 2015) and adapted for use in Myanmar according to the different data sets that are available, the river reaches that are considered to be ecologically sensitive can be identified by combining "scores" for the following parameters that are developed in the subsequent sections. The sources of the data and scoring criteria are described in Annex 1.

- Rarity of river reach classes, using mainstem, large and medium sized rivers - this is based upon river reaches that cover less than 5% of the classes in each of the five sizes of river throughout the country;
- Important fish migration routes - the mainstem reaches of the Ayeyarwady, Chindwin, Thanlwin and Sittaung all receive scores to reflect their importance as fish migration routes;
- Confluences between i) large and mainstem, ii) large and large and iii) medium and large rivers - upstream and downstream, recognizing that confluences are important locations for mixing of biodiversity and for migrations;
- River reaches flowing through karst limestone, recognizing the importance of karst as a distinct set of ecosystems, especially for specialized and endemic species;
- Recognized areas of aquatic endemism - especially for fish, complemented by the predicted presence of endemic species in different sub-basins. These have been mapped based upon reported hotspots of endemism of fish and other aquatic organisms;
- Sub-basins with the presence of threatened fish species (Critically Endangered, Endangered and Vulnerable). This has been taken from the IBAT/Redlist data projected occurrence in each sub-basin (HdroBasin Level 8);
- Sub-basins with the presence of threatened species of other aquatic organisms (crustacea, molluscs, insects (Odonata) and aquatic plants. This has been taken from the IBAT/Redlist data projected occurrence in each sub-basin (HdroBasin Level 8);
- Important wetland areas made up of several layers:
    - KBAs emphasising river KBAs, wetlands and water birds, dolphins and turtles - this overlay is taken from the KBA listings available from IBAT, and potential KBAs identified during an SEA workshop specifically designed to identify further potential KBAs.
    - Wetlands of global importance - this uses the wetland inventory carried out by BirdLife in 2004 which identified wetlands of global importance.
    - Ramsar and potential World Heritage sites - the three sites that have now been designated as Ramsar sites and the potential Natural World Heritage sites.

At this scale, it is not possible to include specific features, e.g. rapids and deep pools, habitats, fish spawning grounds in the rivers etc. that would make certain reaches more ecologically sensitive.

Each river reach is given a score based upon GIS overlays of these criteria or analysis by sub-basin (HydroBasin Level 6 or 8). The combined scores for all parameters gives an indication of its ecological sensitivity and importance.

2.3 Describing pressures from human activities upon the river systems

The trends in human pressures upon the river systems are built up in a similar way through GIS overlays over the river reaches and sub-basin analysis of the following factors.

- Freshwater and Coastal Fisheries - density of commercial fisheries by township. This has not been included in the GIS overlays;
- Pollution from urban development and run-off, based upon size of cities and towns, impacting upon lengths of river reaches downstream of urban centers;
- Rural population density, which reflects the pressure upon the natural resources, especially fish. This is a parameter included in the river reach classification, quantifying population density above each reach;
- Deforestation and loss of forest cover - this is another parameter included in the river reach classification, based upon forest cover in 2000. There has obviously been a rapid loss of forest cover since then described in the biodiversity theme report;
- Intensity of agriculture - this is based upon 2014 land use data interpreted by IWMI and covers the percentage area of cultivation in HydroBasins (Level 6), factored for area under double and triple cropping;
- Presence of road infrastructure - this is taken from globally available data of roads (Open Street Map) and the length of major roads by area of sub-basin within each river system;
- Mining pressure - This is based on the proportion of known mining area compared to the area of each HydroBasin Level 6;
- Irrigation reservoirs - This is based upon factoring the upstream flooded area and the downstream length down to the next confluence with a similar sized or larger river. The irrigation reservoirs were mapped from Google Earth during the development of the Hydropower project;
- Hydropower dams and reservoirs - As with irrigation reservoirs, the overlay factors the upstream flooded area of existing reservoirs and the downstream length of the river down to the next confluence of a similar sized or larger river. The installed capacity of each of the existing hydropower plants has also been factored into the scoring.

The maps showing the ecologically sensitive reaches are to be compared with the maps showing trends in human pressures. During the impact assessment stage of the SEA, the location of proposed hydropower dams will be overlaid on these maps of ecological sensitivity and human pressures.
The sources of the data and scoring criteria for the human pressures are described in Annex 1.

2.4 Distribution of fish species and other aquatic organisms

The analysis of the distribution of fish and other aquatic organisms has been taken from the IUCN Redlist Freshwater assessment carried out for the Eastern Himalaya region in 2008 and in the Indo-Burma region in 2012. This is available through the IBAT (Integrated Biodiversity Assessment Tool) database. This database draws upon the comprehensive redlisting assessments carried out for fish, aquatic plants, aquatic insects (Odonata), crustacea and molluscs. The projected ranges of these species have been developed for most of the sub-basins (HydroBasin Level 8) in Myanmar rivers, based upon their known ecology and habitat requirements. This is a potential presence of the species in the sub-basins based upon specialist knowledge and judgement, rather than a proven presence through surveys. This database was developed from the 2012 freshwater Redlisting assessments and since then there have been several surveys of fish and other aquatic organisms, which illustrate the limitations and how data deficient the aquatic biodiversity data has been.

A comparison has been made of the fish data from the IBAT database with surveys carried out in Putao, Indawgyi Lake and in the Tanintharyi rivers. These surveys have shown how rich the endemic fish and other aquatic biodiversity may be in many of rivers of Myanmar. There would also appear to be a false tendency for endemic and threatened species to be concentrated in border regions reflecting the ranges of species that have been reported in India (Manipur) or in Thailand.

Nevertheless, this IBAT database provides a useful comparative distribution for key aquatic taxonomic groups, and allows the identification of sub-basins projected to contain threatened species. The presence of threatened and endemic species in a sub-basin has been included as one of the parameters for identifying ecologically sensitive river reaches.

2.5 Degree of regulation and fragmentation of rivers by hydropower dams

Two other measurements can be applied to the existing hydropower dams and reservoirs a) the degree of regulation (DOR) and b) degree of fragmentation (DOF) caused by hydropower dams. Both are measures of the disturbance of aquatic ecosystems and can be applied to the rivers in Myanmar. The baseline DOR and DOF caused by existing hydropower plants can be compared with the future planned plants. The process also identifies those rivers that are already impacted. (Grill, 2016)

The degree of regulation can be applied at the individual plant level or at the sub-basin level, using the formula:

$$DOR = \frac{Total\ upstream\ storage\ capacity}{Total\ annual\ flow\ volume} \cdot 100$$

A high DOR value indicates an increased probability that substantial discharge volumes can be stored throughout a given year and released at later times. For example, 10% is used as a threshold in Lehner et al. (2014) to indicate that substantial changes in the natural flow regime are expected to occur.

The degree of fragmentation is applied using the long-term average flows at different points upstream and downstream of hydropower plants and uses the formulae:

For upstream river reaches:

$$DOF_i = 110 - (10 * \frac{d_{bloc}}{d_i})$$

For downstream reaches:

$$DOF_i = 110 - (10 * \frac{d_i}{d_{bloc}})$$

where d_{bloc} is the average flow at the hydropower plant and d_i is the average flow at any given river reach upstream or downstream. These equations were developed so that a change in discharge by a factor of 1/2 or 2 will lead to a 10% reduction in the fragmentation value, a change by a factor of 1/3 or 3 will lead to a 20% reduction, etc. Once the discharge differs beyond one order of magnitude, the fragmentation effect will disappear. For example, if a dam is located on a river with a discharge of 100 m^3/s, all connected rivers with a discharge between 50 and 200 m^3/s, corresponding to a factor of 1/2 in the upstream direction and 2 in the downstream direction, respectively, receive the maximum fragmentation index of 90-100%. Connected rivers in the range of 33-50 m^3/s and 200-300 m^3/s, corresponding to a factor of 1/3 and 3, respectively, fall into the second DOF class of 80-90%, etc.

If there are multiple dams in a basin, the combined impact of all dams on a river reach is calculated as the maximum DOF value that is assigned to the reach from any individual dam in the river network.

3 OVERVIEW OF THE RIVER BASINS IN MYANMAR

Myanmar has eight recognizable major river systems:

1. The Ayeyarwady - divided for this purpose into the Upper, Middle and Lower Ayeyarwady river and the Delta
2. The Chindwin - although this is a tributary of the Ayeyarwady, it is a significantly different river system and so is treated separately
3. The Thanlwin - arising on the Tibetan plateau and flowing substantially through Yunnan in China till it flows into Myanmar and then forms the border with Thailand
4. The Sittaung - a smaller river lying between the two major basins of the Ayeyarwady and the Thanlwin
5. The Myit Ma Hka and Bago - a very much smaller river flowing from the Bago Yoma towards Yangon
6. The Rakhine coastal region containing several shorter rivers from the Rakhine Yoma and Chin Hills
7. The Tanintharyi coastal region containing several rivers draining the range of hills forming the border between Thailand and Myanmar.

The features of these river systems and basins will be considered briefly to set the context for the identification of ecologically sensitive river reaches, and human pressures.

3.1 Ayeyarwady

3.1.1 Upper Ayeyarwady

The Upper Ayeyarwady runs from its source in the mountains of Kachin State to the confluence of the tributary Namthampak about 40 km south of Myitkyina. Its mainstem consists of 336 km of rock cut river channel with a mean annual flow at the end of the zone estimated at 4,325 m^3/sec, converting to an anastomose channel at the bottom of the zone (see Figure 3.1).

The mainstem of the Ayeyarwady really starts with the confluence at Myitisone of two important branches, the Mali Hka from the right side and the Mai Hka from the left bank. The Mali Hka drains the Putao valley and has a mean annual flow of about 2,700 m^3/sec, and the Mai Hka has about half that flow. There are several other tributaries coming into these two branches - NaeMai Hka, Ngaw Chang Hka and Chipwi Hka before it reaches the Namthampak on the left bank. These are significant tributaries with hydropower potential.

The river basin appears to have a very diverse classification, with the four major classes of the large rivers being:

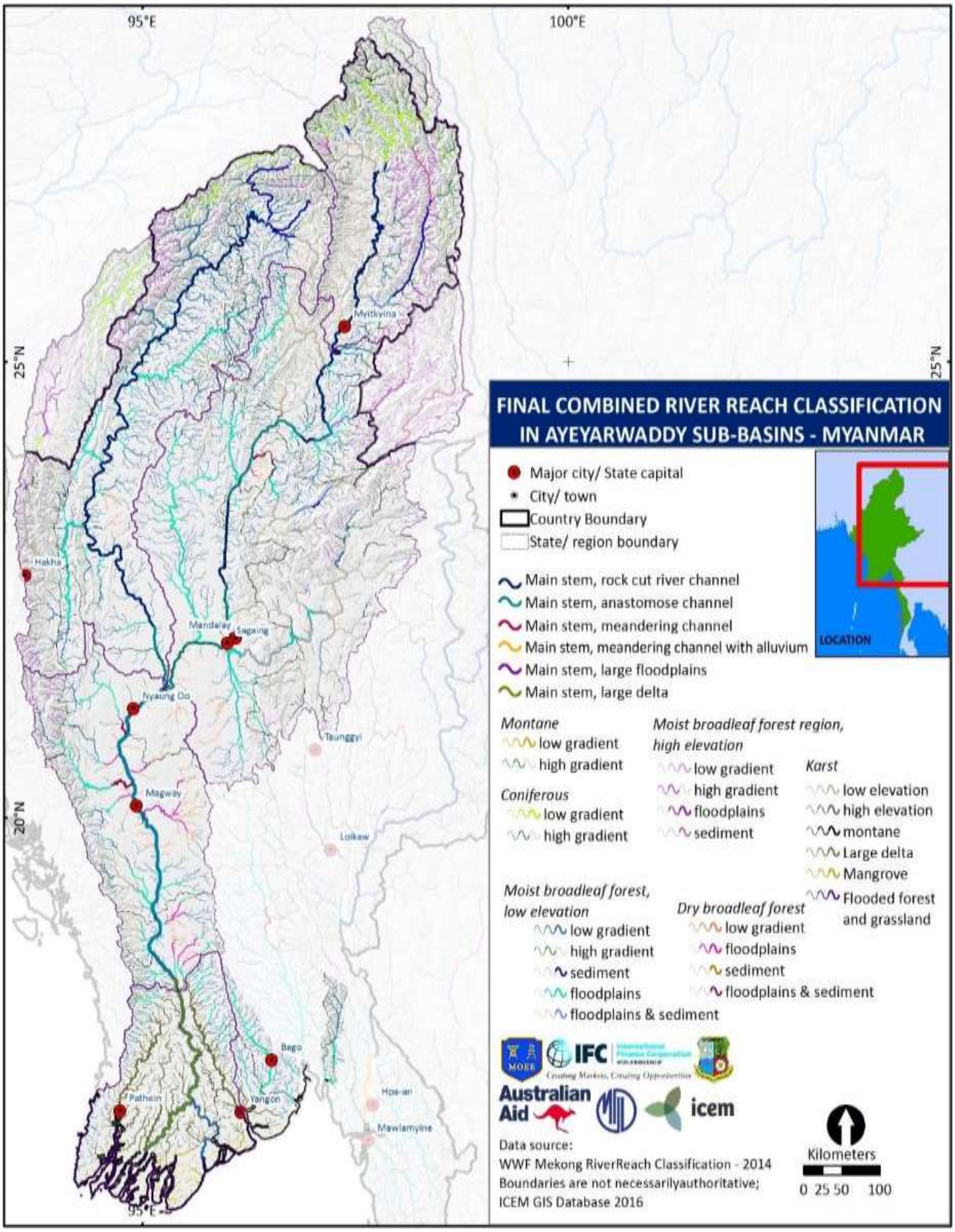
- Large river, in coniferous region, with low gradient - 27%
- Large river, in moist broadleaf forest region at low elevation, with sediment - 21%
- Large river, in moist broadleaf forest region at high elevation, with sediment - 13%
- Large river, in karst region at low elevation - 27%

The medium sized river reaches are similarly diverse but have a high proportion of Medium river, in karst region at low elevation - 39% with lower proportions of Medium river, in coniferous regions, with low and high gradient, and Medium river, in moist broadleaf forest region at low elevation, with low gradient.

The coniferous reaches can be seen clearly in the upper part of the catchment, while the right bank of the mainstem is dominated by the limestone karst reaches and the left bank of the mainstem is dominated by the moist broadleaf forest region at high and low elevations. In the lower large reaches in the moist broadleaf forest region before meeting the mainstem, there are noticeable areas of floodplain and sediment.

Both the Mali Hka and Mai Hka are recognized as areas of high biodiversity and endemicity.

Figure 3.1: Final Combined river reach classification for the Ayeyarwady and Chindwin rivers



3.1.2 Middle Ayeyarwady

The Middle Ayeyarwady is taken from the confluence of the tributary Namthampak to the confluence of the Chindwin River. Before the Chindwin confluence the mean annual flow is about 9,500 m^3/sec and after the confluence it has a mean annual flow of about 15,000 m^3/sec. It receives additional flows from significant tributaries such as the Dapein (c.370 m^3/sec) and Shweli (c. 1,000 m^3/sec), on the left bank, both of which have existing large hydropower plants in China and in Myanmar.

Just below the Namthampak, is the confluence with the right bank tributary which drains the catchment between the Upper Chindwin and the Ayeyarwady. This contains the ecologically important Indawgyi Lake, one of the largest natural lakes in Myanmar, a Ramsar site, Wildlife Sanctuary and area of high endemicity.

Farther downstream the Ma Gyi Chaung joins the mainstem upstream of Mandalay and the Myitinge opposite Sagaing town (c.720 m^3/sec). The Myitinge catchment receives flows from other smaller basins such as the Zawgyi and Panlaung Chaun, which has existing large hydropower plants, including Yeywa.

The main tributary on the right bank is the Mu River which flows from the north between the Chindwin and the Ayeyarwady catchments. On this river, the Thapanzeik dam and reservoir have been constructed for irrigation and hydropower generation.

The mainstem river classes are dominated by an anastomose channel (76%). About 22% of the mainstem is classified as a rock cut channel, consisting of a series of narrow gorges about 250 km north of Mandalay. Immediately after these gorges, the river widens into the braided channel which characterizes most of its form downstream. This is the location where the Irrawaddy Dolphins live and where the conservation efforts are focused.

The large river types are predominantly in karst region at low elevation (43%) and in moist deciduous forest regions at low elevation with floodplains (38%). A small proportion are in dry broadleaf forest region with floodplains and sediment (6%).

The medium sized rivers in the middle Ayeyarwady also show a strong proportion of karst with 26% at low elevation, 5% at high elevation and small lengths of river reaches at montane levels. The largest proportion are the medium-sized rivers in moist broadleaf forest region at low elevation with floodplains (37%). There are about 20% of the medium rivers in montane regions with low gradient. There are also 9% in dry broadleaf forest regions with flood plains.

3.1.3 Lower Ayeyarwady

The Lower Ayeyarwady reaches extend from the confluence with the Chindwin River to the Delta and are much less diverse. Figure 3.1 shows that all of the mainstem river reaches from the Chindwin to the Delta are anastomose, a broad braided river channel within a wide floodplain. When it reaches the delta, a number of distributary channels form in a very wide floodplain with mangroves. The relatively short tributaries flowing into the mainstem in the Lower Ayeyarwady are large and medium sized rivers flowing through moist deciduous forest region with floodplains on the right bank, and dry deciduous forest regions with floodplains on the left bank.

A tributary of interest to this study is the Mon Chaung, which drains the eastern slopes of the Rakhine Yoma, downstream of Nyaung U.

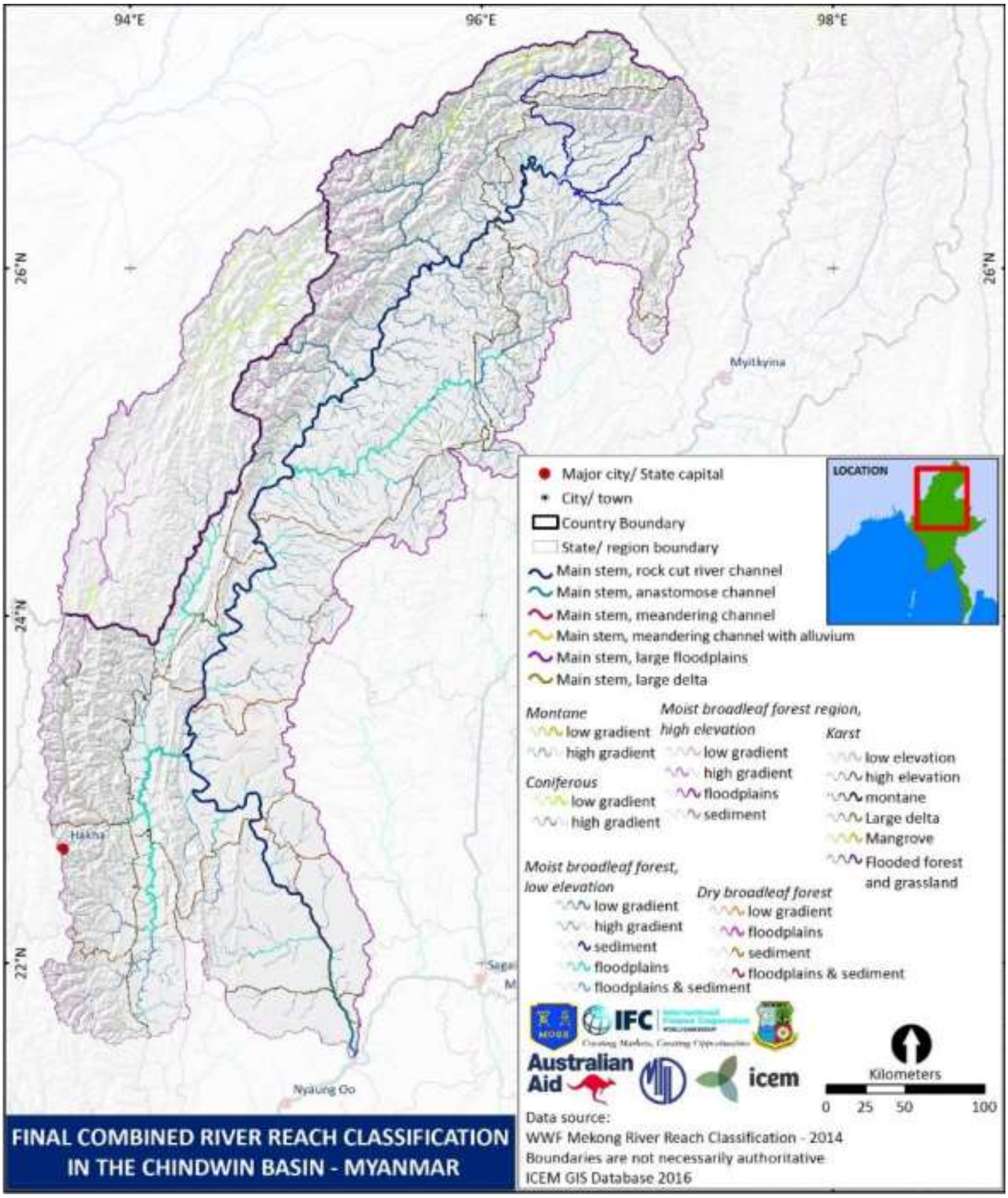
3.1.4 Ayeyarwady Delta

The large delta that has developed at the mouth of the Ayeyarwady is ecologically very important. Covering an area of about 50,000 km^2, it extends from the limit of tidal influence at Myan Aung to the Bay of Bengal and Andaman Sea, 290 km to the south. The delta region is densely populated, and plays a dominant role in the cultivation of rice in rich alluvial soil as low as just 3 metres above sea level, with fishing communities on the many distributary rivers and streams. The alluvial plain is bounded to the west by the Rakhine Yoma and to the east by the Bago Yoma. The principal islands include Haingyi Kyun, Leit Kyun, Pyin Salu Kyun, and Meinmahla Kyun. The latter has recently been declared as Myanmar's 3rd Ramsar site. The river reaches are principally alluvial, with sediments and flowing through mangrove areas, though many mangrove forests have been lost for agriculture.

3.2 Chindwin

The Chindwin River rises in the very north west of Myanmar, and flows south west, with several tributaries, including the Uyu River which joins from the east at the town of Homalin, and the Manipur river which flows south from India, turning north before its confluence with the Chindwin at Kalewa town. The Chindwin River then flows south east and joins into the Middle Ayeyarwady between Mandalay and Nyaung U.

Figure 3.2: Final combined river reach classification for the Chindwin sub-basin



The main channel of the Chindwin consists of 907 km of rock cut river channel and 73 km of anastomose channel (see Figure 3.2). As described in the Geomorphology and sediment transport theme baseline, the Chindwin drains soft geological structures with high soil erosion potential. This determines the character of the Chindwin as a river of high sediment transport.

Of the large rivers in the Chindwin basin, the highest proportion are those lying in moist broadleaf forest regions at low elevation with floodplains and with sediment. There are 23% of river reaches lying in moist broadleaf forest regions at high elevation with low gradient. There is also a significant proportion lying in karst regions at low elevation (15%).

The greatest proportion of medium sized rivers in the Chindwin basin lie in moist broadleaf forest region at low elevation and low gradient (60%), and there are also similar reaches with floodplains (18%). There is 9% in dry broadleaf forest regions with low gradient.

The Chin Hills and the upper Chindwin are important for biodiversity and are recognized as areas of high endemicity. They are also the areas where threatened species of turtles can still be found. There is significant mining activity in the Chindwin catchment and some of its eastern tributaries have been disturbed by alluvial gold and jade mining, e.g. the Uyu river.

3.3 Thanlwin

The Thanlwin River is a very different type of river compared to the Ayeyarwady and the Chindwin, rising in Tibet and being largely rock confined throughout its length, with very few large tributaries. When it flows in from China, the Thanlwin has a mean annual flow of about 1,700 m^3/sec. By the time it reaches the coast at Mawlamyine, the mean annual flow is about 5,000 m^3/sec. The Thanlwin river valley is narrow, with steep often forested slopes.

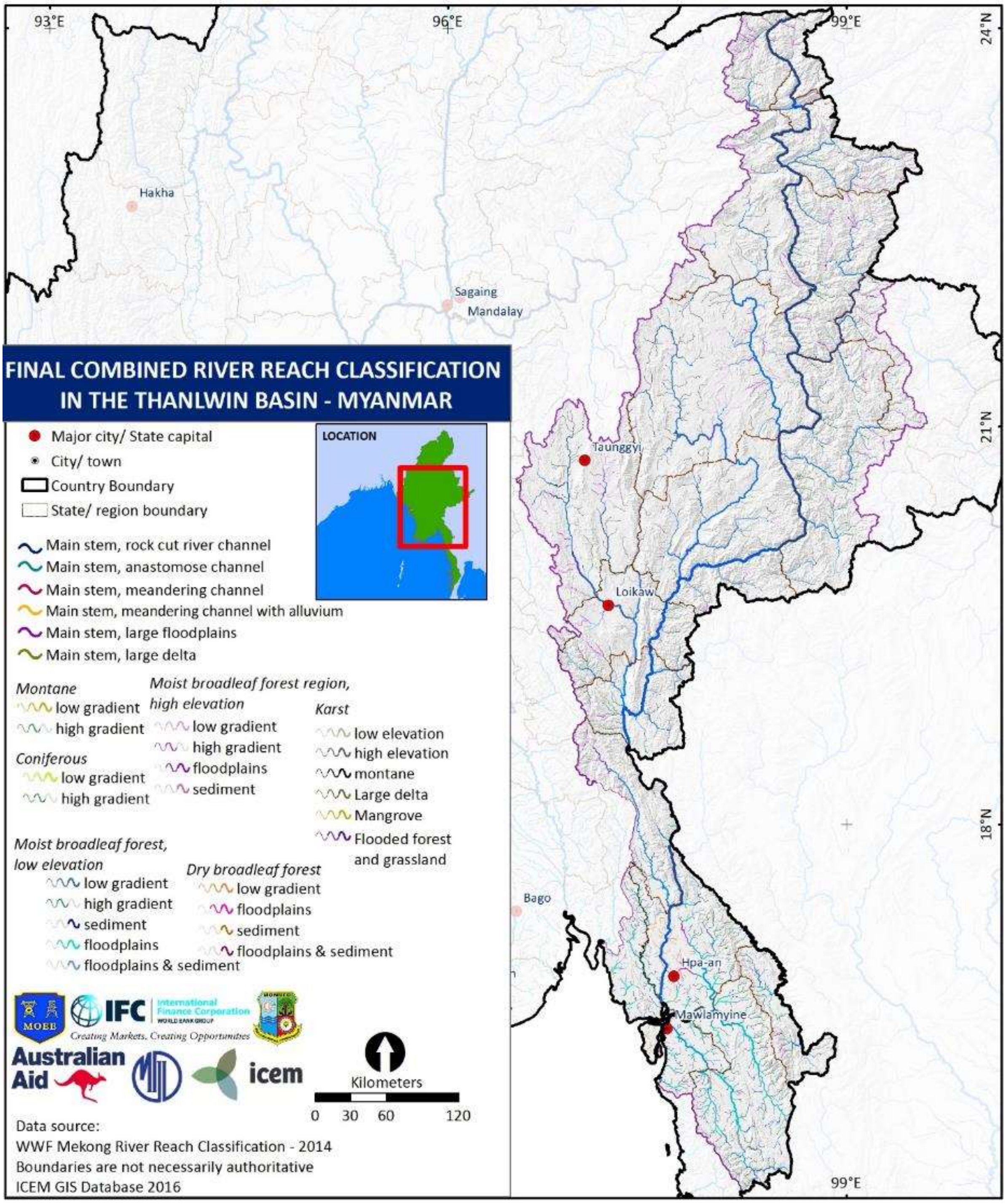
There are several tributaries in Myanmar of interest to this study, the Nam Hka joining from the East, and the Keng Tawng joining from the West. Shortly downstream of the Nam Pawn confluence from the West, the Thanlwin forms the border with Thailand until the confluence with the Moei River. The Moei River flows northwestwards from Tak province in Thailand, through Mae Sot to the confluence with the Thanlwin. The Baluchaung River, which drains the Inle Lake catchment meets the Nam Pawn, shortly upstream of the confluence with the Thanlwin at Hpasawng. The Nam Ma is also a tributary on which hydropower is planned. The Baluchaung River has three hydropower projects in cascade, effectively isolating this river and Inle Lake from the rest of the Thanlwin catchment. Inle Lake has a very unique ecology draining the karst limestone hills surrounding it. Several endemic and threatened species of fish and molluscs are found there.

An analysis of the mainstem, shows that within Myanmar there are 1,174 km of rock-cut channel, with only 106 km of meandering channel with alluvium, which occurs at the southern end of the river (Figure 3.3).

Of the large rivers with average flows between 100 - 1,000 m^3/sec, about 54% of the river reaches lie in moist broadleaf forest regions at low elevation with low gradient, composed of 26% with floodplains, 13% with sediment and 4% with floodplains and sediment. The second largest component covers the large rivers in karst regions of which 27% are at low elevation and 11% at high elevation.

A similar proportion of the medium sized river reaches of the Thanlwin lie in moist broadleaf forest regions at low elevation (56%), mostly lying at low elevation with low gradient and with floodplains and sediment. About 19% lie in moist broadleaf forest regions at high elevation, with low gradient and some have floodplains. Of the remaining river reaches, 24% lie in karst regions, at low and high elevation, and a small proportion in montane regions.

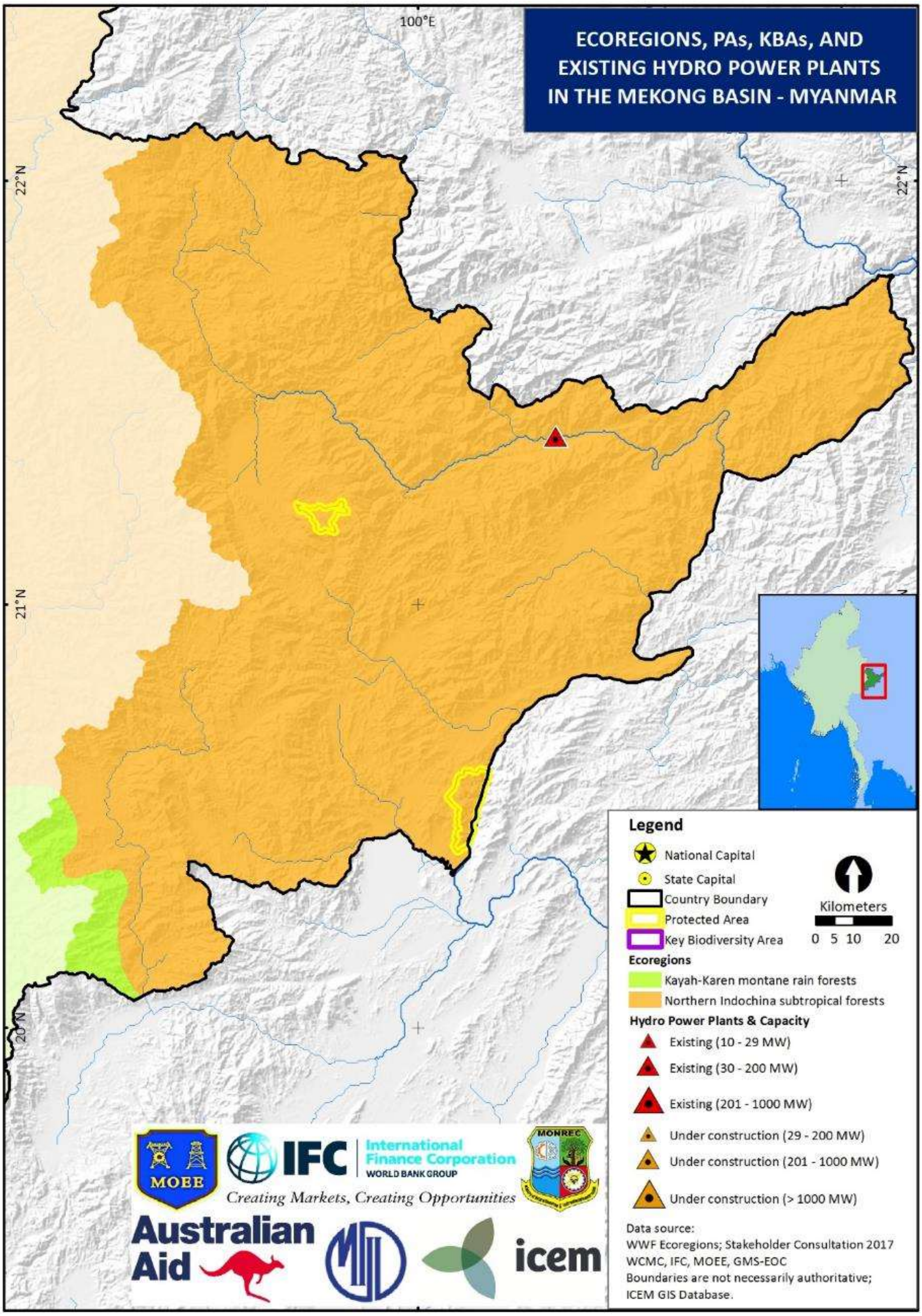
Figure 3.3: Final combined river reach classification for the Thanlwin sub-basin



3.4 Mekong

There is only a very small proportion of the Mekong river basin in Myanmar, extending from the Golden triangle - the meeting of Myanmar with Thailand and Laos on the opposite bank of the Mekong up to the Chinese border, a distance of about 250 km. The Nam Ruak forms the border with Thailand and there is one other major tributary the Nam Lwe on which one hydropower dam is under construction (see Figure 3.4).

Figure 3.4: Mekong river catchment in Myanmar

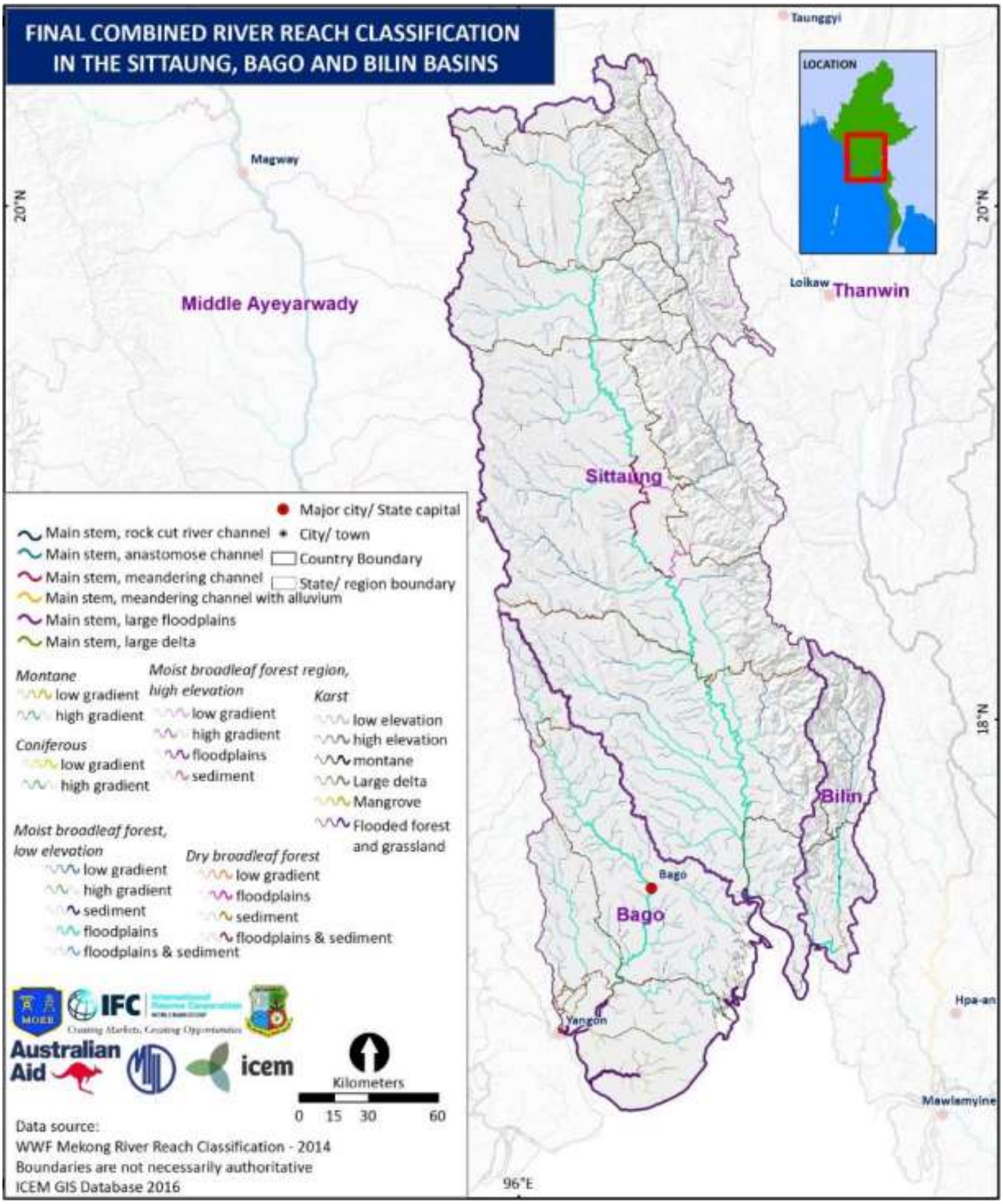


The Mekong itself is generally flowing in a rock confined channel, in a narrow valley with steep forested slopes. There are many rocky outcrops and rapids with large sandbanks. The catchment area and the tributaries flow through moist broadleaf forest region, with high elevation and high gradients.

3.5 Sittaung

The Sittaung River is a smaller river lying between the lower Ayeyarwady and Thanlwin rivers. It has no mainstem flows over 1,000 m^3/sec, and the largest proportion of its river reaches lie in moist broadleaf forest regions at low elevation with floodplains (82%). About 13% of the river reaches lie in dry broadleaf forest regions and contain floodplains and sediment. About 5% of the river reaches lie in low elevation karst regions (see Figure 3.5).

Figure 3.5: Final combined river reach classification for the Sittaung sub-basin



About 95% of the medium sized river reaches of the Sittaung lie in moist broadleaf forest regions, with 36% at low elevation and low gradient, and 59% with floodplains. There is about 4% in dry broadleaf forest regions with floodplains, and a small proportion lying in low elevation karst regions.

The river flows down a narrow valley with steep forested ridges on both sides, e.g. the Bago Yoma to the West. There is an area of karst limestone with a long cave river (Nam Mon cave) in the north east in the upper Paung Laung river. Most of the valley floor consists of agricultural land.

The Sittaung flows out into the sea through the Gulf of Mottama, and there are other important wetland areas in the lower catchment of which the most important is Moyingyi Wetland Wildlife Sanctuary, a Ramsar site.

A number of the tributaries of the Sittaung contain hydropower projects as well irrigation reservoirs. These include the Paung Laung River, Ka Baung River, Chaung River, Taung Ye Khat, Phyu Chaung, Kun Chaung, Shwegyin and Ye New, with hydropower planned on the Bawgata and Bilin.

3.6 Myit Ma Hka and Bago river basin

The Myit Ma Hka and Bago catchment is much smaller and contains no very large rivers lying between the Sittaung and the Lower Ayeyarwady. Of the large river reaches, 42% lie in moist broadleaf forest region at low elevation and with floodplains. The largest proportion of the large rivers lie in a delta region or in mangrove regions (see Figure 3.5).

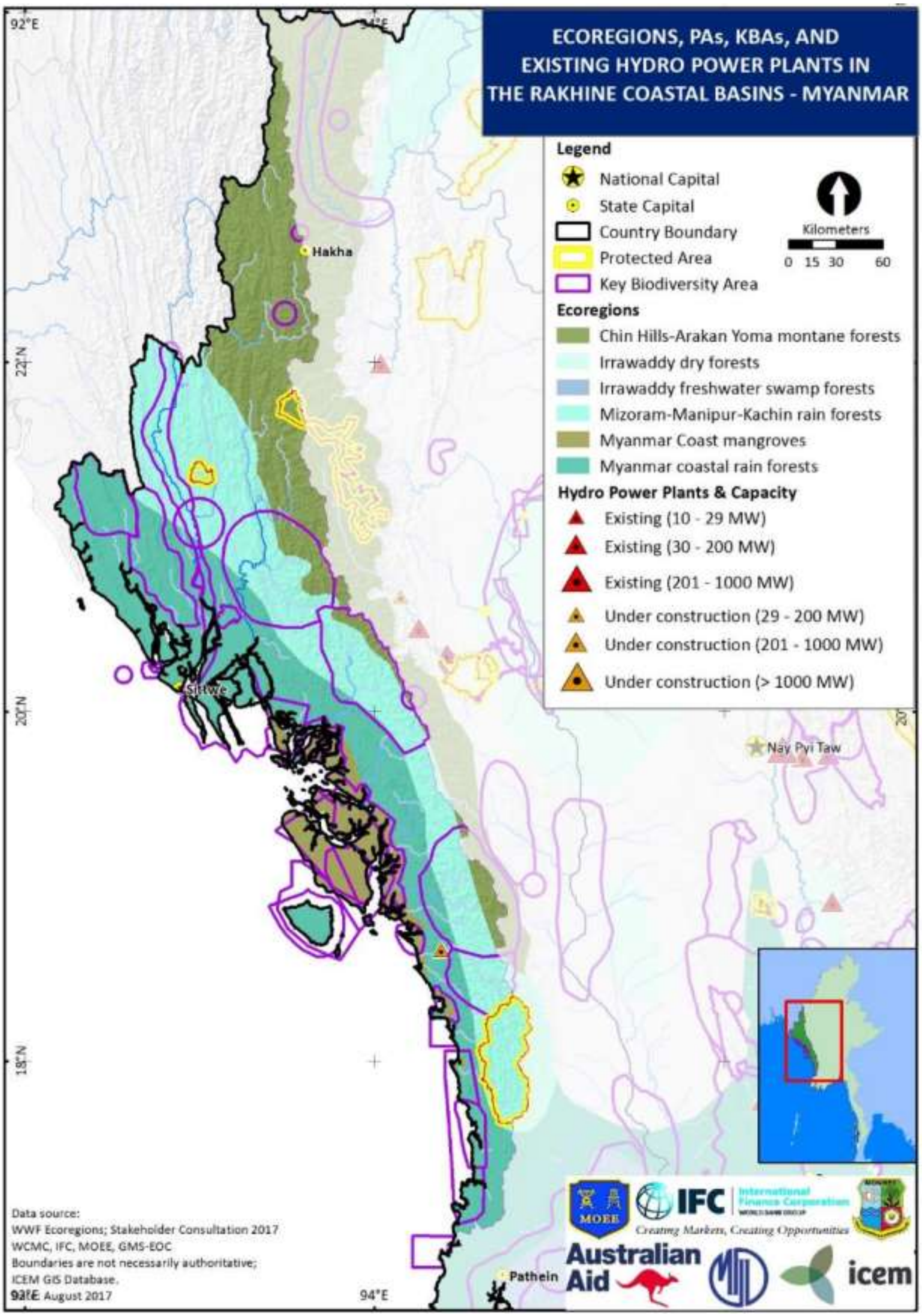
Of the medium sized river reaches, 58% lie in moist broadleaf forest regions at low elevation with floodplains, 35% of the river reaches lie in large delta regions and 7% in mangrove regions.

3.7 Rakhine coastal basin

The Rakhine coastal basin consists of a narrow coastal strip extending from the borders with Bangladesh and India along the west coast of Myanmar to the norther edge of the Ayeyarwady Delta. It is confined by the Chin Hills to the north and the Rakhine Yoma which form a forested mountain ridge along the eastern side of the coastal strip. The rivers in this coastal strip are short, steep and fast flowing through broadleaf forest regions - Irrawaddy dry forests and Myanmar coastal rain forests. They discharge into the sea through complex estuaries and islands with mangroves in the north and sea grass beds in the south (see Figure 3.6).

There are several river systems in the Rakhine coastal basin which include the Kaladan, which flows in from the Chin Hills in India, the Thandwe and the Lemro on which a hydropower plant is under construction, and the Mayu and Naff rivers. A hydropower plant is currently under construction on the Tha Htay River in the south of the Rakhine coastal strip. In view of the relative isolation of the rivers from other river systems in Myanmar, and the ecological importance of the Chin Hills and Rakhine Yoma, it is likely that biodiversity and endemicity in these rivers will be high, though no surveys have been carried out in this region.

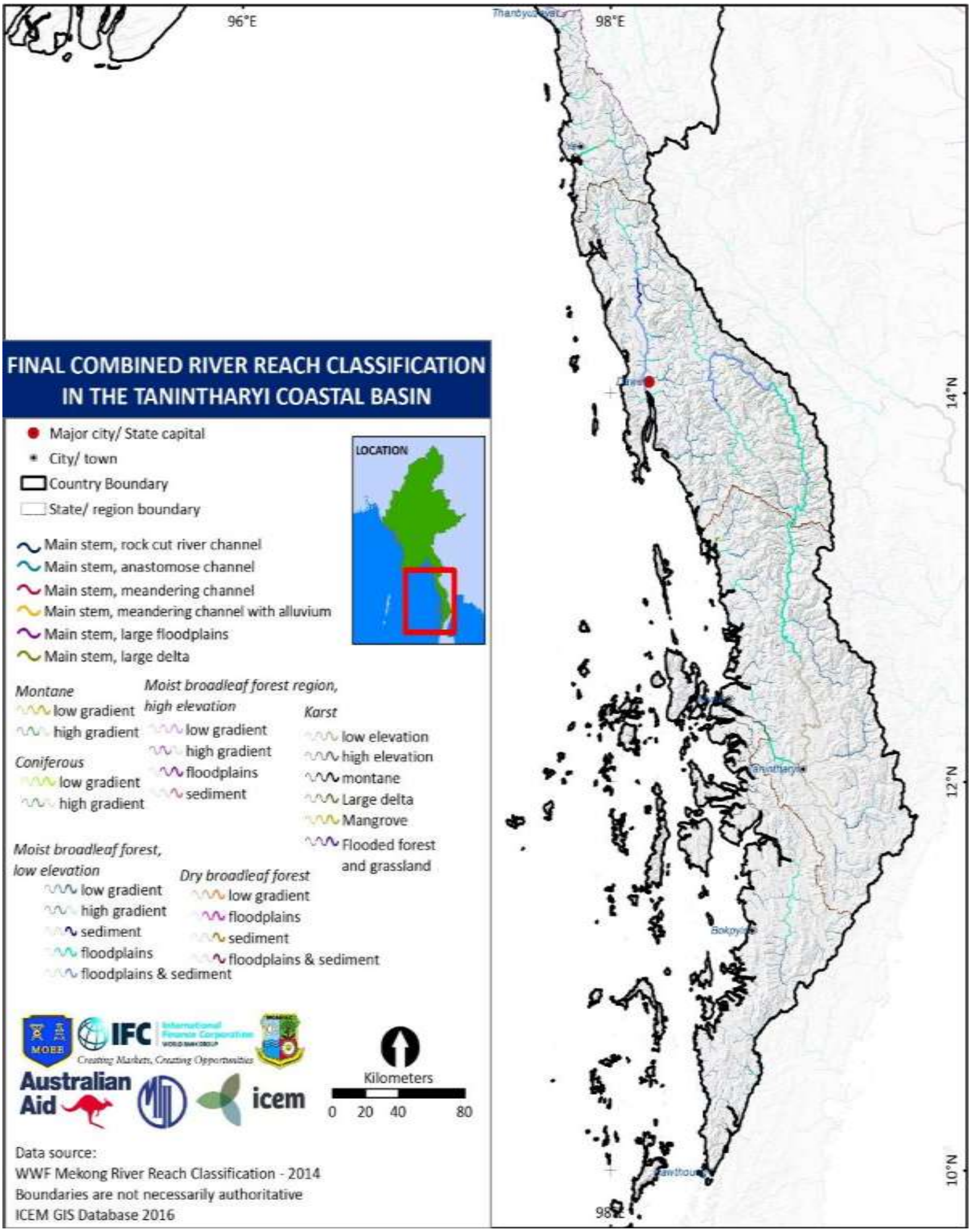
Figure 3.6: Rakhine coastal basin



3.8 Tanintharyi coastal basin

The Tanintharyi coastal basin is (like the Rakhine coastal basin) a narrow coastal strip bordered on the eastern side by steep forested hills, along the border with Thailand. There are several short rivers, including the Lenya River. 19% of the large river reaches lie in karst regions at low elevation, while all the rest lie in moist broadleaf forest regions at low elevation - 61 % with floodplains, 2% with sediment and 18% with floodplains and sediment (see Figure 3.7).

Figure 3.7: Final combined river reach classification for the Tanintharyi coastal sub-basin



11% of the medium sized reaches lie in karst regions at low elevation. 86% lie in moist broadleaf forest regions at low elevation, 35% at low gradient, 1% at high gradient and 50% with floodplains. There are 2% of the medium sized river reaches in dry broadleaf forest regions with floodplains and 1% lying in mangrove regions.

From the north of the coastal strip, the Ataran River flows northwards into the Thanlwin estuary at Mawlamyine, and is mainly a large river in moist broadleaf forest region with floodplains.

The Ye River rises in the hills near the Thai border, flowing south to the sea at Dawei. The Tanintharyi river is longer, rising in the hills at the same latitude as Dawei, doubling back on itself and then flowing south to Tanintharyi town, and then to Myeik town, where it discharges into the sea around the complex system of islands and mangroves that make up the Myeik Archipelago. In the very south of the coastal strip, the Lenya River flows northwards.

3.9 Summary

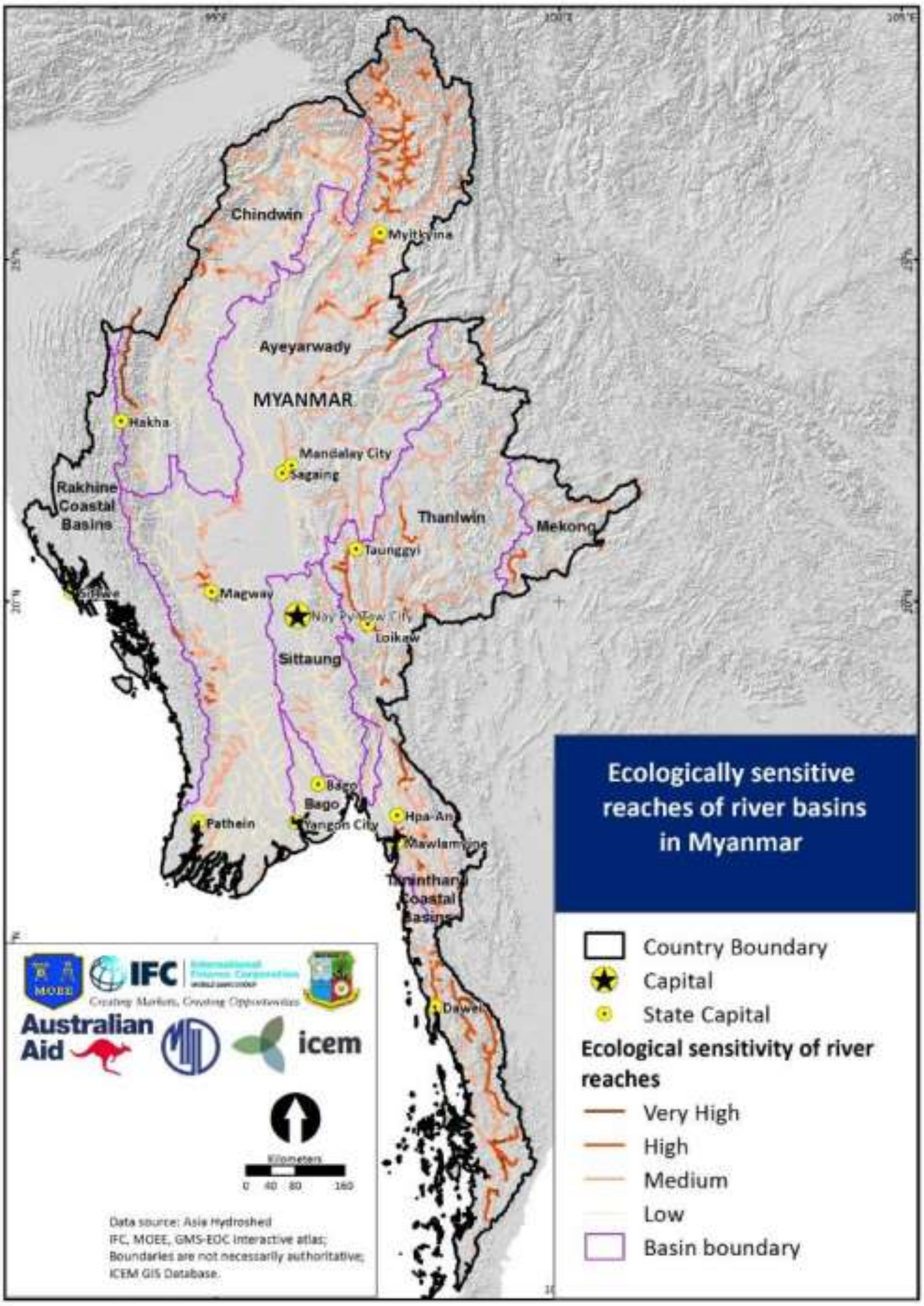
The main rivers of Myanmar have been briefly described. The Ayeyarwady river system has been divided up into the Upper, Middle and Lower Ayeyarwady, leading into the Delta. The Chindwin is a large tributary of the Ayeyarwady and has been described separately, so that there are five main basins of the Ayeyarwady river system. The Thanlwin is described from the point of entry into Myanmar from China through to its estuary at Mawlamyine. It has a very different character to the Ayeyarwady system, being principally a narrow rock cut channel for most of its length. The Sittaung is a much smaller river system running from north to south between the two major river basins, before discharging into the Gulf of Mottama. The Myit Ma Hka and Bago river basins are two very small basins near Yangon between the Sittaung and Ayeyarwady. There are two coastal river basins, the Rakhine coastal basin consisting of a number of smaller rivers, including the Kaladan, Lemyo and Mayu rivers, with water arising in the Rakhine Yoma and flowing into the Bay of Bengal, and in the Tanintharyi coastal basin which contains the Tanintharyi and Lenya rivers, flowing into the Andaman Sea.

4 IDENTIFICATION OF ECOLOGICALLY SENSITIVE RIVER REACHES

The combination of the scores for these parameters leads to identification of ranges of Very High, High, Medium and Low ecological sensitivity for the Ayeyarwady, Chindwin and Thanlwin. These are illustrated in

Figure 4.1. As is to be expected from the analysis of the different parameters discussed below, ecologically sensitive areas include headwaters of the Ayeyarwady and Chindwin and particular stretches of the mainstem of the Ayeyarwady. In the Chindwin, the tributaries flowing in from the Chin Hills, and from Manipur and Nagaland in India are considered to be very highly sensitive due to high proportion of endemic species.

Figure 4.1: Ecologically sensitive reaches of river basins in Myanmar



The tributaries of the Thanlwin are generally medium sensitive, apart from around Inle Lake and the Baluchaung River, which is considered to be very highly sensitive due the presence of endemic species in this very unique area.

However, there have been few surveys of the biodiversity in the Thanlwin catchment and as a result there are few KBAs designated in this catchment. It is probable that future aquatic biodiversity assessment work would lead to higher ecological sensitivity scoring. In the Tanintharyi catchments recent icthyological surveys have shown that that the Tanintharyi and Lenya River reaches are biodiverse and endemically rich and it is likely that the Rakhine coastal basin will be similar.

The parameters listed above can be mapped individually and their importance scored. The scoring components are described in the following sections, and the process is described in Annex 1.

4.1 River reach classification for Myanmar's main river basins

The classification scheme identifies small lengths of river (reaches) within each river basin according to hydrological class, physio-climatic classes and geomorphological classes. The purpose of this approach is to illustrate the characteristics and differences between the rivers, and identify within each river system reaches that may be relatively rare with distinctive ecology and biodiversity. The classification system identifies 5 sizes of stream and river reaches based upon the average annual flows:

1. Mainstem, >1,000 m^3/sec[1]
2. Large rivers, 100 - 1,000 m^3/sec
3. Medium rivers, 10 - 100 m^3/sec
4. Small rivers, 1 - 10 m^3/sec
5. Small headwater streams, 0.1 - 1.0 m^3/sec

Because of the national coverage, only the Mainstem, Large and Medium rivers will be considered in this analysis, since the proposed hydropower plants will be located on rivers with average flows of more than 10 m^3/sec. It is noted that the small rivers and small headwater streams may be important areas for biodiversity and endemism, since specialized endemic species of fish and molluscs tend to be found in such small river reaches[2], but these streams will not be the site of 10 MW and greater HPPs therefore the ecological values should not be affected unless the values are compromised by reduced or blocked upstream migration caused by downstream projects. However, these smaller tributaries and river should be covered when basin-wide CIAs are performed, or on project specific ESIAs.

Table 4.1: Total lengths of river reaches within the WWF classification system in the main river basins in Myanmar

Catchment	Total length of river reaches (km)
Upper Ayeyarwady	27,736
Middle Ayeyarwady	70,382
Lower Ayeyarwady	46,209
Chindwin	16,040
Thanlwin	36,681
Sittaung	17,158
Myit Ma Hka and Bago	10,740
Tanintharyi	32,151

The total lengths of all river reaches (mainstem, large, medium, small rivers and headwater streams) that have been assessed for each of the main river basins are listed in Table 4.1.

Rivers in Rakhine State have not been classified in this way, because they were not included in the original WWF analysis and paper by Lehner.

4.2 Rare river reach classes

In addition to the size of the river as defined by its average annual flow, the WWF river reach classification system describes the rivers in Myanmar in terms of their Bio-physical location - elevation (Montane, High - above 700 m above sea level, and Low - below 700 m above sea level), the steepness of the slope of the river reach (high and low slopes), and the original ecological zone (coniferous, moist deciduous forest, dry deciduous forest, mangrove forest) and reaches flowing through karst limestone. They are also defined by their geomorphological character - rock-confined channel, anastomosing channel,[3] with floodplains, with sediment, and delta area.

The more detailed analysis of the composition of the river reaches in Myanmar's rivers and the differences in their character is provided in Annex 2. The lengths of the different classes of mainstem,

[1] Note that the mainstem class refers to the channels of each of the main river basins, wherever the flow is more than 1,000 m^3/sec. There may be a few tributaries of the Ayeyarwady where the average flows are also more than 1,000 m^3/sec, e.g. Mai Hka 1,364 m^3/sec, Shweli 1,018 m^3/sec, Myitinge 1,810 m^3/sec and the Lower Baluchaung where it meets the Thanlwin 1,042 m^3/sec. These are all classified as large rivers.
[2] Areas of high endemism are recognized as a parameter in section 2.3.
[3] An anastomosing river is composed of two or more interconnected channels that enclose floodplains.

large and medium river reaches for Myanmar rivers is shown in Table 4.2. These have been arranged by the total length of reach in each size class in order to identify those that are common and those that are less common or rare. Very rare reaches are those that make up less than 5% of all reaches in the size class, Rare reaches are those that make up 5 - 10% of all reaches, and Common are those reaches between 10 - 20 % of all reaches. The Very common reaches make up more than 20% of those in each size class.

The parameter that is used to contribute to ecological sensitivity is the rarity of the river reach, to identify where the rare river reach types are distributed. Rare river reaches may be important because they could contain unique habitats that support endemic aquatic species.

The commonest river reach types are associated with the mainstems, and the rarer types of river reach are located in the western catchment of the Chindwin, and the watershed between the Ayeyarwady and the Thanlwin (Figure 4.2).

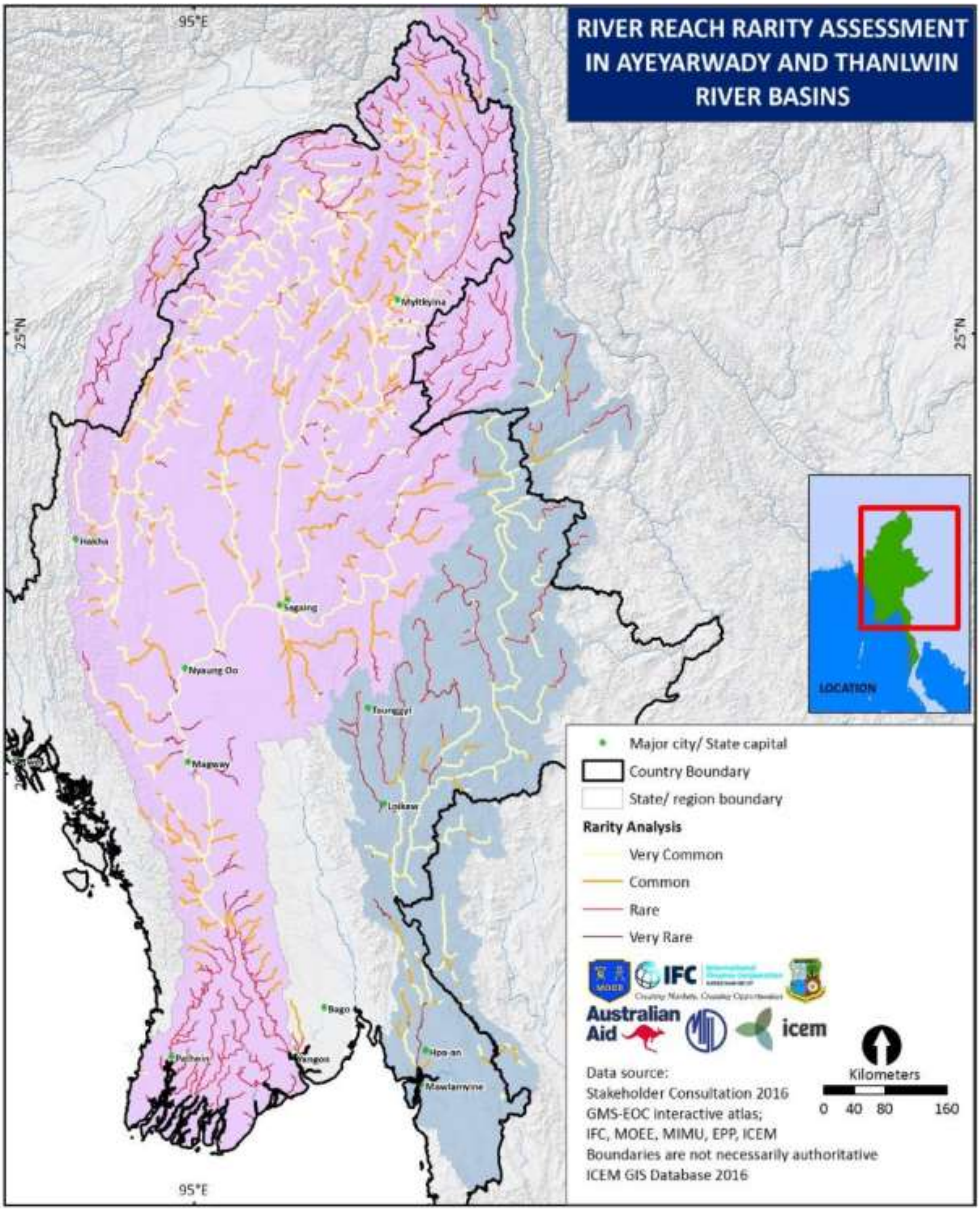
The mainstem of the Ayeyarwady, Chindwin and Thanlwin are predominantly scored as Common or Very Common 1) Main stem, anastomose channel - 20.3% and 2) Main stem, rock cut river channel - 71%. The two least common mainstem classes are 3) Main stem, meandering channel with alluvium - 2.5% and 4) Main stem, large delta - 6.5%. These two types of reach therefore score as Very Rare and Rare river reach types.

For the large rivers, the commonest types of river reach are those in moist broadleaf forest region at low elevation, with floodplains and in karst region at low elevation. For the medium sized rivers, the commonest river types are moist broadleaf forest region at low elevation with low gradient followed by those in moist broadleaf forest region at low elevation, with floodplains and in karst region at low elevation.

Table 4.2: Lengths of the different classes of river reach for Myanmar's rivers

River Reach Classification - Mainstem	River Reach length (km)	% of all mainstem reaches	Rarity
Main stem, meandering channel with alluvium	112.68	2.39	Very rare
Main stem, large delta	304.58	6.47	Rare
Main stem, anastomose channel	959.36	20.38	Very common
Main stem, rock cut river channel	3330.83	70.76	
River Reach Classification - Large rivers	**River Reach length (km)**	**% of all large river reaches**	**Rarity**
Large river, in dry broadleaf forest region, with floodplains	0.63	0.01	Very rare
Large river, in mangrove region	8.5	0.12	
Large river, in montane region, with low gradient	12.16	0.17	
Large river, in moist broadleaf forest region at high elevation, with low gradient	56.07	0.78	
Large river, in dry broadleaf forest region, with floodplains and sediment	108.99	1.52	
Large river, in moist broadleaf forest region at high elevation, with floodplains	169.94	2.37	
Large river, in moist broadleaf forest region at low elevation, with floodplains and sedim	204.91	2.86	
Large river, in karst region at high elevation	206.21	2.88	
Large river, in karst within montane region	251.7	3.51	
Large river, in moist broadleaf forest region at high elevation, with sediment	353.2	4.93	
Large river, in large delta region	448.08	6.25	Rare
Large river, in moist broadleaf forest region at low elevation, with low gradient	506.75	7.07	
Large river, in moist broadleaf forest region at low elevation, with sediment	634.06	8.85	
Large river, in coniferous region, with low gradient	1033.71	14.42	Common
Large river, in moist broadleaf forest region at low elevation, with floodplains	1585.62	22.12	Very common
Large river, in karst region at low elevation	1587.79	22.15	
River Reach Classification - Medium rivers	**River Reach length (km)**	**% of all medium river reaches**	**Rarity**
Medium river, in dry broadleaf forest region, with low gradient	18.74	0.09	Very rare
Medium river, in montane region, with high gradient	145.32	0.73	
Medium river, in mangrove region	185.76	0.93	
Medium river, in moist broadleaf forest region at low elevation, with high gradient	245.39	1.23	
Medium river, in moist broadleaf forest region at high elevation, with high gradient	325.86	1.64	
Medium river, in karst within montane region	347.02	1.74	
Medium river, in moist broadleaf forest region at high elevation, with floodplains	363.43	1.83	
Medium river, in coniferous region, with high gradient	422.47	2.12	
Medium river, in dry broadleaf forest region, with floodplains	493.92	2.48	
Medium river, in coniferous region, with low gradient	1172.14	5.89	Rare
Medium river, in montane region, with low gradient	1239.07	6.23	
Medium river, in large delta region	1284.07	6.45	
Medium river, in moist broadleaf forest region at high elevation, with low gradient	1305.72	6.56	
Medium river, in karst region at high elevation	1436.37	7.22	
Medium river, in karst region at low elevation	2980.58	14.98	Common
Medium river, in moist broadleaf forest region at low elevation, with floodplains	3215.01	16.16	
Medium river, in moist broadleaf forest region at low elevation, with low gradient	4719.35	23.72	Very common

Figure 4.2: River reach rarity assessment for Myanmar rivers[4]



Looking at the rarer types of large and medium rivers the following stand out, organized from the lowest percentage of the combined lengths of large and medium rivers:

1. Large river in montane region with low gradient (0.04% of river reaches)
2. In dry broadleaf forest region, with low gradient (0.07% of river reaches) (Medium river reaches only)

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[4] Note that Sittaung and Tanintharyi catchments have not yet been analysed.

3. In moist broadleaf forest region at high elevation, with low gradient (0.2% of river reaches) (large river reaches only)
4. In dry broadleaf forest region, with floodplains and sediment (0.4% of river reaches) (Large river reaches only)
5. In montane region, with high gradient (0.5% of river reaches) (medium river reaches only)
6. In mangrove region (0.7% of river reaches)
7. In moist broadleaf forest region at low elevation, with floodplains and sediment (0.8% of river reaches) (Large river reaches only)
8. In moist broadleaf forest region at low elevation, with high gradient (0.9% of river reaches) (Medium river reaches only)
9. In moist broadleaf forest region at high elevation, with high gradient (1.2% of river reaches) (Medium river reaches only)
10. In moist broadleaf forest region at high elevation, with sediment (1.3% of river reaches) (Large river reaches only)
11. In coniferous region, with high gradient (1.6% of river reaches) (Medium river reaches only)
12. In dry broadleaf forest region, with floodplains (1.8% of river reaches)
13. In moist broadleaf forest region at high elevation, with floodplains (2.0% of river reaches)
14. In karst montane region (2.2% of river reaches)

Table 4.3: Matrix of rare river classes, arranged by elevation, slope, ecological zone and geomorphology

	Elevation			Slope		Ecological zone					Geomorphology			Rarity
Description of rare river reaches	Montane	High elevation	Low elevation	High gradient	Low gradient	Karst	Coniferous	Moist broadleaf	Dry broadleaf	Mangroves	With floodplains	With sediment	With sediment and floodplains	% of large and medium river reaches
Large & Medium river, in karst within montane region	x					x								2.21
Large river, in montane region, with low gradient	x				x									0.04
Medium river, in montane region, with high gradient	x			x										0.54
Medium river, in coniferous region, with high gradient				x			x							1.56
Large river, in karst region at high elevation		x				x								0.76
Medium river, in moist broadleaf forest region at high elevation, with high gradient		x		x				x						1.20
Large river, in moist broadleaf forest region at high elevation, with low gradient		x			x			x						0.21
Large river, in moist broadleaf forest region at high elevation, with sediment		x						x				x		1.30
Large river, in moist broadleaf forest region at high elevation, with floodplains		x						x			x			1.97
Medium river, in moist broadleaf forest region at low elevation, with high gradient			x	x				x						0.91
Large river, in moist broadleaf forest region at low elevation, with floodplains and sediment			x					x					x	0.76
Medium river, in dry broadleaf forest region, with low gradient					x				x					0.07
Large & Medium rivers, in dry broadleaf forest region, with floodplains									x		x			1.83
Large river, in dry broadleaf forest region, with floodplains and sediment									x				x	0.40
Large river & Medium rivers, in mangrove region										x				0.72

Table 4.3 arranges these rare river classes by elevation, slope, ecological zone, and geomorphology.

It is noteworthy that a large proportion of the river reaches in the Ayeyarwady and Thanlwin lie in karst regions especially at low elevation. Karst limestone is an important geological feature of the catchments that affects water chemistry and aquatic species. Only the karst river reaches in montane regions and large karst rivers at high elevation are considered to be very rare.

At the next elevation down, medium river reaches in coniferous forests at high gradient are rare.

It is also clear that large rivers in moist broadleaf forest regions at high elevation with different slopes and geomorphological features tend to be rare. The rivers in dry broadleaf forest regions are those with low gradients, with floodplains and with floodplains and sediments.

Large and medium river reaches within mangrove forest regions are rare.

These rare river reaches may provide important ecological functions or hold specialized biodiversity, and it is therefore important to identify where they occur as shown in Figure 4.2

4.3 Areas of aquatic species endemism

Areas of aquatic species endemism, especially fish, are important ecologically. Aquatic endemism usually occurs where the rivers are relatively isolated e.g. by steep gradients, rapids and water falls, and where conditions in the habitats are significantly different from the commoner forms of aquatic habitats. The rarer forms of river reach classification types discussed earlier provide one method of identifying potential areas of endemism. However, certain broad areas have been recognized as areas of high endemism, but in Myanmar further surveys and red listing assessments are required to ensure a comprehensive understanding of the endemic fish, molluscs and odonata and their distribution.

In the Ayeyarwady, the highest level of endemism is found in its mountain tributaries along the Rakhine Yoma and Chin Hills, the Bago Yoma and its northern tributaries around the Chinese border.[5] As can be seen from Figure 4.2, there is some correlation with the rare river reaches identified in the headwaters of the Chindwin and the headwaters of Ayeyarwady near the Chinese border. The rivers leading into Inle Lake and the upper Baluchaung are also identified as rare river reach types.

Recent icthyological surveys around Indawgyi Lake and in the Putao region in the headwaters of the Ayeyarwady observed 78 species in the Lake, 18 recorded for the first time, and bringing the number of fish species now known in the basin to 95.[6, 7]The survey term concluded:

Considering that the fish fauna of Lake Indawgyi is one of the best and longest documented in Myanmar, this high number of new records in 8 days of actual sampling shows that the inventory is still not complete. This also shows how many new discoveries are awaiting in unsurveyed areas of northern Myanmar.

And

Fish surveys conducted in the area of Putao, Kachin State, in November-December 2014 observed 42 species. The number of fish species now known from this area is 46, of which 16 (38 %) were first recorded by our survey. There has been only little field observation on the fishes of the upper Mali Hka basin and a large number of additional species should be expected.

In the Thanlwin catchment, a major area of endemism is around Inle Lake which contains the highest number of restricted range species (23 to 31 species per sub-catchment) comparable only to Mekong River around Khone Falls. High endemism is suspected around the limestone tributaries in the southwest of the Thanlwin catchment. In the Tanintharyi river catchment, where until recently very little surveys of aquatic biodiversity had been carried out, recent surveys identified 103 species of which 7 are endemic and 9 potentially new to science and unnamed.[8] In the Lenya river drainage, in southern Tanintharyi, ichthyological surveys in 2014 collected 54 species of which one was endemic and 5 were potentially new to science and unnamed.[9]

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[5] IUCN study by Allen, 2010, *The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya.*

[6] Kottelat, 2015, *Fish species observed in Lake Indawgyi and its basin; December 2014 update*, ,

[7] Kottelat, 2015, *Fish species observed in Mali Hka River and tributaries in Putao area, Kachin State, in November–December 2014*

[8] Kottelat, 2015, *Fish Species Observed In Tanintharyi Drainage in April–May 2014*

[9] Kottelat, 2015, *Fish Species Observed In Lenya River Drainage in Tanintharyi Region, in November 2014*

Box - FFI fisheries surveys

Despite the general lack of data on fish biodiversity in Myanmar, during 2014 Fauna & Flora International, working in collaboration with the Myanmar Department of Fisheries & Department of Forestry, conducted a series of high quality field surveys aimed at assessing fish stocks in several key biodiversity areas. Four surveys have been completed to date. These were;

1) Survey of the Mali Hka River & tributaries in Putao, Kachin, Nov- Dec 2014 -
    a. Total fish species: 46; Endemic species: 15; Potential new species to science 2;
2) Survey of Tanintharyi Drainage Apr - May 2014 -
    a. Total fish species: 103; Endemic species: 10; Potential new species to science: 9;
3) Survey of Lenya River Drainage, Tanintharyi Region, November 2014 -
    a. Total fish species: 50; Endemic species 1: Potential new species to science: 5; and
4) Survey of Lake Indawgyi and its Basin - Dec 2014 -
    a. Total fish species: 95; Potential new species to science: 6.

The contribution that FFI has made, and continues to make, in documenting Myanmar's aquatic biodiversity, is noteworthy.

4.4 Globally important wetland sites

In 2004, BirdLife International carried out a wetland inventory for Myanmar and surveyed 99 sites, focusing on the Chindwin and Ayeyarwady but also including sites in the Thanlwin (6 sites), Rakhine (3 sites) and Sittaung (5 sites). (Davies, 2004). This inventory recognized four important wetland types

1. The Dry Zone Wetland Complex
2. The Delta Wetlands of the Ayeyarwady, Sittaung and Thanlwin
3. The Coastal Wetlands of Arakan and Tanintharyi
4. Large Natural Freshwater Lakes - Indawgyi and Inle lakes.

The survey identified 17 sites considered to be globally important, some of which were prospective Ramsar sites, and most of which have been identified as Key Biodiversity Areas (Table 4.4).

Table 4.4: Globally important wetland sites identified in the 2004 Wetland inventory

No.	Site	Fulfilment of Remarks	Criteria for Global Conservation Initiatives
1	Inle Lake	Ramsar Site	High fish diversity & endemism
		World Heritage Site	Highest macrophyte diversity in Myanmar
		Anatidae Network Site	Global freshwater hotspot for fish & molluscs
		Important Bird Area	High tourism value
			One of the most threatened wetlands in Myanmar
2	Indawgyi Lake	Ramsar Site	Globally important for fish diversity & endemism together with the wider Mogaung Chaung sub-basin
		World Heritage Site	
		Important Bird Area	High macrophyte diversity
		Anatidae Network Site	High tourism value
3	Mogaung Chaung	Ramsar Site	Globally important for fish diversity & endemism
		Important Bird Are	
		Anatidae Network Site	
4	Ayeyarwady (Bagan-Singu)	Ramsar Site World Heritage Site	Irrawaddy Dolphin population confined to river under severe threat nationally High tourism value
		Important Bird Area	

No.	Site	Fulfilment of Remarks	Criteria for Global Conservation Initiatives
		Anatidae Network Site Shorebird Network Site	
5	Ayeyarwady (Myitkyina-Simbo)	Ramsar Site Important Bird Area Anatidae Network Site	Endangered Irrawaddy Dolphin population
6	Moeyungyi	Ramsar Site Important Bird Area Anatidae Network Site	High tourism value
7	Hukaung Valley WS	Ramsar Site Important Bird Area	Existing protected Area
8	Indaw Lake	Important Bird Area	High macrophyte diversity
9	Letkokkon	Ramsar Site Important Bird Area Anatidae Network Site Shorebird Network Site	Mangroves & mudflats under severe threat from over-cutting and erosion
10	Yemyet In	Ramsar Site Important Bird Area	Threat from reclamation for agriculture & conversion to fishpond
11	Chaungmagyi	Important Bird Area	High macrophyte diversity
12	Khule In		2nd highest macrophyte diversity in Myanmar
13	Thanlwin River basin wetlands		Globally important for fish diversity & endemism
14	Kye Ni Tank	Important Bird Area Anatidae Network Site	High macrophyte diversity Historical value
15	Taung Kan	Important Bird Area Anatidae Network Site	High macrophyte diversity
16	Mahananda Kan	Important Bird Area	Historical value
17	Nyaung Yan - Min Hla	Important Bird Area	Historical value

The 2004 Wetland Inventory surveyed 99 different wetland sites within Myanmar and identified these 17 sites to be globally and nationally important for the reasons shown above. The 99 wetland sites surveyed in 2004 are shown in Annex 3. The 17 sites shown above have been incorporated into the scores for ecologically sensitive areas and river reaches.

4.5 Ramsar and World Heritage sites - existing and potential

Myanmar has designated three Ramsar sites: Indawgyi, Moyingyi Wetland and Meinmahla Kyun Wildlife Sanctuaries. The three profiles described below are taken from the Ramsar Convention website[10] (Ramsar Convention, Downloaded April 2017)

Indawgyi Wildlife Sanctuary Ramsar Site comprises Indawgyi Lake, the largest natural freshwater lake in Myanmar, and surrounding lowlands which have mostly been converted to wet rice agriculture. The Lake plays a role in flood control and provides regionally important habitats to at least 20,000 migratory and resident water birds. These include globally threatened birds such as the vulnerable lesser adjutant (*Leptoptilos javanicus*), sarus crane (*Grus antigone*) and wood snipe (*Gallinago nemoricola*). The Site is home to globally threatened mammals such as the endangered hog deer (*Axis porcinus*) and Shortridge's langur (*Trachypithecus shortridgei*), and the vulnerable eastern hoolock gibbon (*Hoolock leuconedys*). It also hosts five species of globally threatened chelonians, of which three are endangered:

[10] http://www.ramsar.org/wetland/myanmar

the Asian brown tortoise (*Manouria emys*), Burmese peacock softshell turtle (*Nilssonia formosa*), and the yellow tortoise (*Indotestudo elongata*). Indawgyi Lake has a high diversity of fish, including seven species recently discovered and endemic to the Site. The 30,000 people living in 16 villages around the lake basin depend on a mixture of rice farming and fishing for their livelihoods. The annual festival held in March at the Shwe Myint Zu Pagoda on the west side of the lake attracts tens of thousands of Buddhist pilgrims.

Moyingyi Wetland Wildlife Sanctuary is in the Bago Region and covers 10,359 ha. It is a state-owned area comprising floodplain and a storage reservoir that is important for flood control. Originally constructed as a reservoir to provide water to the Bago-Sittaung canal (linking the Bago and Sittaung rivers) for transport of timber by boat, the site now functions as a source of fresh water for downstream areas where rice cultivation takes place. It floods in the wet season (May-October), and from October to March hosts over 20,000 migratory water birds. These include the globally threatened Baer's Pochard *Aythya baeri*, Sarus Crane *Grus antigone* and Greater Spotted Eagle *Aquila clanga*, as well as >1% of the regional population of the Northern Pintail *Anas acuta*. The site is also important for supporting the vulnerable Burmese Eyed Turtle *Morenia ocellata*. The local communities use the site for fishing, grazing, duck-rearing and some rice-growing; and there is a small tourist facility to accommodate birdwatchers.

Meinmahla Kyun Wildlife Sanctuary is a coastal wetland in the southern part of the Ayeyarwady Delta, which is also an ASEAN Heritage Park. It supports one of the largest remaining mangrove areas in the Delta, where mangrove ecosystems have declined due to activities including logging, fishing and development of shipping lanes. Now the mangrove species are being replaced by mangrove date palm (*Phoenix paludosa*). The Ramsar Site is of international importance for a number of reasons. It has a substantial carbon sequestration capacity, and so is important in mitigating global climate change. It also supports globally threatened species such as the critically endangered hawksbill turtle (*Eretmochelys imbricata*) and mangrove terrapin (*Batagur baska*). The latter is particularly significant for the Site because it is listed under the IUCN Red List as regionally extinct in Myanmar. Other threatened species include the endangered great knot (*Calidris tenuirostris*), Nordmann's greenshank (*Tringa guttifer*), green turtle (*Chelonia mydas*) and dhole (*Cuon alpinus*). Vulnerable species include the Pacific ridley turtle (*Lepidochelys olivacea*), fishing cat (*Prionailurus viverrinus*), lesser adjutant (*Leptoptilos javanicus*) and the Irrawaddy dolphin (*Orcaella brevirostris*). The Site is also the last estuarine habitat in Myanmar for the salt water crocodile (*Crocodylus porosus*). It holds significant cultural and historic value for the people of Myanmar, based on myths and pilgrimages which closely connect them to their environment.

Myanmar has designated one cultural World Heritage site (Pyu ancient cities) and has identified others as potential World Heritage sites. The following natural river and wetland sites have been included on the UNESCO World Heritage tentative list, described below[11] (UNESCO, Downloaded April 2017)

- **Inle Lake (1996)** - A large mountain lake in a well-preserved landscape. Several ethnic groups use the lake and its shores as their central landmark. The cultural traditions of numerous villages around it focus on the lake and have distinctive features: - internal navigation, fishing and commerce; - floating vegetable gardens installed on artificial rafts. - distinctive housing shapes and types. - annual Buddhist festival on the lake. The symbiosis and ecology of the lake, its shores and its villagers constitute a genuine instance of cultural landscape.
- **Ayeyarwady River Corridor (2014)** -The Ayeyarwady River Corridor (ARC) covers a 400 km stretch of one of the last major undammed rivers in Asia. Tributaries originating high in Myanmar's northern mountains flow south before joining northeast of Myitkyina to form the Ayeyarwady River. The river basin lies almost entirely within Myanmar and covers nearly 60% of its land surface. Above the city of Mandalay until Bhamo, the river is home to the globally VU Irrawaddy Dolphin. The CR sub-population of Irrawaddy Dolphin in this river is famous for its cooperative fishing behavior with humans. The **Ayeyarwady** provides habitat for these dolphins, as well as for other wildlife including the White-bellied Heron and several species of

[11] https://aseanup.com/unesco-world-heritage-sites-myanmar/

globally threatened turtle. In total, the corridor covers 400 km and would protect 90,000 hectares of river and riparian habitat.

  - **ARC (Lower: Mingun to Kyauk Maung segment)** (N22 19 11, E96 0 2). The southernmost segment is the only section that is formally protected. This section is coincident with the Irrawaddy Dolphin Protected Area (PA). This PA was established in 2005 after surveys by the Department of Fisheries (DOF) and WCS estimated that at least 59 dolphins were present (Tun 2005; WCS 2013). The area is managed by DOF but it has yet to be formally gazetted. The PA is 72 km in length and runs from Mingun to Kyauk Myaung. It covers 32,600 hectares and is 10 km at its widest. Surveys have found 35 fish species. Of these, the Bago Labeo (*Labeo boga*), Aspidoparia (*Aspidoparia morar*), and Gangetic mystus (*Mystus cavasius*) are the most common (Tun 2004; Ng 2013).
  - **ARC (Middle: Moda Section,Takaung to Shwegu segment)** (N24 1 18, E96 21 48) The middle part would extend 160 km from 9.5 km south of Takaung to 4.8 km north of Shwegu, and cover 37,200 hectares. The area provides habitat for the Irrawaddy Dolphin and many fish species (Tun 2005). Although little detailed data is available on this segment, it likely has similar species composition to the lower and upper segments.
  - **ARC (Upper: Shwegu to Bhamo segment)** (N24 10 55, E97 7 21) The uppermost part would start 9 km to the north of the middle section and continue to the town of Bhamo, 41 km to the north, covering 19,900 hectares. Its northern extent would end at a narrow point in the river that is believed to be impassable to dolphins. Birds found here include the CR White-bellied Heron and VU Lesser Adjutant.

- **Indawgyi Lake Wildlife Sanctuary (2014)** described earlier.

4.6 KBAs with aquatic species

Key Biodiversity Areas that have been described are indicative of ecological importance of many reaches of the rivers in Myanmar. Until recently a total of 122 KBAs had been identified and a further 37 are in the process of being described. Some of these KBAs have been designated based purely upon terrestrial fauna, or their importance for coastal and marine ecosystems, whilst others have been described for the presence of aquatic birds. Still others are focused on river fauna. It is therefore possible to differentiate the KBAs in Myanmar based upon their relevance to important aquatic ecosystems in the rivers as follows:

- KBA defined upon terrestrial fauna
- KBA defined on terrestrial fauna, but containing a medium or large sized river
- KBA defined on aquatic birds
- KBA defined for a river reach or wetland

There are 20 KBAs that can be described as fully riverine or important wetland areas. These are listed in Table 4.5 and Table 4.6, with their associated river basin and the KBA trigger groups. There are 36 KBAs that have been designated principally for their importance for birds with riverine and aquatic habitats (Table 4.5 and Table 4.6). It is likely that such KBAs will also be important for other forms of aquatic biodiversity. The locations of all 122 KBAs in Myanmar are shown on Figure 4.3, with their importance for aquatic and riverine ecosystems identified. There are relatively few KBAs designated in the Thanlwin catchment. This is likely due to the relatively few surveys that have been carried out on the Thanlwin.

Table 4.5: KBAs that are important for river species and wetlands

Name	River basin	Trigger species
Ayeyarwady River: Myitkyina to Sinbo Section	Ayerawady	Water birds
Ayeyarwady River: Bhamo Section	Ayerawady	Water birds, Dolphin

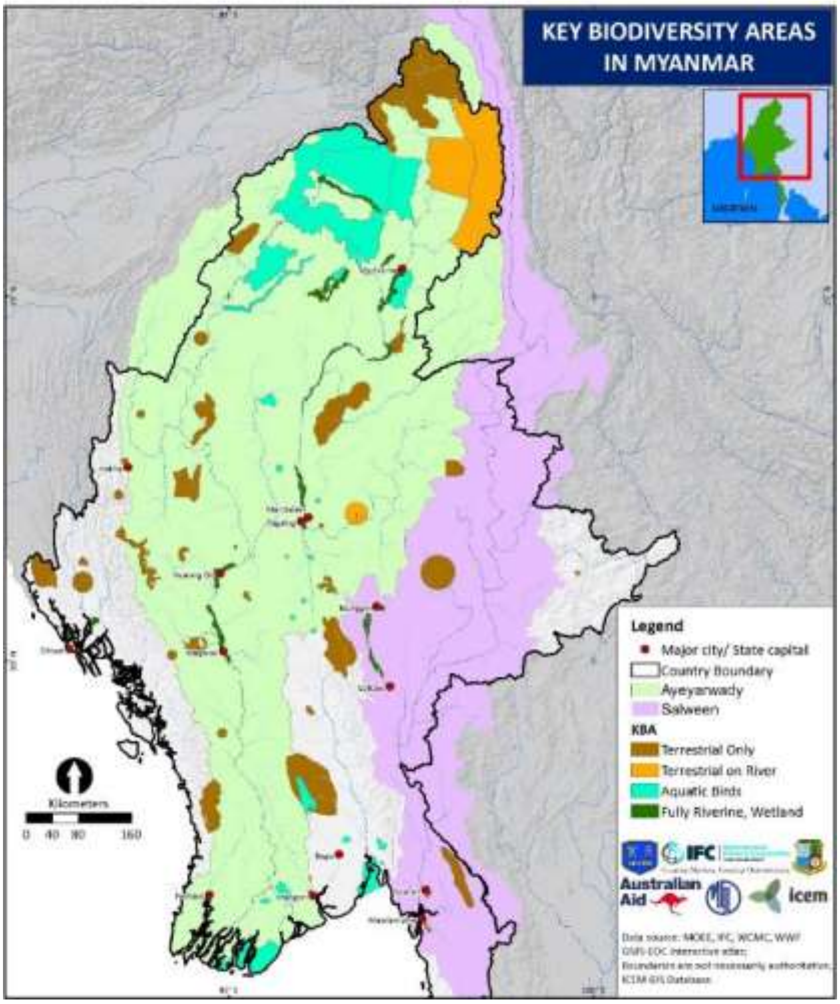
Name	River basin	Trigger species
Ayeyarwady River: Shwegu Section	Ayerawady	Water birds, Dolphin
Irrawaddy Dolphin Reach	Ayerawady	Dolphin, Turtles
Ayeyarwady River: Bagan Section	Ayerawady	Water birds
Ayeyarwady River: Singu Section	Ayerawady	Water birds
Ayeyarwady River: Sinbyugyun to Minbu Section	Ayerawady	Water birds
Peleik Inn	Ayerawady	Water birds, Turtles
Indawgyi Wildlife Sanctuary	Ayerawady	Water birds, Turtles
Meinmahla Kyun	Ayerawady	Water birds
Pidaung	Ayerawady	Turtles
Taunggyi	Ayerawady	Turtles
Mone Chaung	Ayerawady	Turtles
Man Chaung	Ayerawady	Turtles
Upper Chindwin River: Kaunghein to Padumone Section	Chindwin	Terrestrial, Water birds, Turtles
Tanai River	Chindwin	Water birds
May Yu	Rakhine	Dolphin
Kaladan River	Rakhine	Water birds, Turtles
Pyaungbya River	Rakhine	Water birds
Inle Lake	Thanlwin	Water birds, Turtles

Table 4.6: KBAs that are important for Water birds

Name	River basin	Trigger species
Chaungmagyi Reservoir	Ayerawady	Water Birds
Nyaung Kan-Minhla Kan	Ayerawady	Water Birds
Upper Mogaung Chaung Basin	Ayerawady	Water Birds
Myitkyina-Nandebad-Talawgyi	Ayerawady	Water Birds
Nam Sam Chaung	Ayerawady	Water Birds
Mahanandar Kan	Ayerawady	Water Birds
Myittha Lakes	Ayerawady	Water Birds
Yemyet Inn	Ayerawady	Water Birds
Taung Kan at Sedawgyi	Ayerawady	Water Birds
Nadi Kan	Ayerawady	Water Birds
Kyee-ni Inn	Ayerawady	Water Birds
Bumphabum	Ayerawady	Terrestrial, Water birds
Chatthin	Ayerawady	Water Birds
Taungtaman Inn	Ayerawady	Water Birds
Minzontaung	Ayerawady	Water Birds
Kadonkani	Ayerawady	Water Birds
Khaing Thaung Island	Ayerawady	Water Birds
Pyin-ah-lan	Ayerawady	Water Birds
Yelegale	Ayerawady	Water Birds
Maletto Inn	Ayerawady	Water Birds
Kelatha	Ayerawady	Water Birds
North Zarmayi Elephant Range	Ayerawady	Terrestrial, turtle
Indawgyi Grassland and Indaw Chaung Wetland	Ayerawady	Water Birds
Hukaung Valley	Chindwin	Terrestrial, Water birds

Name	River basin	Trigger species
Hukaung Valley extension	Chindwin	Terrestrial, Water birds
Htamanthi	Chindwin	Terrestrial, Water birds, turtles
Uyu River	Chindwin	Terrestrial, Water birds
Kamaing	Chindwin	Water Birds
Moyingyi	Sittaung	Water Birds, turtles
Kyaikhtiyoe	Sittaung	Turtles
Gulf of Mottama	Sittaung	Water Birds
Payagyi	Sittaung	Water Birds
Pyindaye	Sittaung	Water Birds
U-do	Sittaung	Water Birds
Pachan	Tanintharyi	Water Birds
Kawthaung District Lowlands	Tanintharyi	Turtles
Karathuri	Tanintharyi	Terrestrial, Water birds

Figure 4.3: Locations showing the different types of KBA, with emphasis on aquatic and riverine KBAs



4.7 Areas of turtle importance

The Wildlife Conservation Society has an active turtle and tortoise conservation program.[12] They report that there are at least 27 species of freshwater turtles and tortoises known to occur in Myanmar, including eight endemic forms. Despite such high levels of diversity, the chelonians of Myanmar are among the least studied and poorly known in the world; even basic distributional and life history information is unavailable for many species. This situation is especially alarming given the threats faced by turtle populations throughout Myanmar from rampant commercial and subsistence harvesting, and habitat destruction.

Because of these combined threats, chelonian populations in many areas are now severely depleted, and some species are approaching "ecological" or biological extinction. For example, Mangrove terrapins (*Batagur baska* and *B. affinis*) are almost certainly extinct in Myanmar, and the Burmese roofed turtle (*Batagur trivittata*) only just survives in the wild.

The Burmese roofed turtle is a critically endangered endemic species known only from the Ayeyarwady, Chindwin, Sittaung, and lower Thanlwin rivers, where it was historically reported to be common. However, rampant egg collection, conversion of nesting beaches to seasonal agricultural fields, and chronic over-harvesting of adults by fishermen led to long-term population declines, and by the 1970s the Burmese roofed turtle was assumed to be extinct. The species was "rediscovered" in Dokthawady River (which becomes the Myitinge River, and thence into the Ayeyarwady) during a 2001 WCS expedition (Platt et al., 2005). Subsequent surveys located additional turtles along the Dokthawady River and in temple ponds in Mandalay, and a remnant breeding population was found in the upper Chindwin River (Kuchling, 2002). Unfortunately, the Dokthawady population is now thought to be extinct after the construction of the Yeywa hydropower dam allowed an influx of fishermen and inundated nesting beaches. However, turtles obtained from the river and temple ponds in Mandalay were used to found a captive assurance colony at the Yadanabon Zoological Gardens in Mandalay.

Two areas have been identified for reintroduction - the first area is a stretch of the upper Chindwin River near Limpha Village, already inhabited by several nesting females, while the second is along Nam Thalet Chaung, a relatively pristine tributary of the Chindwin, flowing out of Nagaland in India and flowing into the Chindwin near Htamanthi.

Five species of softshell turtles are known to occur in Myanmar (*Amyda cartilaginea, Nilssonia formosa, Chitra vandijki, Dogania subplana, Lissemys scutata*), and three of these are endemic (*N. formosa, C. vandijki,* and *L. scutata*). A. *cartilaginea, N. formosa,* and *C. vandijkii* are declining rapidly and will likely become critically endangered within the coming decade.

As a group, softshell turtles are in high demand by Chinese wildlife markets and populations of most species have been decimated throughout much of Myanmar. A softshell turtle assurance colony is currently being established at a Buddhist monastery near Bago, about 60 km north of Yangon. Ponds are fenced and fitted with artificial sandbanks to provide a nesting substrate. Seven adult softshell turtles (three narrow-headed softshell turtles (*C. vandijkii*), two Asian giant softshell turtles (*A. cartilaginea*), and two Burmese peacock softshell turtles (*N. formosa*) have been acquired for the assurance colony. These turtles were either confiscated from wildlife traffickers by the Forest Department or donated by fishermen.

Relatively secure populations of the Arakan forest turtle (*Heosemys depressa*) were found in two wildlife sanctuaries in western Myanmar. Gwa is also home to an assurance colony of Arakan forest turtles, a poorly known and critically endangered species endemic to the Rakhine Hills.

IUCN Redlist assessment of threatened species has been carried out on 20 of these species of freshwater turtles. (IUCN, Downloaded on 01 May 2017.)[13] Of these, two are Critically Endangered, seven are Endangered, six are Vulnerable. The distribution of these turtles in Myanmar is still uncertain. KBAs in Myanmar which include the presence of turtle species as one of the designation criteria are shown in Table 4.7. Noting the gaps in this distribution, it is clear that the important turtle areas have not been comprehensively identified.

[12] https://programs.wcs.org/myanmar/Wildlife/Turtle-and-Tortoise.aspx
[13] IUCN Redlist searches on http://www.iucnredlist.org

Table 4.7: Myanmar freshwater turtles with IUCN Redlist assessment and noted presence in KBAs

KBA / Turtle species for Myanmar	Red list	Irrawaddy Dolphin	Indawgyi Lake	Peleik Inn	Pidaung	Taunggyi	Mone Chaung	Man Chaung	Htamamthi	Upper Chindwin: Kaunghein to Padumone	Kaladan River	Inle Lake	Moyingyi	Kyaikhtiyoe	North Zarmayi Elephant Range	Kawthaung District Lowlands
		Noted presence														
Amyda cartilaginea (Asiatic Softshell Turtle)	VU	X		X	X		X	X				X			X	X
Batagur baska (Northern River Terrapin)	CR															
Batagur trivittata (Burmese Roofed Turtle)	EN								X	X	X					
Chitra indica (Indian Narrow-headed Softshell Turtle)	EN															
Cuora amboinensis (Southeast Asian Box Turtle)	VU				X											X
Cuora mouhotii (Keeled Box Turtle)	EN				X											
Cyclemys dentata (Brown Stream Terrapin)	NT															
Dogania subplana (Malayan Soft-shelled Turtle)	LC															
Heosemys depressa (Arakan Forest Turtle)	CR															
Heosemys grandis (Giant Asian Pond Turtle)	VU															
Heosemys spinosa (Sunburst Turtle)	EN															X
Lissemys punctata (Indian Flapshell Turtle)	LC															
Lissemys scutata (Burmese Flapshell Turtle)	DD															
Melanochelys trijuga (Indian Black Turtle)	NT															
Melanochelys trijuga (Indian Black Turtle)	VU															
Morenia ocellata (Burmese Eyed Turtle)	VU												X		X	X
Nilssonia formosa (Burmese Peacock Softshell)	EN	X	X		X		X	X		X						
Pelochelys cantorii (Asian Giant Softshell Turtle)	EN															
Platysternon megacephalum (Big-headed Turtle)	EN					X								X		
Siebenrockiella crassicollis (Black Marsh Turtle)	VU															

In addition to the above KBAs, the following stretches of rivers have been identified as being important for turtle conservation:

1. Dokthawady river near Hsipaw, though this stretch of river has now been effectively cleared of turtles
2. Upper Chindwin from Htamanthi to Hkamti, including Limpha village
3. Nam Thalet Chaung tributary to the Upper Chindwin
4. Bago
5. Gwa and Rakhine Yoma Elephant Range

4.8 Areas of mollusc importance

The Ayeyarwady and Chindwin river basins are considered to have mollusc species richness of between 85 - 101 species with greater richness in the Upper Chindwin and norther Rakhine. (Allen D. M., 2010). These richer areas are also considered to have the highest rate of endemic species (8 - 9 endemics). However, one third of the Eastern Himalayan freshwater molluscs are considered to be Data Deficient. There is one Vulnerable species that occurs in the Chindwin river basin - *Lymnaea ovalior*, which probably occurs in 24 sub-basins. Allen (2010) mentions that *L. ovalior* currently occurs in Loktak Lake in Manipur, which is impacted by settlements around the edge of the lake, especially sedimentation and siltation, and from the effects of the Loktak hydropower plant on the Manipur river.

Within the Ayeyarwady and Chindwin sub-basins 137 species of mollusc have been projected to occur, made up of 50 bivalve and 87 gastropod species. Of these there are 1 Vulnerable species, noted above, 1 Near Threatened, 100 Least Concern and 35 Data Deficient species.

The Thanlwin has 2 Critically Endangered molluscs (1 Gastropod and 1 Bivalve) and 1 Vulnerable gastropod. Allen notes that the species richness of molluscs in the Thanlwin basin are lower than in the Chao Pharaya and Mekong basins, with between 35 - 46 species (Allen D. S., 2012), but with a concentration of threatened species around the Inle Lake sub-basins. This matches a distribution of endemic species of between 14 - 31 species around Inle Lake and in the lower reaches of the Thanlwin.

Species	**Class**	**Order**	**Family**	**RedList Status**	**No. of sub-basins reported**

Gabbia alticola	Gastropoda	Littorinimorpha	Bithyniidae	CR	3
Physunio ferrugineus	Bivalvia	Unionoida	Unionidae	CR	3
Brotia citrina	Gastropoda	Sorbeoconcha	Pachychilidae	VU	6

Both *Gabbia alticola* and *Physunio ferrugineus* are known only from Inlé Lake in Myanmar with a highly restricted distribution area of less than 50 km^2. *Physunio ferrugineus* lives in the muddy bottom of the lake between 2- 4 m. Although direct threats to the species are unknown, the lake is under threat from several anthropogenic factors such as aquaculture, agricultural runoff, industrial pollution, and sedimentation has reduced the water cover of the lake by 22 km^2 over 75 years. Although efforts are now being made to preserve the lake, it currently meets the criteria for Critically Endangered. If conservation in the area is successful, this species may be downgraded to a lower threat category in the future. (http://www.iucnredlist.org/details/173147/0)

Brotia citrina inhabits cold, well oxygenated and fast-flowing rivers and streams and is usually found buried in sand or mud, or under rotten leaves or wood where it feeds on detritus. This species is strictly associated with limestone substrates in creeks and streams of the Moei River system only near Mae Sot, Kamphaeng Phet province, northern Thailand. The Moei or Myawaddy River flows into the Thanlwin from the south forming the border between Myanmar and Thailand. The species is not common, and has an uneven distribution, but where present, it is abundant. The IUCN Redlist justification for the assessment as Vulnerable under criterion D2 is that it has only been found in two locations with an area of occupancy of less than 20 km^2. Although the specific current threats to this species are not known, the Moei river system is likely to be subject to similar threats as other river systems in Thailand, and the population is therefore prone to the effects of human activities and capable of declining dramatically over a short space of time.[14]

There are a total of 142 mollusc species (50 Bivalves and 92 Gastropods) projected to occur in the Thanlwin. In addition to the species mentioned above there are 135 Least concern and 34 Data Deficient species.

From the IBAT freshwater database, 43 species of bivalve and 63 species of gastropod probably occur in the sub-basins of the Sittaung. 79 of the species are considered to be of Least Concern and the rest are data deficient.

In the Tanintharyi sub-basins, there are 128 species of molluscs projected to occur, of which 95 are of Least Concern and 33 are Data Deficient.

In the Rakhine sub-basins, there are 136 species of mollusc projected to occur, of which 1 is Vulnerable - *Lymnaea ovalior* in 3 sub-basins. In the same 3 sub-basins, a Near Threatened bivalve *Sphaerium austeni* is also projected. There are 102 Least Concern mollusc specie and 32 Data Deficient species.

In the Mekong sub-basins, there are 111 species of mollusc projected to occur of which 84 are of Least Concern and 27 are Data Deficient.

However, recent reports of mussel surveys in the Sittaung and Ayeyarwady basins (Ilya, 2016) found that the Indo-Burma biodiversity hotspot has exceptionally species-rich fauna of freshwater bivalves, with about 80 species of the Unionidae. The freshwater mussel survey of some water bodies in Sittaung and Ayeyarwady drainages in Myanmar confirmed high conservation value of the region. Molluscs are a good indicator for a biodiverse aquatic ecosystem.

Eleven species of Unionoida were collected in seven tributaries and the main channel of Sittaung River, some of which may be new to science. Exceptional species richness of the Sittaung River is comparable with some tributaries of the Mekong River - the most species rich freshwater basin in South East Asia. The Sittaung tributaries in Karin hills hold the unique freshwater pearl mussel *Margaritifera laosensis*, which is only tropical representative of the family and has been assessed as Endangered. The report considers that the Sittaung drainage is a centre of endemism with high priority for conservation.

[14] (http://www.iucnredlist.org/details/189409/0)

Lakes in the Bhamo section of the Ayeyarwady KBA contained a diversity of mussel species and were also recommended for conservation and watch for the invasive Chinese Pond mussel which was found there.

4.9 Important areas for aquatic insects - Odonata

According to Allen (2010) the Chin Hills-Arakan Coast eco-region is a hotspot for dragon flies, and endemicity is high in this region. In the Ayeyarwady/Chindwin sub-basins there are 144 species of Odonata projected to occur, of which 1 is Near Threatened, 120 are Least Concern and 23 are Data Deficient species.

In the Thanlwin, there are a total of 189 species of Odonata projected to occur. There are two Vulnerable species and 1 Near Threatened, with 165 of Least Concern and 21 Data Deficient species.

Table 4.8: Vulnerable species of Odonata in the Thanlwin sub-basins

Species	Order	Family	RedList Status	No. of sub-basins reported
Bayadera hyalina	Odonata	Euphaeidae	VU	30
Petaliaeschna flavipes	Odonata	Aeshnidae	VU	2

Bayadera hyalina is known from Meghalaya in India and from Doi Inthanon in Chiang Mai in northwest Thailand. It is likely to occur in Myanmar, and should be looked for in streams in montane forest in the country. Its habitat is threatened by clear-felling, although it may be sensitive to lesser degrees of disturbance.

Petaliaeschna flavipes is currently known only from two locations, one in Viet Nam and in Doi Inthanon National Park in Thailand. Both of these restricted locations are severely threatened by anthropogenic activities, and it is therefore assessed as Vulnerable. However more research is needed into the species full distribution, and more survey work may reveal a wider distribution, and it can be downgraded to a non-threatened category. It is found in stream margins in high mountain forests. Construction and road making are destroying the habitat of the species. The location in Doi Inthanon is not in in the National Park and streams are being degraded by agriculture and tourist activities.

In the Sittaung sub-basins there are 112 species of Odonata, of which 1 is considered to be Near Threatened and the rest are of Least Concern (99 species) or Data Deficient (12 species).

In the Tanintharyi sub-basins, there are 182 species of Odonata projected to occur of which 1 is Vulnerable - *Bayadera hyalina*, 162 are of Least Concern and 19 are Data Deficient species

In the Rakhine sub-basins, there are 111 species of Odonata, of which 1 is considered to be Near Threatened, and the rest are of Least Concern (104 species) or Data Deficient (6 species)

In the 37 Mekong sub-basins, there are 159 species of Odonata of which one is considered to be Vulnerable - *Bayadera hyalina*, projected to occur in 13 different sub-basins, 143 species are of Least Concern and 15 are Data Deficient.

4.10 Important areas for crustacea

In Allen (2012), it is reported that Myanmar has 23 species of freshwater crab, in 16 genera and 2 families, out of the 173 species of freshwater crab described for the Indo Burma region. The five countries in the Indo-Burma hotspot have a rich and highly diverse and distinctly recognizable freshwater crab fauna, changing from basin to basin and vegetation cover. Freshwater crabs appear to be noticeably more abundant in rainforest, especially in highland regions, and fewest in lowland ecosystems. Most of the threatened species described below are restricted range species that have been found in neighbouring countries.

In the Chindwin, there is one Vulnerable freshwater crab species - *Liotelphusa quadrata* - This species is listed as Vulnerable because its extent of occurrence is estimated to be approximately 20,000 km², it is only known from five localities in Nagaland and Meghalaya, India, i.e. adjacent to the Upper Chindwin. There is a continuing decline in the extent and quality of its habitat due to human induced degradation driven by population increases and industrial and agrarian development. However, the threats to the species are not well-known, and its proximity to human habitations may well indicate that it is robust and resistant to human-led disruption of habitat. More information is needed, but if this is the case then the species could be downgraded to Least Concern.

In the Ayeyarwady/Chindwin sub-basins there are 62 species of crustacea, made up of 3 Atyid shrimps, 16 Palaemonid prawns and 43 crab species. In addition to the one Vulnerable species of crab, there are 2 Near Threatened crabs, 31 Least Concern and 28 Data Deficient crustacean species.

In the Thanlwin sub-basins in Myanmar, there are no threatened freshwater crustacea, amongst the 48 species projected to occur. There are a total of 5 Atyid shrimps, 15 Palaemonid prawns and 28 species of crabs. 28 of these crustacea are Least Concern and 20 are Data Deficient species.

The Sittaung sub-basins, have been identified as probably within the range of 28 species of decapods crustacea. 15 of these are of Least Concern and 13 are Data Deficient. These include 3 species of Atyid shrimps, 13 Potamid crabs and 10 Palaemonid prawns, including 9 Macrobrachium species.

In Tanintharyi sub-basins, there are 39 species reported on the IBAT database, including 4 Atyid shrimps, 13 Palaemonid prawns, 19 Potamid crabs and 3 Gecarcinucid crab species. 27 of these are of Least Concern and 12 are Data Deficient.

In the Rakhine sub-basins, 27 species of crustacea are projected to occur (13 Palaemonid prawns and 14 Potamid and Gecarcinucid crabs). 1 of these crab species is Near Threatened and 15 of these species are of Least Concern and 11 are Data Deficient.

In the Mekong sub-basins in Myanmar, there are 30 crustacean species projected to occur, 19 are Least Concern and 11 are Data Deficient. There are 2 Atyid shrimps, 11 Palaemonid prawns including 8 Macrobrachium species, and the rest are Potamid and Gecarcinucid crabs.

4.11 Important areas for aquatic plants

There are no threatened aquatic plant species recorded in the IBAT freshwater database for the Ayeyarwady and Chindwin river basins. Out of the total 130 species, there are 68 species of Liliopsida, 57 species of Magnoliopsida, and 5 species of Polypodiopsida. 1 of the Liliopsida species is Near Threatened. 124 species of the plants are Least Concern and 5 of them are Data Deficient.

In the Thanlwin sub-basins, there are 69 species of Liliopsida, 83 species of Magnoliopsida and 6 species of Polypodiopsida. There are four threatened aquatic plant species that may occur, one Critically Endangered, 1 Endangered and 2 Vulnerable species. These are habitat specialists that have very restricted ranges and have only been recorded from Thailand. The rest are Least Concern (139 species) and Data Deficient (15).

Table 4.9: Threatened species of aquatic plants in the Thanlwin sub-basins

Species	Order	Family	RedList Status	No. of sub-basins reported
Terniopsis ubonensis	Magnoliopsida	Podostemaceae	CR	52
Terniopsis chanthaburiensis	Magnoliopsida	Podostemaceae	EN	52
Dalzellia ranongensis	Magnoliopsida	Podostemaceae	VU	52
Hanseniella heterophylla	Magnoliopsida	Podostemaceae	VU	52

Terniopsis ubonensis has only been found in one location on the Mun River in Thailand, where it occurs in a small area attached to rocky substrates in river rapids and waterfalls. It has not been recorded on the Thanlwin.

Terniopsis chanthaburiensisis only found in one locality in Thailand. It grows attached to rocks in water rapids and waterfalls and can only flower in the dry season when the water level decreases. There is a small dam located downstream of the known population which is affecting the reproductive cycle of the species. The reason for this is that the subpopulation close to the dam remains permanently submerged while the upper part is seasonally submerged. Hence only part of the population benefits from natural flow alteration is able to flower. This has an important influence in the population and also affects the river's natural cycle which is vital for the species survival. The subpopulation upstream from the dam is not being impacted by any threat. It has not been recorded on the Thanlwin.

Dalzellia ranongensis has only been recorded from one locality near Haew Lom waterfalls in Chumphon, peninsular Thailand. Habitat degradation and water pollution have been identified as potential threats to the only known population. Species from this family are habitat specialists which only occur attached to rocks in waterfalls and river rapids and populations are therefore sensitive to any disturbance in the river flow and water quality. It is listed as Vulnerable; based on its restricted occurrence and the potential impacts from pollution and disturbance.

Hanseniella heterophylla has only been recorded from three localities in Thailand from three waterfalls in a river in northern Thailand. It is a habitat specialist which only occurs attached to rocks in waterfalls and river rapids in clean and oxygenated water. Populations are therefore sensitive to any disturbance in the river flow and water quality. Listed as Vulnerable D2 based on restricted number of locations and known potential threats which will likely affect part of the global population in the future.

In the Sittaung river basin, according to the IBAT freshwater database, there are 102 species of aquatic plants in 3 orders Polypodiopsida (4 species), Magnoliopsida (47 species) and Liliopsida (51 species). All are widely distributed throughout the sub-basins, and are mostly (98 species) are of Least Concern, and 4 are Data Deficient.

In the Tanintharyi sub-basins there are 151 species of plants listed in the IBAT database, with the same Critically Endangered, Endangered and Vulnerable species as for the Thanlwin, all with a possibility of occurring in the same 55 out of the 93 sub-basins for which projections have been made.

In the Rakhine sub-basins, there are 125 species of aquatic plants projected to occur, of which 120 are of Least Concern and 5 are Data Deficient species.

In the 37 Mekong sub-basins, the IBAT database projects that 160 species of aquatic plants may occur, with the same Critically Endangered, Endangered and Vulnerable species described above. There are 140 Least Concern species and 16 Data Deficient species.

4.12 Presence of other threatened aquatic species in the Myanmar sub-basins

The presence of other threatened aquatic species in the sub-basins of Myanmar which has been described above for molluscs, insects (Odonata), crustacea and aquatic plants have been mapped according to the number of threatened species projected under the IBAT freshwater database to occur in each sub-basin. These are shown in Figure 4.4, Figure 4.5, Figure 4.6, and Figure 4.7 for the Ayeyarwady, Rakhine, Mekong in Myanmar, Thanlwin, Sittaung and Tanintharyi basins.

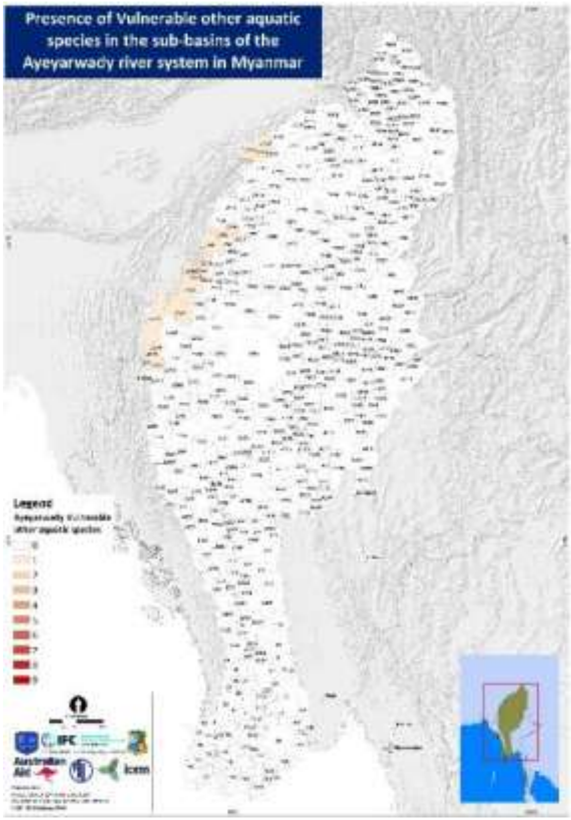
In the Ayeyarwady, the sub-basins with threatened species of other aquatic organisms include the Upper Chindwin, and Chin Hills, and these are complemented by threatened species found in the Rakhine sub-basins on the other side of the Chin Hills.

In the Mekong sub-basins, the CR, EN and VU plant species are generally found in the southern part of the basin and along the Myanmar banks of the Mekong, together with one Vulnerable species of dragon fly.

In the Thanlwin, the range of the same four species of threatened plants lies in the sub-basins bordering Thailand - i.e. where these rare and highly specialized plants were first described. The two Critically Endangered molluscs occur in Inle Lake, and the range of the Vulnerable mollusc species lies in the sub-basins, bordering Thailand. The other Vulnerable aquatic species include the 2 Odonata, which are also found in the same sub-basins.

In the Sittaung, there are no threatened other aquatic organisms. In the Tanintharyi, the distribution of Endangered and Vulnerable species follows a similar pattern following the upland areas bordering Thailand, with an additional focus at the southernmost sub-basins. These include the same four threatened, specialized plant species, 1 Endangered crab species, 1 Vulnerable Odonata species, but no threatened molluscs.

Figure 4.4: Presence of other Vulnerable aquatic species in the Ayeyarwady and Rakhine river basins in Myanmar



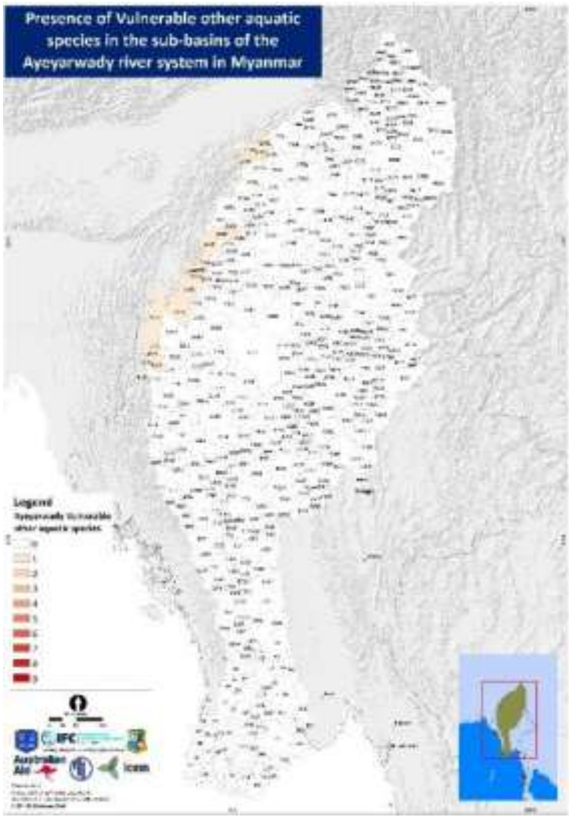


Figure 4.5: Presence of other Critically Endangered, Endangered and Vulnerable aquatic species in the Thanlwin river basins in Myanmar

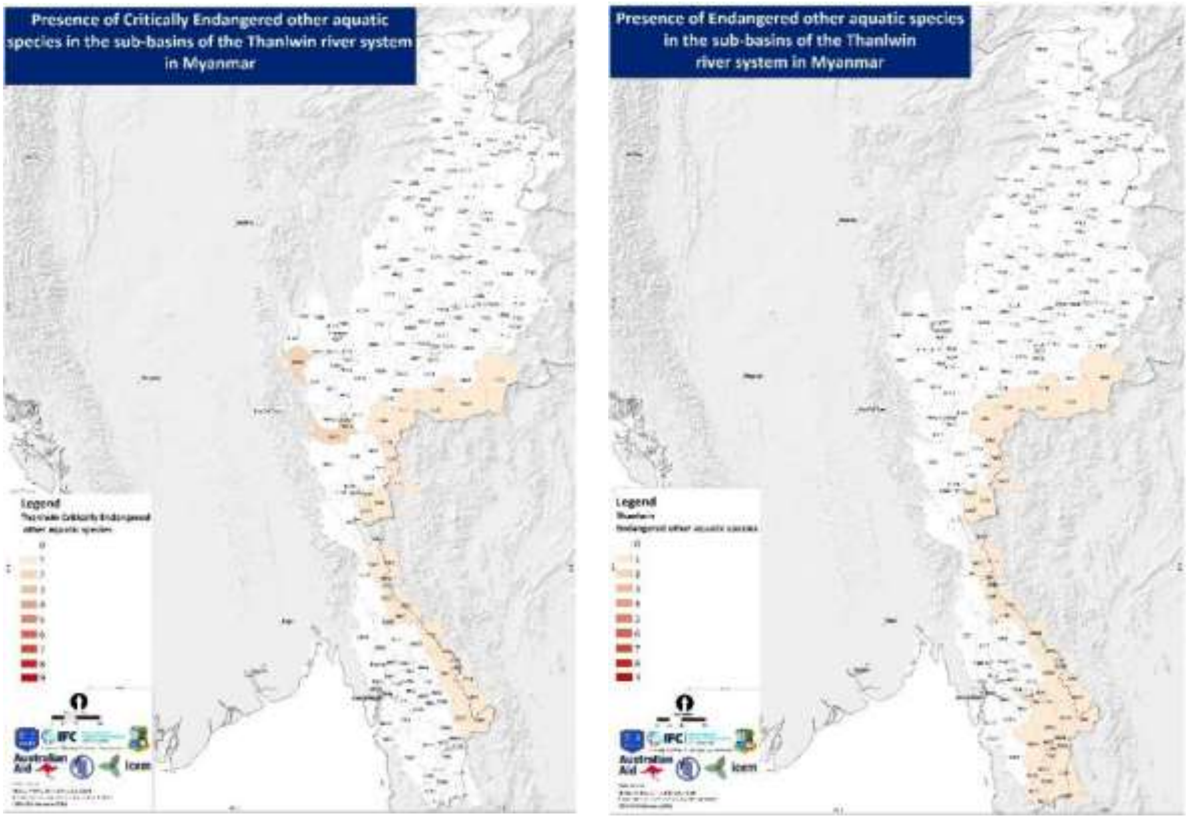


Figure 4.6: Presence of other Critically Endangered, Endangered and Vulnerable aquatic species in the Mekong sub-basins in Myanmar

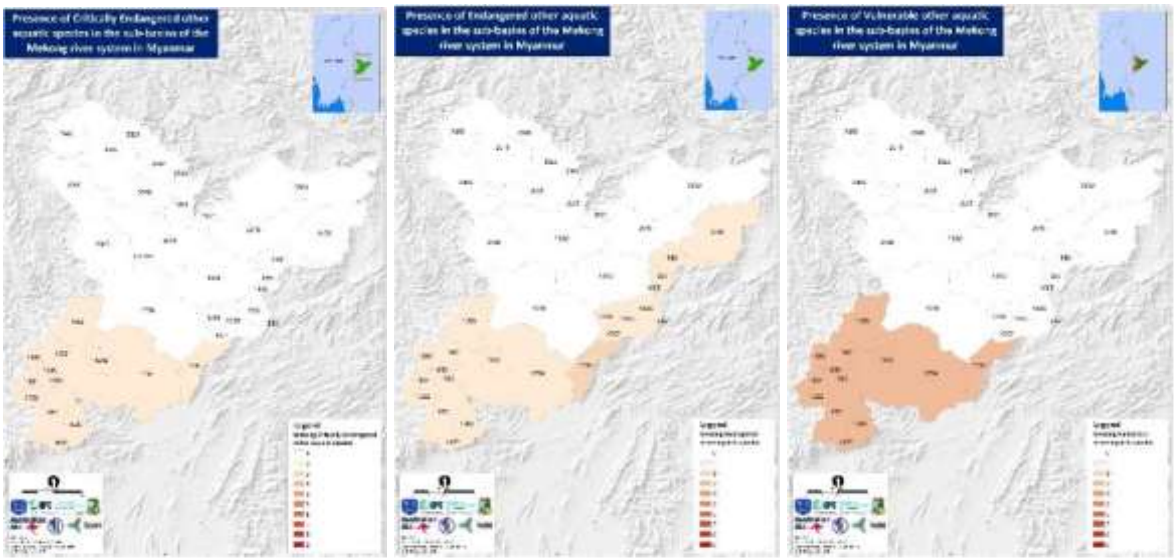
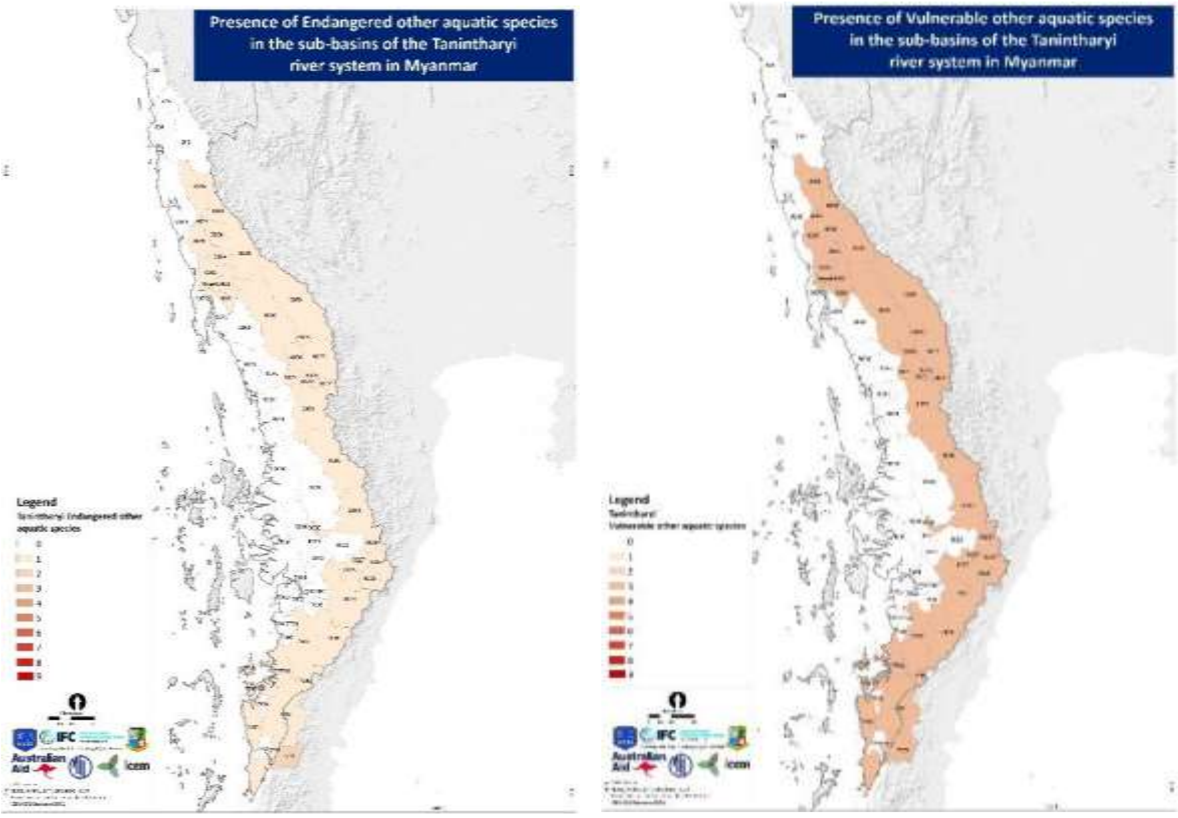


Figure 4.7: Presence of other Endangered and Vulnerable aquatic species in the Tanintharyi sub-basins



4.13 Important areas for amphibians

According to the IUCN Redlist, there 91 Amphibian species occurring in Myanmar.[15] Two of these are Endangered, 4 are Near threatened, 57 Least concern and 14 Data Deficient. Wogan et al (2008) reported the presence of 12 additional species of amphibians to the 2003 total of 82 species, bringing the total up to 94, showing their locations and range extensions of many other recorded species in different Divisions and States (Wogan, 2008). No comprehensive distributional analysis has been developed for amphibians. The Smithsonian Institute are carrying out genetic studies of amphibians and reptiles in the lowland forests of Tanintharyi.

The two Endangered species are:

Ansonia thinthinae Thin Thin's Stream Toad

- This species is associated with the rocky edges of permanent streams within semi-evergreen forest. Adults remain hidden under stones during the day. Tadpoles inhabit submerged stones within the streams. Much of the species' ecology and most of its reproductive biology remain unknown.
- Endangered B1ab(iii) ver 3.1
- Pop. trend: decreasing

Leptobrachium rakhinensis

- This species is currently known from the protected area of Rakhine Yoma Elephant Sanctuary. This species inhabits low elevation hills and evergreen rainforest in monsoonal areas and is associated with thick leaf litter on the forest floor, as well as small streams and waterfalls.
- Endangered B1ab(iii) ver 3.1
- Pop. trend: decreasing

[15] Note that the IBAT freshwater database does not include amphibians, so these cannot be analysed in the same way as fish, odonatan, molluscs, crustacea and aquatic plants.

The 4 Near Threatened species are:

- ***Bufo pageoti* -** Near Threatened ver 3.1; Pop. trend: decreasing
- ***Glyphoglossus molossus* -** Blunt-headed Burrowing Frog; Near Threatened ver 3.1; Pop. trend: decreasing
- ***Limnonectes blythii* -** Giant Asian River Frog; Near Threatened ver 3.1; Pop. trend: decreasing
- ***Nanorana arnoldi* -** Near Threatened ver 3.1; Pop. trend: decreasing

There is one Salamander species that has been assessed as of Least Concern in Myanmar - *Tylototriton verrucosus* - Himalayan Salamander.

4.14 Areas of fish importance

None of the KBAs in Myanmar has been specifically designated because of the presence of any species of fish, let alone Critically Endangered, or Endangered species. As mentioned previously, the aquatic biodiversity of Myanmar's rivers has been underestimated in past studies. Field studies in the upper river reaches are identifying new species on a fairly regular basis. For example, the 2014 Flora Fauna International study of the Mali Hka River and Tributaries in the Putao area in Kachin state[16] identified 42 fish species, 5 of which may be new to science.

As mentioned in the introduction and methodology, a crude analysis of Myanmar's fish species is possible using a combination of two global databases; the IBAT database[17] and the IUCN Red list. These can be used in tandem to assess fish species in specified river reaches/areas and to cautiously arrive at a basic comparison between rivers and river reaches.

To date, analysis of IBAT data is complete for 76 river and lake sites throughout the country, (see Annex 4). Analysis of the IBAT allows for the following conclusions to be drawn:

- The site with the highest freshwater fish biodiversity was found in the Middle Thanlwin where the IBAT database suggests that 91 fish species could be present
- The site with the lowest freshwater fish biodiversity was found in the Upper Thanlwin. Other sites with low biodiversity were found in Rakhine state.
- The database suggests that the lower reaches of the Ayeyarwady have higher fish biodiversity than the upper reaches. However, since the datasets were developed in 2010- 2012, they do not include the many endemic species and species 'new to science' that are now being found through field surveys.

The IBAT datasets are far from perfect. For example, the IBAT species list for a FFI surveyed area in Putao, Kachin State lists 42 fish species that are likely to live in the surrounding hydroshed. The comprehensive field survey by FFI confirmed the presence of only 9 of the same species. In addition. 16 species were identified from the field sites that do not feature in the IBAT species list for the corresponding hydroshed.

A further shortcoming of the IBAT database is the apparent exclusion of some long distance migratory species such as Hilsa, *Tenualosa ilish,* from the Ayeyarewady species list, though it is present in the Thanlwin and Sittaung lists, and the omission of cartilagenous fish species, e.g. sting rays. The other Hilsa species, *Tenualosa toli* is also omitted. In the crustacean section, it does include some commercially important crustacean species such as *Macrobrachium rosenbergii*.

Analysis of different river reaches suggests that the IBAT database might be more reliable in lower and middle river reaches, rather than higher reaches where endemism rates will be higher. It also appears to be less reliable in the southern Region of Tanintharyi, where it appears that, until recently, very few

[16] Kottelat, M. (2015). Fish species observed in Mali Hka River and tributaries in Putao area, Kachin State, in November-December 2014, Report No. 45 of the Myanmar Conservation and Development Program, a joint initiative of Fauna & Flora International (FFI) and the Myanmar Government. FFI, Yangon

[17] The IBAT Alliance is currently formed of four international conservation organizations - BirdLife International, Conservation International (CI), International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), working in partnership with leading institutions from the public and private sector. IBAT provides spatial information about protected and unprotected areas of the terrestrial and marine biodiversity globally. The information provided by IBAT can help with the first step in project planning and can help inform and prioritize subsequent data collection, assessment and planning in the project cycle.

freshwater fish biodiversity studies have been carried out. These shortcomings highlight the need to use the IBAT database extremely cautiously and to carry out field studies to verify any conclusions drawn.

The IUCN Red list suggests that a large majority of fish species in all of the areas analysed are classified as being of Least Concern. In the lower Ayeyarwady 69-88% of the fish species listed are of Least Concern. The areas analysed so far have identified very few endangered fish species. However, this may be due to the limited number of fish species (234) identified from the IBAT database for Myanmar so far. Of the analysis completed only one endangered fish species has been identified in one reach of the Thanlwin and one endangered fish species in 3 areas of Tanintharyi Region have been identified. Near Threatened species are more numerous with one area of Upper Thanlwin having the highest percentage of near threatened species (12%) in the total number of fish species identified for that site. It is possible that the number of endangered and near threatened fish species may increase if field surveys are done to map the distribution of important, rare and threatened species.

The IBAT database suggests that between 48-88% of fish species identified at the 76 sites can be classified as being of Least Concern, and between 2-12% can be classified as Near Threatened. An important finding is the high proportion of species that have been classified as Data Deficient. Species classified as such account for between 6-27% of the total number of species identified and reflects the scarcity of information about many fish species. More specific information about threatened species in each of the main river basin is provided below.

The IBAT freshwater database identifies the following threatened fish species for each of the major river basins.

Ayeyarwady/Chindwin has a total of 227 species of fish with 4 Endangered species and 21 Vulnerable species whose probable distribution is projected in 481 sub-basins (HydroBasins level 8) out of 526 sub-basins. There are 19 Near Threatened species, 125 Least Concern species and 58 Data Deficient species.

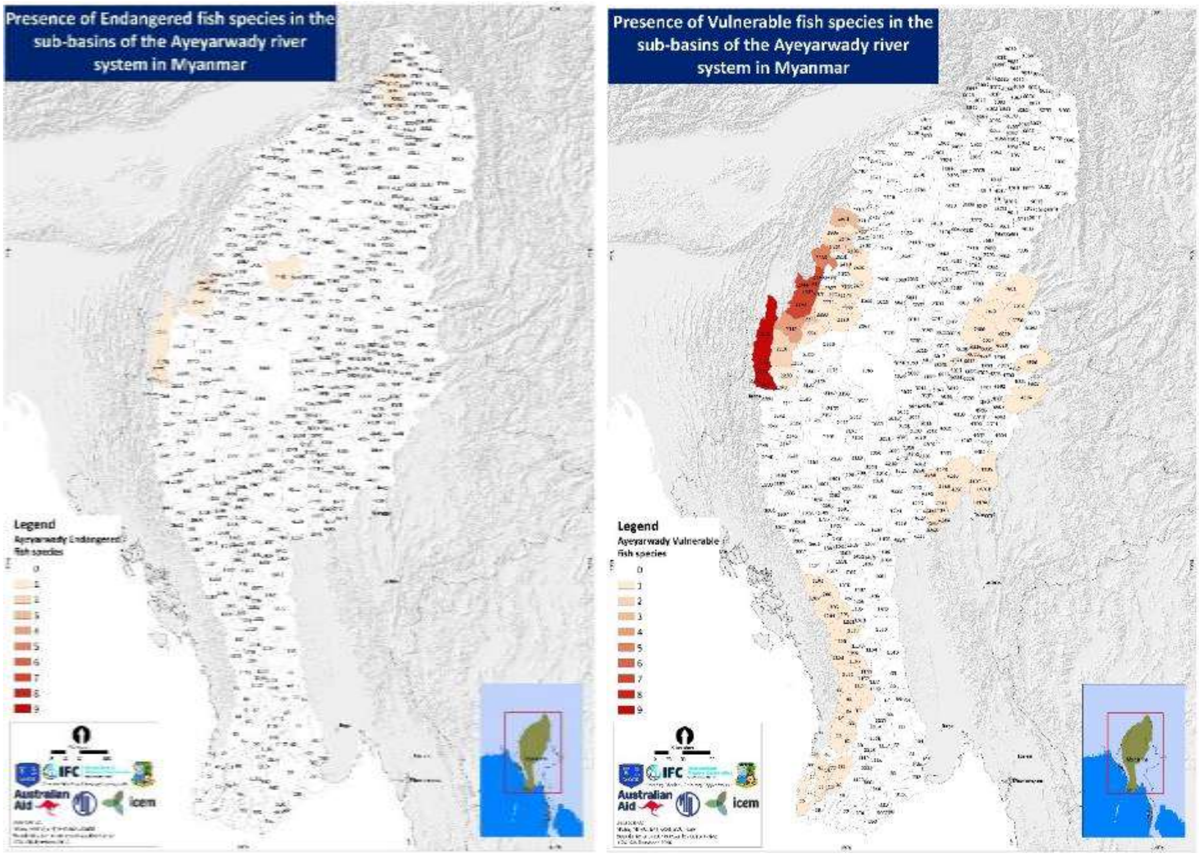
Table 4.10: Threatened fish species in the Ayeyarwady river basin

Species	Group	Family	RedList Status	No. of sub-basins reported
Badis tuivaiei	Perciformes	Badidae	EN	1
Psilorhynchus microphthalmus	Cypriniformes	Psilorhynchidae	EN	11
Schistura minutus	Cypriniformes	Balitoridae	EN	5
Schistura reticulata	Cypriniformes	Balitoridae	EN	14
Barilius chatricensis	Cypriniformes	Cyprinidae	VU	5
Barilius dogarsinghi	Cypriniformes	Cyprinidae	VU	2
Barilius ngawa	Cypriniformes	Cyprinidae	VU	5
Danio jaintianensis	Cypriniformes	Cyprinidae	VU	7
Devario acuticephala	Cypriniformes	Cyprinidae	VU	1
Devario browni	Cypriniformes	Cyprinidae	VU	26
Devario naganensis	Cypriniformes	Cyprinidae	VU	31
Devario yuensis	Cypriniformes	Cyprinidae	VU	13
Garra bispinosa	Cypriniformes	Cyprinidae	VU	5
Garra compressa	Cypriniformes	Cyprinidae	VU	5
Garra flavatra	Cypriniformes	Cyprinidae	VU	7
Garra manipurensis	Cypriniformes	Cyprinidae	VU	7
Garra nambulica	Cypriniformes	Cyprinidae	VU	5
Garra paralissorhynchus	Cypriniformes	Cyprinidae	VU	5
Laubuca khujairokensis	Cypriniformes	Cyprinidae	VU	1
Pseudecheneis ukhrulensis	Siluriformes	Sisoridae	VU	11
Rasbora ornata	Cypriniformes	Cyprinidae	VU	16

Schistura khugae	Cypriniformes	Balitoridae	VU	1
Schistura nagaensis	Cypriniformes	Balitoridae	VU	11
Schistura prashadi	Cypriniformes	Balitoridae	VU	5
Yunnanilus brevis	Cypriniformes	Balitoridae	VU	14

The presence maps of Endangered and Vulnerable fish species for the Ayeyarwady and Chindwin is shown in Figure 4.8, which shows the number of VU fish species occurring in each of the sub-basins. The largest concentration of VU fish species appears in the Chin Hills in the western part of the catchment. There are patches of Vulnerable fish species presence in the south west of the catchment into the Delta, and in the far eastern sub-basins. A similar but less strong pattern emerges for Endangered fish species, but also including Indawgyi Lake and around Putao.

Figure 4.8: Presence of Endangered and Vulnerable fish species in the Ayeyarwady/Chindwin sub-basins



In the **Thanlwin** there is a total of 212 species of fish of which 8 are Endangered species and 4 are Vulnerable species whose probable distribution is projected in 154 sub-basins (HydroBasins level 8) out of 178 sub-basins in Myanmar. In addition, 8 of the species are Near Threatened, 114 species are of Least Concern and 78 are Data Deficient.

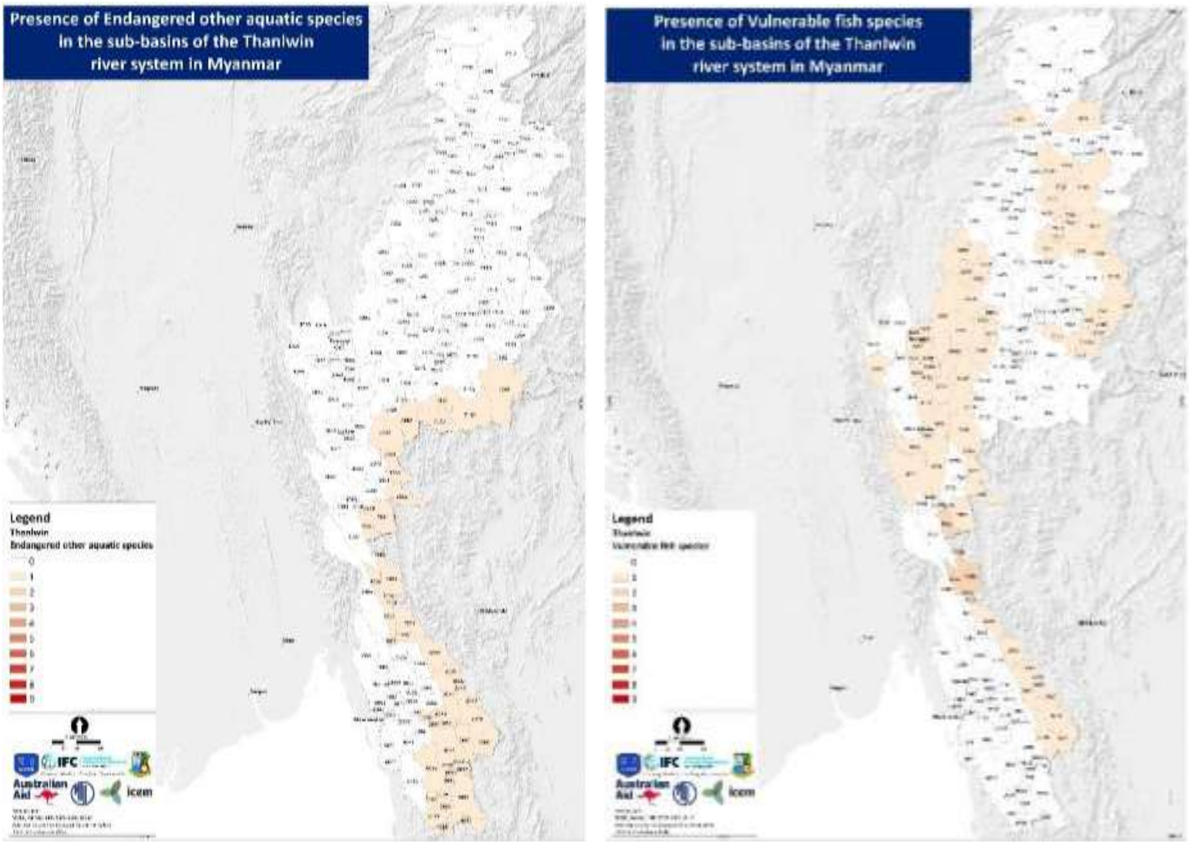
Table 4.11: Threatened fish species in the Thanlwin river basin

Species	Group	Family	Redlist Status	No. of sub-basins reported
Cyprinus intha	Cypriniformes	Cyprinidae	EN	3
Danio erythromicron	Cypriniformes	Cyprinidae	EN	3
Devario auropurpureus	Cypriniformes	Cyprinidae	EN	3
Gymnostomus horai	Cypriniformes	Cyprinidae	EN	3
Mastacembelus oatesii	Synbranchiformes	Mastacembelidae	EN	3

Microrasbora rubescens	Cypriniformes	Cyprinidae	EN	3
Sawbwa resplendens	Cypriniformes	Cyprinidae	EN	3
Scleropages formosus	Osteoglossiformes	Osteoglossidae	EN	12
Devario browni	Cypriniformes	Cyprinidae	VU	16
Garra flavatra	Cypriniformes	Cyprinidae	VU	20
Mystacoleucus lepturus	Cypriniformes	Cyprinidae	VU	9
Yunnanilus brevis	Cypriniformes	Balitoridae	VU	40

The presence of Endangered and Vulnerable fish species in the Thanlwin is shown on the maps in Figure 4.9. There are a high proportion of the Endangered fish in 3 sub-basins in the western catchment of the Baluchaung river, and then one of the Endangered species, *Scleropages formosus*, in the southeastern tributary of the Thanlwin. There is presence of Vulnerable fish species in many of the sub-basins of the Thanlwin, especially around Inle Lake and the north-eastern parts of the catchment.

Figure 4.9: Presence of Endangered and Vulnerable fish species in the Thanlwin sub-basins



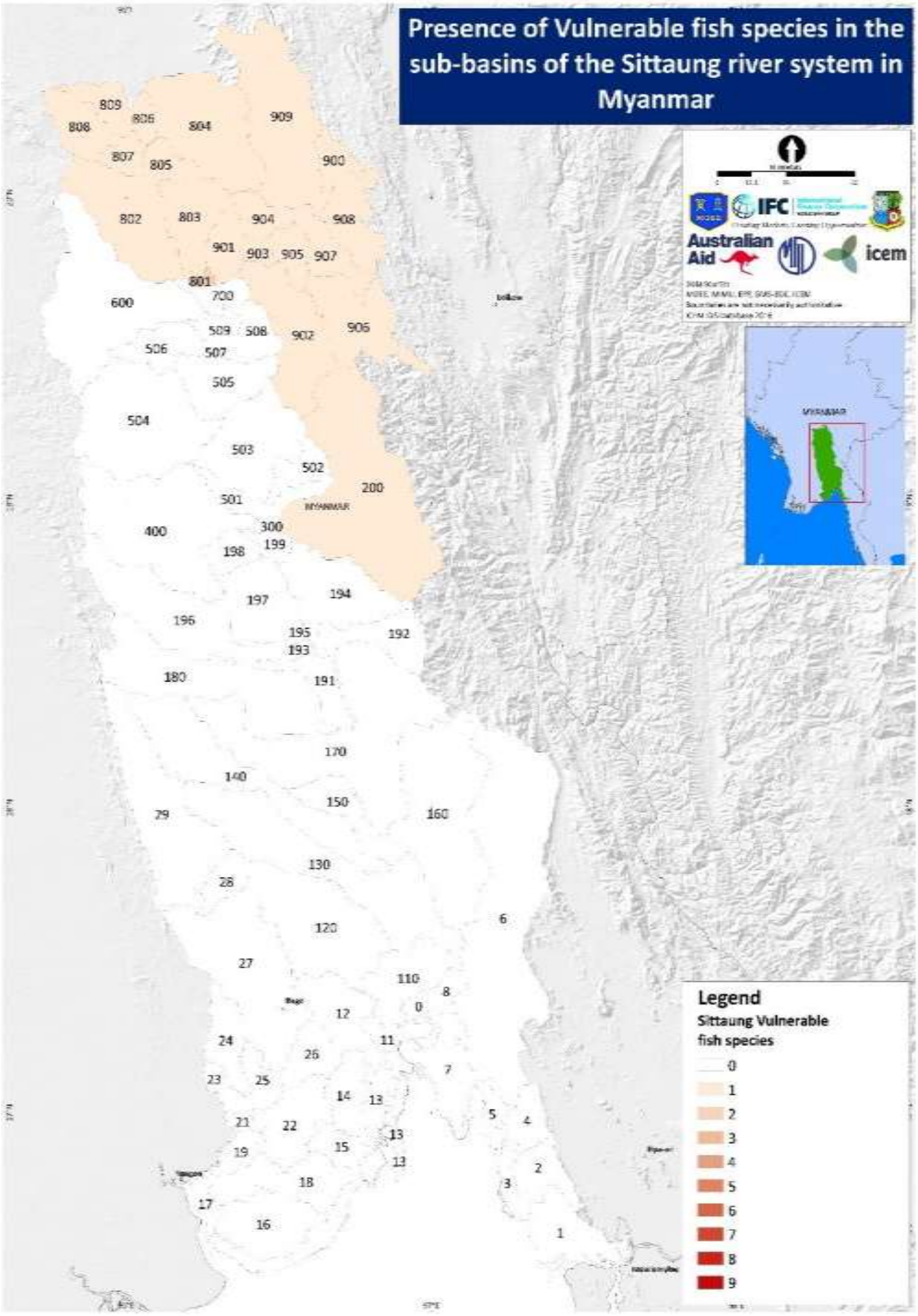
Sittaung has 2 Vulnerable species whose probable distribution is projected in 9 to 12 out of 77 sub-basins. The presence of these Vulnerable species is shown in

Figure 4.10. These sub-basins are in the upper (northern and eastern) catchment of the Sittaung.

Table 4.12: Threatened fish species in the Sittaung river basin

Species	Group	Family	Redlist Status	No. of sub-basins reported
Garra flavatra	Cypriniformes	Cyprinidae	VU	9
Yunnanilus brevis	Cypriniformes	Balitoridae	VU	12

Figure 4.10: Presence of Vulnerable fish species in the Sittaung sub-basins



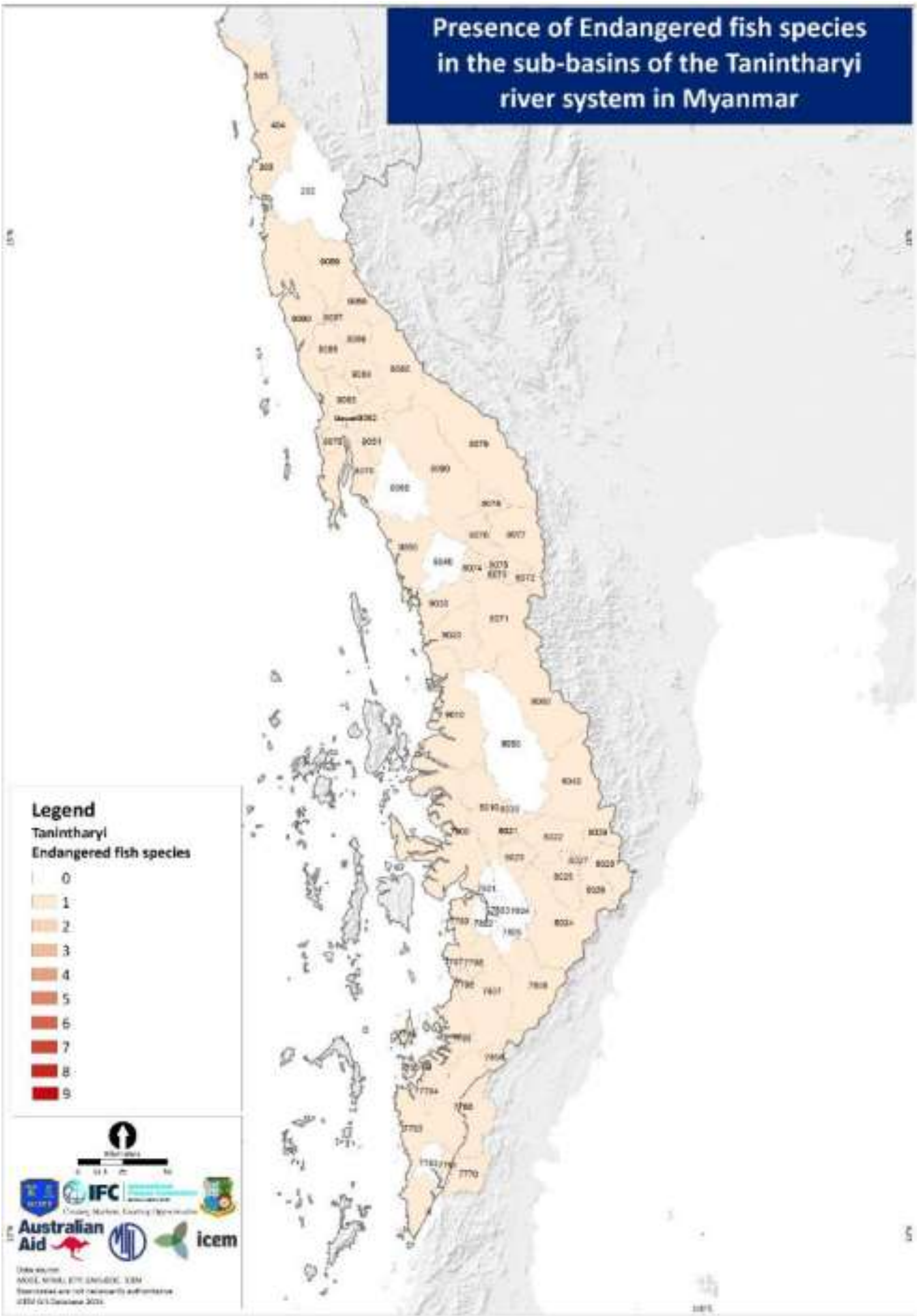
The Tanintharyi sub-basins contains 171 fish species whose range covers 93 out of 103 sub-basins on the IBAT freshwater database, including 1 Endangered (see below) and 4 Near Threatened, 124 Least Concern and 43 Data Deficient species. The distribution of the Endangered, *Scleropages formosus,* is shown in Figure 4.11. It is widespread throughout the Tanintharyi.

Table 4.13 Threatened fish species in the Tanintharyi river basins

Species	Group	Family	Redlist Status	No. of sub-basins reported

Scleropages formosus	Osteoglossiformes	Osteoglossidae	EN	93

Figure 4.11: Presence of Endangered fish species in the Tanintharyi sub-basins

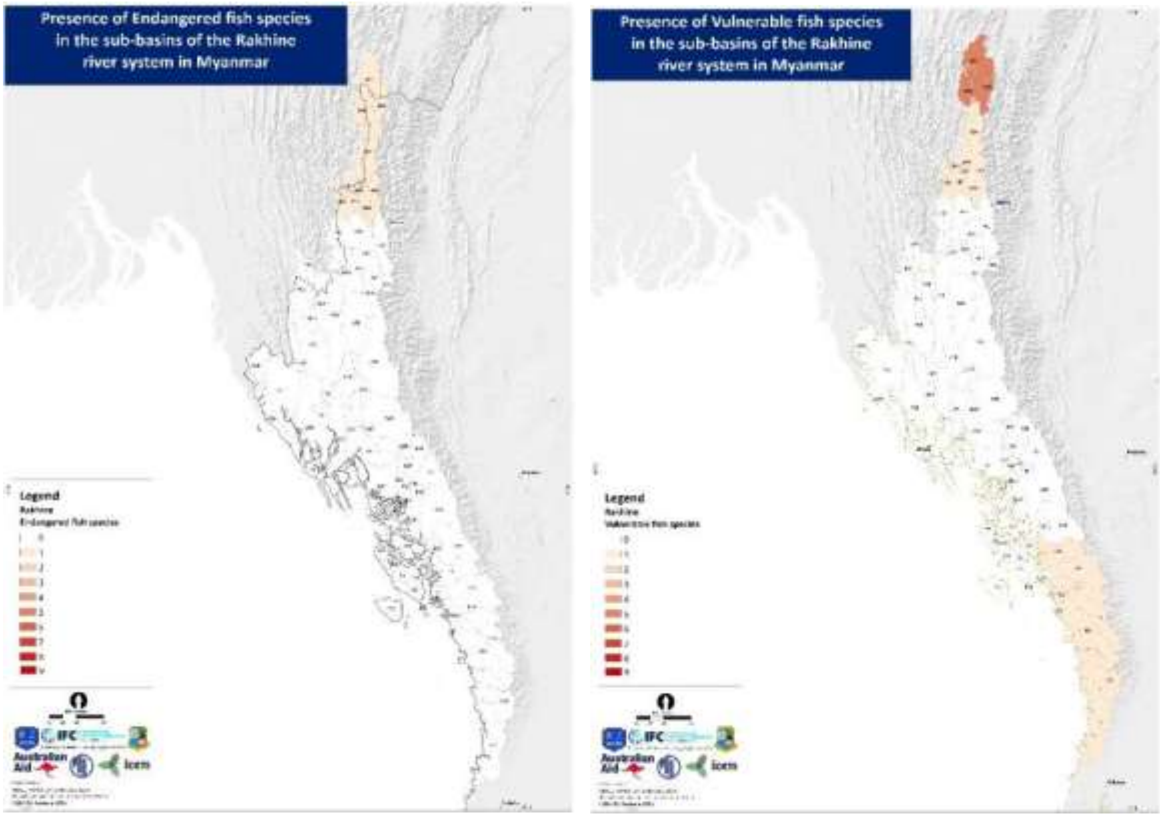


In the Rakhine sub-basins, out of 93 fish species projected to occur, 1 is Endangered, and 6 are Vulnerable all with fairly restricted ranges as shown below, and in Figure 4.12. This distribution shows that the Endangered *Badis tuivaiei* has a restricted range up in the northern upper sub-basins in the Chin Hills. A large proportion of the Vulnerable species also occur in these sub-basins, with the distribution of *Garra manipurensis*, extending to sub-basins further south and with 1 Vulnerable species (*Garra flavatra*) being present in the sub-basins along the southern Rakhine coast.

Table 4.14. Presence of Endangered and Vulnerable fish species in the Rakhine sub-basins

Species	Group	Family	Redlist Status	No. of sub-basins reported
Badis tuivaiei	Perciformes	Badidae	EN	11
Garra flavatra	Cypriniformes	Cyprinidae	VU	9
Garra manipurensis	Cypriniformes	Cyprinidae	VU	11
Garra nambulica	Cypriniformes	Cyprinidae	VU	3
Garra paralissorhynchus	Cypriniformes	Cyprinidae	VU	3
Glyptothorax manipurensis	Siluriformes	Sisoridae	VU	3
Schistura chindwinica	Cypriniformes	Balitoridae	VU	3

Figure 4.12: Presence of Endangered and Vulnerable fish species in the Rakhine sub-basins



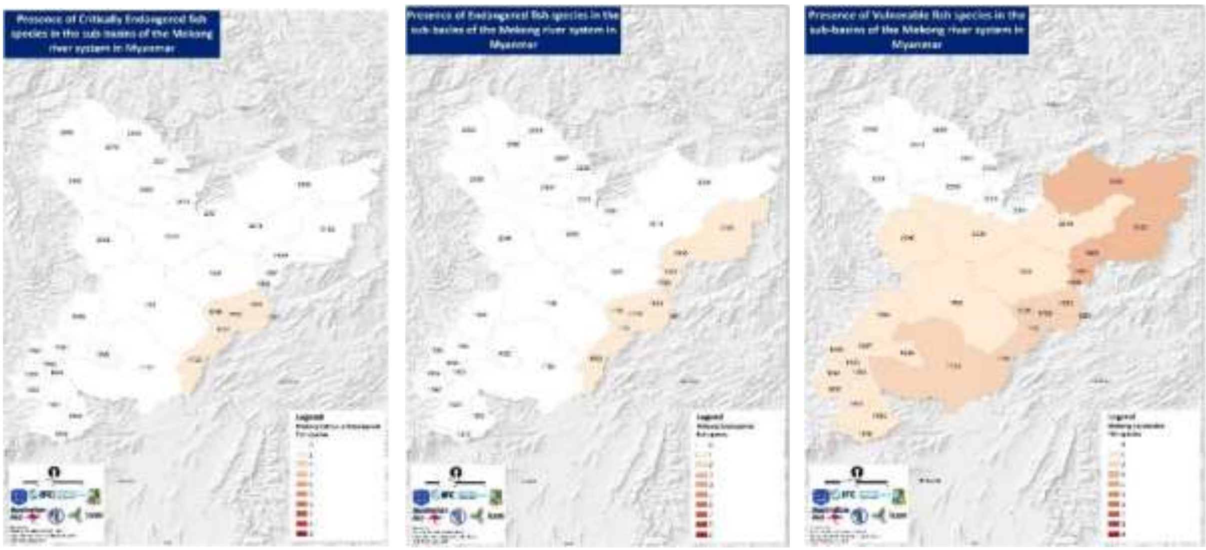
In the 37 sub-basins of the Mekong lying in Myanmar, there are 128 species of fish projected as potentially occurring, including 1 Critically Endangered, 2 Endangered and 4 Vulnerable species. These include the Giant Mekong catfish, as shown below. There are also 5 Near Threatened, 82 Least Concern and 29 Data Deficient species. The distribution of these is shown in Figure 4.13. The Mekong giant catfish range includes the stretch of the Mekong from the Golden Triangle northwards. The two Endangered species occupy similar sub-basins along the Myanmar Mekong and tributaries. The Vulnerable species are more widespread throughout the sub-basins.

Table 4.15: Presence of Critically Endangered, Endangered and Vulnerable fish species in the Mekong sub-basins in Myanmar.

Species	Group	Family	Redlist Status	No. of sub-basins reported
Pangasianodon gigas	Siluriformes	Pangasiidae	CR	6
Luciocyprinus striolatus	Cypriniformes	Cyprinidae	EN	5
Probarbus jullieni	Cypriniformes	Cyprinidae	EN	6
Bangana behri	Cypriniformes	Cyprinidae	VU	11

Cirrhinus microlepis	Cypriniformes	Cyprinidae	VU	6
Garra flavatra	Cypriniformes	Cyprinidae	VU	1
Mystacoleucus lepturus	Cypriniformes	Cyprinidae	VU	28

Figure 4.13: Presence of Critically Endangered, Endangered and Vulnerable species in the Mekong sub-basins in Myanmar



4.15 Migratory Fish

All freshwater and brackish water fish species in Myanmar migrate to some extent. Even the "Blackfish" such as the snakeheads and clariads migrate laterally, often travelling several kilometers to take advantage of freshly inundated floodplain areas and then migrate back to perennial water bodies at the end of the rainy season. Many of Myanmar's riverine fish species will be longitudinal migrants, moving many kilometres upstream to spawn, often but not always in tributaries of the main stem. Of the 450 fish species listed in Fishbase for Myanmar, 56 of them are known long distance migrants and 151 are probable long distance migrants. The shifting salinity profiles in the lower river reaches, influence coastal and estuarine fish migrations considerably.

Then there are the classic long distance migrants; the anadromous *Tenualosa ilish*, that can travel up to 70km a day, and catadromous species such as *Anguilla bengalensis bengalensis*, *Anguilla bicolor bicolor & Macrobrachium rosenbergi*. The abundance of all of these types of aquatic animals depends on the connectivity of the river and floodplain systems, and poorly sited obstructions impact on their life cycles resulting in lost biodiversity and productivity.

The Hilsa, *Tenualosa ilisha* is found in marine, brackish and freshwater environments and is of considerable commercial importance for the Myanmar fishery sector.[18] *Tenualosa ilisha* is distributed along the coasts of the Indian Ocean, from the Arabic peninsula to Thailand and Northern Indonesia. Hilsa schools in coastal waters and ascends rivers for as much as 1200 km.

Hilsa breeds mainly in rivers, although younger fish may breed in the tidal zone of rivers. Baran et al (2015)[19] carried out an extensive survey of Hilsa breeding grounds along the Ayeyarwady River. The survey identified the largest Hilsa breeding site was the river section stretching from Zalun to Monyo, (centred around Hintada town) which is 230 - 310 km from the sea. The study indicated that the Ayeyarwady mainstream was the most important migration route to the upstream breeding sites. However, the important contribution of the Toe River and Twantay Canal should also be noted. It is the convergence of these three migration routes that probably contributes most to breeding and

[18] DoF statistics (2014), list Hilsa exports as 10,910 tonnes, with a value of more than 26m US$.

[19] Eric Baran, Win Ko Ko, Zi Za Wah, Norberto Estepa, Saray Samadee, Xavier Tezzo, Khin Myat Nwe, Edward Maningo. *Distribution, migrations and breeding of Hilsa (Tenualosa ilisha) in the Ayeyarwady system in Myanmar*. WorldFish Myanmar Department of Fisheries, September 2015.

sustainability of the stock.

Survey reports suggest that the catadromous fish species; *Anguilla bengalensis bengalensis*, and *Anguilla bicolor bicolor* are able to migrate from the ocean to the upper reaches of the Ayeyarwaddy in Myanmar, and one specimen of another anguilla species, *Anguilla nebulosi*, is reported from tributaries of the Ayeyarwaddy in China.[20] The authors speculate that this individual specimen had been isolated by the cascade dams and can no longer return to the ocean to complete its life cycle.

4.16 Important areas of aquatic mammals

4.16.1 Irrawaddy Dolphin

As a species, the Irrawaddy Dolphin (*Orcaella brevirostris)* has a fairly wide distribution in both marine and freshwater environments and has been classified as Vulnerable on the IUCN Redlist. Irrawaddy dolphins have a discontinuous distribution in the tropical and subtropical Indo-Pacific, almost exclusively in estuarine and fresh waters. They occur from Borneo and the central islands of the Indonesian Archipelago north to Palawan, Philippines, and west to the Bay of Bengal, including the Gulf of Thailand. There are freshwater subpopulations in three large rivers: Ayeyarwady (up to 1,400 km upstream) in Myanmar, Mahakam (up to 560 km upstream) in Indonesia, and Mekong (up to 690 km upstream) in Viet Nam, Cambodia and Lao PDR, and two marine-appended brackish water bodies or lakes: Chilika in India and Songkhla in Thailand. (Reeves, 2008)

Recent surveys indicate dramatic range declines in the Mekong, Mahakam and Ayeyarwady freshwater subpopulations (IWC 2001, Smith et al. 2007-b). All three of these subpopulations were classified as Critically Endangered in the 2004 Red List because the numbers of reproductively mature individuals were estimated to be < 50 and continuing population declines were projected based on known and potential threats. Two other geographically isolated subpopulations - one living in inner Malampaya Sound, Palawan, Philippines, and the other in Songkhla Lake, Thailand, were classified as Critically Endangered, also in 2004, due to their low numbers and limited ranges.

The first scientific survey of dolphins in Myanmar was conducted in 2002, which found them in a 400 km stretch of river between Bhamo and Mingun. There is now roughly a minimum of 60 dolphins left in the Ayeyarwady River. In December 2005, the Ayeyarwady Dolphin Protected Area (ADPA) was established as the first national aquatic protected area in Myanmar by the Department of Fisheries, with support from WCS, to protect this critically endangered species and a biologically unique human-dolphin cooperative fishery. The ADPA stretches 74 km of river starting from Mingun in the south up to Kyaukmyaung and Singu townships in the north. The protected area was established to reduce threats to dolphins, which include electric fishing, gill nets, pollution, sedimentation of key habitat and breeding areas, and boat traffic. In 2015, the ADPA was selected as one of Myanmar's official strategic ecotourism pilot sites as part of the Myanmar Ecotourism Policy and Management Strategy. Community-based ecotourism in the ADPA is currently being developed to create a link between tourism and conservation and to provide visitors with a quality educational experience focusing on the uniqueness of the human-dolphin cooperative fishing phenomenon, local culture, and other natural attractions including observing migratory water birds.[21]

4.16.2 Otters

The IUCN Redlist distinguishes 4 species of otter native to Myanmar. No distribution of these species in the different river basins has been described.

Aonyx cinereus (Asian Small-clawed Otter)

- Status: Vulnerable A2acde ver 3.1.
- The Asian Small-clawed Otters occur in freshwater and peat swamp forests, rice fields, lakes, streams, reservoirs, canals, mangrove and along the coast, up to 2000 masl.

[20] M.-L. Yang et al. (2016) Fish assemblages and diversity in three tributaries of the Irrawaddy River in China: changes, threats and conservation perspectives Knowledge & Management of Aquatic Ecosystems (2016) 417, 9

[21] https://programs.wcs.org/myanmar/Wildlife/Dolphins

- Pop. trend: decreasing - in Indochina, the range of the species is shrinking, and hunting appears to play a major role in its rapid decline in the eastern end of its global range. Although quantitative data on population sizes or trends are lacking, it is inferred that the global population of the Asian Small-clawed Otter has declined by >30% over the past 30 years.

Lutra lutra (Eurasian Otter)

- Status: Near Threatened ver 3.1.
- The Eurasian Otter has one of the widest distributions of all Palaearctic mammals. Its range covers parts of three continents: Europe, Asia and Africa. Its occurrence has been confirmed from South Korea, southern China, Viet Nam, Cambodia, Lao PDR, Myanmar and Bangladesh. The Eurasian Otter lives in a wide variety of aquatic habitats, including highland and lowland lakes, rivers, streams, marshes, swamp forests and coastal areas independent of their size, origin or latitude. In a study conducted in Thailand in Huai Kha Khaeng where the Eurasian, Smooth-coated and Small-clawed Otters live sympatrically, Kruuk et al. (1994) found that the Eurasian Otters used rapidly flowing upper parts of the river.
- Pop. trend: decreasing.

Lutra sumatrana (Hairy-nosed Otter)[22]

- Status: Endangered A2cde ver 3.1.
- The Hairy-nosed Otter is the rarest and least known among the five species of otters occurring in Asia, occupying low lying peat swamps, flooded forests and coastal wetlands. It is endemic to Southeast Asia and reported to be regionally extinct in Myanmar. However, recently during surveys of the wildlife trade in the town of Mong La, Shan State, Myanmar, three species of otters were observed, including a skin of a hairy-nosed otter. This observation constitutes the first record of Hairynosed Otter in trade in Myanmar.
- Pop. trend: decreasing. Its populations are under rapid decline almost across mainland Southeast Asia, through trade-driven hunting and habitat degradation. It is considered to be Endangered due to past population declines. The species is suspected to have declined by at least 50% or more in the past three generations due to illegal poaching and hunting, pollution, by catch and prey depletion due to over fishing.

Lutrogale perspicillata (Smooth-coated Otter)

- Status: Vulnerable A2cde ver 3.1.
- The Smooth-coated Otter is distributed throughout south Asia and Southeast Asia. It is essentially an otter of lowlands and floodplains. Generally, it uses large rivers and lakes, peat swamp forests, mangroves and estuaries, and it even uses the rice fields for foraging. In Southeast Asia rice fields appear to be one of the most suitable habitats in supporting its viable populations.
- Along the large rivers in India, the Smooth-coated Otters prefer rocky stretches since these stretches provide sites for den and resting. River stretches with bank side vegetation and marshes are used in proportion to their availability especially in summer as they provide ample cover while travelling or foraging. Open clayey and sandy banks are largely avoided as they lack escape covers.
- Pop. trend: decreasing. Major threats to this species are loss of wetland habitats due to construction of large-scale hydroelectric projects, reclamation of wetlands for settlements and agriculture, reduction in prey biomass, poaching and contamination of waterways by pesticides.

4.17 Summary

In the absence of strong data bases to describe the ecological value of the different river systems in Myanmar, the approach has been taken of attributing importance of different aspects to a standard dataset classifying all of the 36 different types of river reach found in Myanmar rivers. River reach

[22] Aadrean, A., Kanchanasaka, B., Heng, S., Reza Lubis, I., de Silva, P. & Olsson, A. 2015. Lutra sumatrana. The IUCN Red List of Threatened Species 2015: e.T12421A21936999. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T12421A21936999.en. Downloaded on 28 May 2017.

rarity according to the total lengths of river reach is taken as an important ecological attribute, as are the areas around confluences and rivers flowing through limestone karst geology. Reaches lying within known areas where endemic fish species are found, including areas such as the Rakhine and Bago Yomas, headwaters of the Ayeyarwady and Chindwin, Indawgyi and Inle Lake areas and in the Tanintharyi coastal rivers. The important river and wetland areas have been noted including those identified from the Key Biodiversity Areas, Ramsar and potential Natural World Heritage Sites and wetlands surveyed during the 2004 Wetland Inventory of Myanmar. The IBAT and IUCN Redlist databases have been used to identify areas important for threatened species of turtles, molluscs, aquatic insects, crustacea and aquatic plants. Similarly, the likely presence of threatened fish species in different sub-basins has been used to identify importance of river reaches using the IBAT and Redlist databases. The importance of migratory fish such as Hilsa, eels, and Tor species are recognized and the mainstem reaches of each river receive recognition of the importance of ecosystem connectivity. Areas where aquatic mammals are found such as the Irrawady Dolphin and otter species have been described. The process provides an identification of the ecological sensitivity of the different river reaches in all the rivers in Myanmar, except for the Rakhine Coastal Basin, where the primary river reach database does not extend. These rivers are described qualitatively.

5 ECOSYSTEM SERVICES

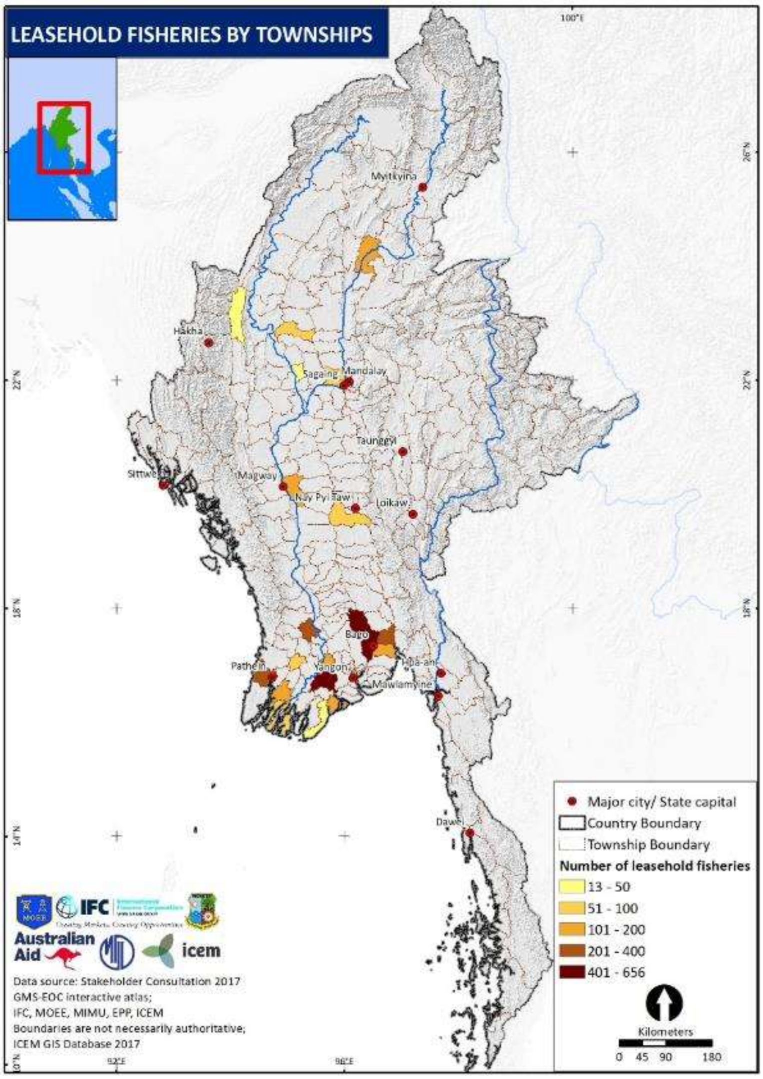
5.1 Provisioning Services - Fisheries

This section of the report provides a short overview of Myanmar's freshwater fisheries and their importance to the Myanmar economy, nutrition and livelihoods. It analyses the importance of the various fish species in terms of supporting rural livelihoods.

5.1.1 Freshwater Fisheries

Myanmar's freshwater capture fisheries are amongst the largest and most productive in Southeast Asia. [i], SEAFDEC 2012[ii] placed Myanmar as the top Southeast Asian producer from inland fisheries, with a production volume almost twice that of the next biggest, Indonesia, demonstrating the exceptional importance of inland fisheries in Myanmar. The inland and inshore capture fish resources are considerable and significant to the national economy, food security and rural livelihoods. Myanmar's freshwater fisheries are mostly rural and artisanal; i.e. "small-scale, multi-species, multi-gears, involving large number of fishers with many part-time fishers, while the major parts of the fishery production are meant for household consumption" (SEAFDEC 2012). Statistics from the Department of Fisheries (DoF) (2014) suggest that over 1,380,000 metric tons of fish were caught from Open and Leasable fisheries, (called '*Inn*') most of which are in freshwater floodplain areas, their productivity depending upon the annual flood and drought cycle.

Figure 5.1: Distribution of Fish Leaseholds in Myanmar



Department of Fisheries data, (compiled with that from other sources) on the numbers and areas of leasehold fisheries can be used to identify those areas that are of most importance for commercial freshwater fisheries. From the data available, there are 3,290 leasehold fisheries in Myanmar, with a total area of around 61,000 ha. The most productive inland fisheries areas are found on the floodplains of Ayeyarwady and Bago. These two regions account for around 80% of the total number and area of leasehold fisheries in Myanmar. Leasehold fisheries are also found in Sagaing, Magway, Mon & Naypyitaw administrative area. Small-scale fishing is practiced over a much wider area, supported by the DoF statistics (2013/14) that suggest open fisheries production is more than 3 times (> 1m tons) that from the leaseable fishery, (300,000 metric tons).

Trends- Significant threats to the sustainability of Myanmar's freshwater fisheries exist. Increasing pressures from land reclamation for agriculture, and water use are having negative impacts on freshwater fisheries and fish production is reported by many fishers to be declining in terms of both quality and quantity, although this is not yet reflected in national statistics. There is evidence of a significant reduction in the catch per fisher (catch per unit effort) and in the abundance of high market value fish species. These declines are thought to be due to several reasons including; short-term concessions that encourage overfishing practices, disregard for Regional and State freshwater fisheries laws; degradation of freshwater habitats, lost connectivity through infrastructure development including irrigation and roads. The widespread use of exotic fish species in aquaculture and their inevitable escape into the wild, also pose a threat to the Country's capture fisheries. Pollution from industry is as yet not significant except for the mining industry that can cause localized but severe degradation of fisheries in many areas.

The Government's response to these declines has been to encourage the establishment of fish conservation areas, the stocking of fingerlings in open water bodies, the piloting of community fisheries co-management and the promotion of commercial aquaculture. The 2008 Constitution allows for the decentralisation of freshwater fisheries governance to individual States and Regions and could offer scope for co-management of fisheries that might result in more equitable sharing or resources amongst local people.

5.1.1 Inshore Fisheries

Statistics from coastal (inshore) fishery areas are combined with marine fishery data, which was estimated to be around 2.7 million tonnes (2014). Myanmar's inshore fisheries support the livelihoods of millions of Myanmar citizens living in the coastal zone. These people are among the most marginalized, poorest and most vulnerable people in Myanmar society. The coastal zone is also home to some of Myanmar's distinct ethnic minorities such as the "Salone" people of Thayintharyi. Coastal fishing families are often asset poor, landless and have limited livelihood alternatives. Lifting the inhabitants of coastal fishing communities out of poverty must be an important part of Myanmar's social and economic development. However, the capacity of inshore fisheries to support fisheries-based livelihoods and make a significant contribution to the local economy is under threat from a number of sources including, reductions in fish stocks, damage to critical habitats, and environmental pollution. Hydropower development that reduces the flow of sediments and nutrients into the coastal waters is likely to further reduce the fisheries productivity of these waters.

Trends- In recent years Myanmar's coastal fisheries have been in rapid decline. The 2013 marine stocks survey by the Fridtjof Nansen - a Norwegian Government research vessel, suggested that Myanmar's marine fish stocks have been depleted by up to 80% since 1979. The coastal areas appear to have been particularly hard hit. The overharvesting of stocks combined with insecure tenure and competition with other users, (including encroachment by domestic and foreign fishing vessels) appears to have seriously degraded the natural resource base. The Government's limited capacity to monitor fishing activities in the inshore areas may also have exacerbated the problem. Like the freshwater fisheries sector, decentralisation of inshore fisheries governance to individual States and Regions offers scope for improved management for the benefit of local people.

5.1.2 Aquaculture

Production from aquaculture in Myanmar is estimated to be around 1 million metric tonnes per year and is seen as having massive potential to raise rural incomes and meet domestic and global demand. The bulk of Myanmar's aquaculture production is from relatively large farms. Myanmar is somewhat unusual in SE Asia as not having a vibrant small-scale aquaculture sector integrated into rural rice farming systems. Where small-scale aquaculture is established it is often to provide inputs, (such as fingerlings) into adjacent commercial operations. There is broad agreement that small-scale aquaculture development could be stimulated by the liberalization of Myanmar's land use policies and laws (particularly Lanna 39) which discourages the adaptation of rice fields for other farming activities such as aquaculture.

Trends- Aquaculture in Myanmar mirrors trends occurring globally in that farmed fish production is growing rapidly against the backdrop of stagnant or declining capture fisheries. The sub-sector has been growing quickly in Myanmar, at a rate of around 8.7%/year since 2004. At present aquaculture is concentrated geographically, with 90% of inland fish ponds located in the Ayeyarwady Delta, west of Yangon. A single species (rohu), accounts for around 70% of the fish produced in Myanmar. Shrimp, a high value crop grown mainly for export, contributes just 5.6% of production.

5.1.3 Fish for nutrition

Using data from the 2014 population census[23] and studies of fish consumption[24] (2006) and household expenditure on fish products,[25] it can be estimated that the people of Myanmar consume around 1,100,000 tons of fish and fisheries products annually. Per capita fish consumption rates appear to vary widely across the country, from 31.9 kg per person per year in Tanintharyi Region to 7.2 kg per person per year in Chin State. Average national fish consumption level is thought to be between 21.4 - 28.2 kg/person/year, representing 22.6% of total protein consumed nationally. Of this around 31.5% of the fish consumed are from freshwater sources. Processed freshwater, (dried, fermented etc.) fish are also important nutritionally for fish deficit areas and during off-seasons. Urban and rural total fish consumption levels are broadly similar, although urban dwellers tend to eat more fresh fish (53%) than do rural dwellers (45%).

Trends- Detailed fish consumption studies are needed to understand regional and national trends but it may well be that per capita fish consumption is on the rise. Fish consumption in urban areas is becoming increasingly dependent on fish from aquaculture. In many rural areas, people continue to rely on wild fish caught from the countries extensive and diverse, freshwater, brackish and marine fisheries. Declines in these capture fisheries are likely to have negative impacts on nutrition in remote areas, although farmed fish can be found in most town markets throughout the country.

5.1.4 Fisheries Livelihoods

Statistics on fisheries livelihoods are difficult to obtain and gender-disaggregated data does not generally exist. As a result, the fisheries sector has a relatively low priority amongst policy makers and development planners. Officially, (DoF 2014 statistics) 3,196,284 people or 6.43% of the population are involved in the fisheries sector in Myanmar, either on a full time, part time or occasional basis.[26] This is likely to be an under-estimate as it may not include the many unregistered fishers and other fish market chain actors. LIFT Baseline data (2012) from 4,000 households, (disaggregated by hilly, dry and Delta/coastal regions) suggest that this figure would be around 6.5m (12.2% of the total population). The number of people benefitting from fisheries livelihoods varies in different parts of the country, with some of the highest levels being found in Ayeyarwaddy, Tanintharyi and Rakhine, where many households are landless, a high percentage of these people are involved in fishing. The LIFT 2012 data found that 41% of casual labourers are involved in fishing in the Delta/Coastal regions. The data also shows that 18% of these casual labour households listed fishing as their primary source of income. The remaining 22% of casual labour households would be alternating fishing and other labour opportunities,

[23] UNFPA Population Census report 2015
[24] FAO study 2006
[25] 2015 CSO data
[26] Department of Fisheries Statistics 2014-2015

(farming, construction and fishing) in the area. The creation of new water bodies in the existing network of hydropower and irrigation dams have the potential to offer livelihood opportunities for people, such as subsistence fishing, stock enhancement and cage aquaculture. However current national policies do not allow for reservoirs to be fully utilized for fisheries purposes.

Trends- The lack of reliable data makes trend analysis impossible. In the past, small-scale fishing has acted as a livelihood of last resort, attracting new entrants who have lost other livelihood opportunities, as was the case with many Delta farmers following Cyclone Nargis in 2008. On the other hands, Myanmar's accelerating development is creating new employment opportunities, particularly in the larger cities. Similar trends in neighboring countries have seen large-scale migration of young people to the cities, leaving fishing and farming to the old and very young.

5.1.5 Gender issues in Fisheries

Gender disaggregated data on fisheries in Myanmar are scant. However, FAO[20] found that whilst fishing and aquaculture are male dominated activities, women also play significant roles. In Myanmar, some small-scale fishers around Inle Lake, for example, are women. Men are traditionally involved in fishing and wholesale trading while women are engaged in net repair, processing, and vending in local retail markets.

Trends- The important role that women play in the fisheries sector in Myanmar is slowly becoming more widely understood. Government institutions including the Department of Fisheries and universities now regularly hire women fisheries sector professionals, roles that in the past were dominated by men.

5.1.6 Fish utilization

Using the IBAT and IUCN Redlist databases, analysis has been done on the utilization of the various fish species at each site. Fish utilization trends appear to be quite consistent across the various rivers and river reaches. The example below is from site 7 (EUR60181) in the middle mainstem Ayeyarwaddy is typical. 75 % of the fish species identified can be used for either commercial or subsistence fishing.[27] Only 14% of species are classified as unutilized. In Figure 5.2, 11% of fish species have the potential to be utilized as ornamental fish. However, this opportunity is probably not yet being taken up in the vast majority of fisheries in Myanmar.

Figure 5.2: Utilization of fish species from middle mainstem Ayeyarwaddy, (Site 7 EUR60181).

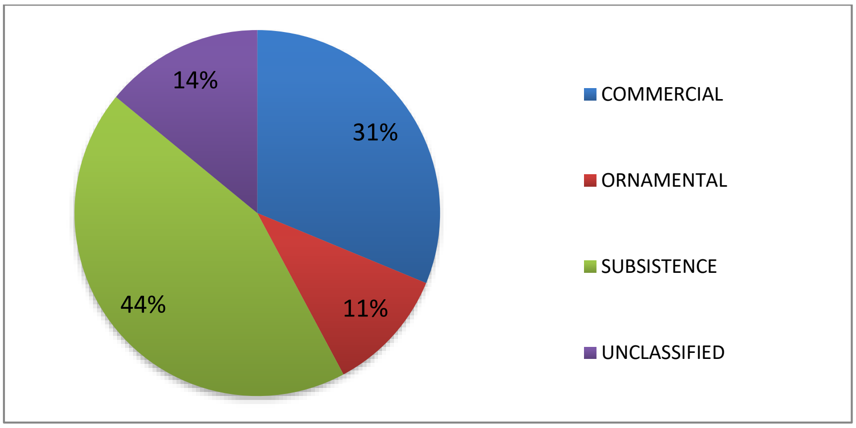


Table 5.1 below summarizes fish utilization in support of livelihoods in each of the rivers and areas analyzed. This analysis highlights the importance of freshwater and estuarine fish species for people's livelihoods, for either commercial or subsistence fishing in all areas. Table 5.1 is a summary taken from the table in Appendix 4. The river with the fewest percentage of commercial species is the Sittaung, which from the sites analyzed so far indicates that 14-20% of the fish species can be classified as commercial. Rakhine has the highest percentage of commercial fish species (42-49%) but this reflects

[27] Commercial species are considered to be those species that are commonly found in local town markets following their handling through a value chain. Subsistence fish species are taken to be those fish species caught using small-scale fishing gears and eaten by people living close to the fishery with small surpluses being found in local markets.

lower overall biodiversity and the influence of more coastal commercial fish species. The importance of all rivers and catchments for subsistence fishing is clear from Table 5.1. The site with the lowest number of fish species (15%) used for subsistence purposes was on the Thanlwin. However the next lowest site was on the Sittaung and Tanintharyi with 39%. All rivers had sites with at least 43% of the fish species being used for subsistence purposes.

Table 5.1: Summary of fish utilization in Myanmar rivers

River	% of commercial fish species	% of subsistence fish species	% fish species with ornamental potential	% of fish species unutilized
Ayeyarwaddy	23-39	35-49	6-14	18-21
Chindwin	24-29	43-46	9-12	17-19
Sittaung	14-20	39-46	7-11	18-25
Thanlwin	19-50	15-50	4-14	10-31
Tanintharyi	22-29	39-43	14-22	13-17
Rakhine	42-49	42-49	8-33	11-14

Fish species with the potential to support the ornamental fish industry were found at all locations, usually around 10% of fish species, although Tanintharyi sites appear to have higher potential. These ornamental fish represent an untapped potential and could support small-scale livelihoods in rural areas once Myanmar's 'aquatics industry' develops, as it has done in most neighbouring countries. It should also be noted that some of these fish species with ornamental potential had near threatened IUCN red list status. At most sites between 12-25% of species did not appear to have any direct utilization in terms of supporting livelihoods. These were usually very small species. Field verification of these species would likely show some of them utilized for subsistence or as feed for ducks or pigs.

5.1.7 Other provisioning services

Natural resources of the river and wetlands are also used as important food and livelihood sources such as the other aquatic organisms - molluscs, shrimps and crabs, and aquatic plants. Turtles are considered a delicacy and form an important component of the wildlife trade to such an extent that WCS have established a Turtle Rescue Facility in December 2012 on the Mandalay-Lashio Highway, a major conduit for illegally harvested turtles moving into China. Other provisioning services include timber and textiles from riparian vegetation.

5.2 Regulating Services

The regulating services of the river system include the hydrological and sediment transport services which are dealt with largely in the baseline section on geomorphology.

- Hydrological services include groundwater recharge and storage of water and its slow release though into the dry season. The importance of groundwater is appreciated during drought periods. The artificial storage of water in dams for irrigation is an example of the hydrological services provided by the rivers where impoundment has created reservoirs for irrigation. There are some 187 irrigation reservoirs that have been built on many of the rivers throughout Myanmar, especially around the Dry Zone in the tributaries of the Ayeyarwady and the Sittaung (Figure 6.7). Using analysis based on the Global Surface Water database,[28] it has been estimated that these cover a total area of 105,500 ha, with an average size of 564 ha, ranging from some very small reservoirs of a few hectares up to nearly 8,000 ha. The very large irrigation reservoir at Thapanzeik, which is 39,370 ha, also has a hydropower scheme associated with it. By the end of the dry season most of these reservoirs are drawn down with water surface area showing about 50% of the permanent water cover.
- Flood alleviation services are provided by rivers like the Chindwin and Ayeyarwady which have very large flood plains. These rivers create meanders through the floodplain which slow the rate of flow down, and allowing high volumes of water to be stored temporarily in the floodplains and reducing the risks of much higher floods further downstream and in the Delta. The high

[28]https://global-surface-water.appspot.com/

productivity of these seasonally wetted flood plains contributes to the provisioning services mentioned above.

- Sediment transport is the other component of flows down the river. As described in the geomorphology baseline report, all the major rivers have high sediment transport, especially visible in the Chindwin and Ayeyarwady, but also significant in the Thanlwin. The Delta of the Ayeyarwady and the Gulf of Mottama from the Sittaung are the recipients of the high quantities of sediment transported by these rivers, forming ecologically and economically productive areas. The sediments from the Thanlwin are swept into deeper waters by the currents and no significant delta is formed.
- Sand and gravel are extracted from the rivers, throughout their lengths, providing important sources of building materials in all parts of the country. Over-extraction of sand and gravel may be occurring in some parts, with remobilization of sediments and subsequent bed and bank erosion.
- Water quality is deteriorating in some reaches of the rivers, especially near centres of population, industry and from increasingly intensive agriculture. However, all rivers perform a critical ecosystem service, in breaking down organic pollutants, re-oxygenating the water, and taking some toxic materials out of solution and storing them as inert compounds in the sediments. Solid wastes are carried downstream and out to sea and may also be broken down, but plastics form an increasingly difficult problem throughout the rivers and coasts.

5.3 Supporting Services

- **Nutrient transport -** nutrients such as nitrates and phosphates are carried on the very small sediment particles. Their deposition in the flood plains and deltas contribute to the general productivity of such areas, as they do in suspension in the coastal areas. The high productivity of Myanmar's coastal fisheries is largely due to the nutrients carried down the rivers.
- **Biodiversity support** - the very high aquatic biodiversity is supported by the very diverse ecosystems and habitats to be found throughout Myanmar's rivers and wetlands. According to the river reach analysis described earlier there are about 36 different river reach types, which may allow the development of the diversity of fish and other aquatic organisms. The variety of habitats from the high elevation, high gradient reaches where many of the endemic species are found, to the detailed habitat features found in all the rivers - rapids and waterfalls, riffles and pools and in channel wetland areas, all contribute to the diversity of species found in Myanmar. The high proportion of rivers flowing though karst landscapes and underground rivers are also indicative of high speciation and diversity.
- **River connectivity -** all Myanmar's rivers are major fish migration routes, some species of fish travelling from the ocean to the highest reaches, several thousand kilometres upstream, e.g. mature Hilsa to spawn and young Anguilla to grow and reach maturity. Shorter and localized migrations are also an important feature of Myanmar rivers, with other fish species moving from the mainstems into the tributaries and smaller seasonal streams to spawn, or into the floodplain wetlands and rice fields to spawn and grow, before moving back to dry season refuges. The mainstems of all the rivers are important routes for fish migration.

5.4 Cultural Services

- **Cultural importance -** Myanmar's rivers have tremendous cultural importance both nationally and locally, and many of the major towns have developed in association with the rivers as major "highways". Many temples are located on the banks of rivers and festivals are celebrated around the rivers and seasons. Major confluences often have special cultural significance, e.g. Myitsone for the people of Kachin State. Local features such as lakes, rapids, deep pools and waterfalls may have significance for local people, and cultural diversity and fishing practices have developed around areas such as Inle Lake. The association between fishermen and the Ayeyarwady Dolphin in the reaches upstream of Mandalay is another example of rare cultural practices associated with the river.

- **Navigation -** the Ayeyarwady River is a major navigation route between the ocean and reaches up to Mandalay and beyond. The river provides for reasonably safe passage for large cargo ships and barges throughout the year, though the high volumes of sediment transported and changing channel alignments can cause bottlenecks. Local boat transportation between villages and local markets, and across the river is also very important, especially in the wet season, when road transport through the floodplains is difficult.
- **Tourism -** River tourism has long been an important feature of the Ayeyarwady, with tourist routes combining the land based attractions in Mandalay and Bagan and Yangon. Recreational areas on beaches along some of the tributaries, e.g. on the Myitinge and on the Mekong are also developing.

5.5 Summary

The ecosystem services provided by Myanmar's rivers have been described qualitatively. In particular, detail has been provided on the fisheries provisioning services, which is one of the most important ecosystem services provided by the rivers. Information is provided on the freshwater and inshore fisheries and aquaculture and their contributions to livelihoods and nutrition of people living along the rivers. The distribution of the leasehold areas for commercial fishing by township is provided. Note is taken of the increasing recognition of the role of women in the fisheries sector. An analysis of the distribution of fish species which have different utilization is provided - commercial uses, subsistence and their potential as ornamental species. Other provisioning services include timber and textile materials from riparian vegetation, and the use of molluscs, crustacea and turtle species for food.

Regulating services include hydrological services such as the seasonal flows patterns, groundwater recharge, flood alleviation in the floodplains, sediment transport and sand and gravel extraction, and maintenance of water quality. Supporting services include nutrient transport from the upper reaches to the floodplains and delta, biodiversity support providing ecosystems and habitats for the different lifecycles of fish and other aquatic organisms, and the river connectivity, which is so important for migratory species. Cultural services include the cultural importance of the rivers of Myanmar to its peoples, and of specific features such as confluences e.g. at Myitsone, deep pools, rapids and water falls. Cultural services include navigation and tourism, especially on the Ayeyarwady.

Box - Inle Lake

Inle Lake is the second largest freshwater lake in Myanmar (116.3 km²) after Indawgyi Lake. Scientists have estimated its age as between 1.6 - 65 million years, making it one of the world's oldest surviving lakes. Inle Lake Wetland Sanctuary is a wildlife reserve located around the lake and occupies an area of 1,660 km2. It was established in 1985 and designated as an ASEAN Heritage Parks in 2003. The Lake also forms part of the 1,891 square miles Inle Lake Biosphere Reserve that covers an area of 489,721 hectares.

The UNESCO website states that the wetland ecosystem of this freshwater lake is home to 267 species of birds, (of which 82 are wetland birds), 43 species of freshwater fishes, otters and turtles. Diverse flora and fauna species are recorded and the Lake area is reported to be the nesting place for the globally endangered Sarus crane (Grus antigone). Inlay Lake has at least 9 endemic fish species including the Inle swamp eel (Chaudhuria caudata), the Inle barb (Sawbwa resplendens) and the famous Inle Carp (Cyprinus intha). In recent years, a number of exotic fish species, including Oreochromis nilotica have found their way into the Lake and look to be displacing some of the native fish species. The proportion of Tilapia in fishermen's catches has increased at an alarming rate and now makes up at least two thirds of the total fish catch. It is understood that the African catfish (Clarias gariepinus, (or hybrids with native Clariad species) may also have been introduced or escaped into the lake in numbers.

In addition to its ecological importance, Inle Lake is also unique for the way the local inhabitants have adapted their lifestyle to the environment. Farmers from one of the dominant ethnic groups in the region, the Intha, practice floating island agriculture, locally called 'Yechan". Inle Lake and its watershed provides several ecosystem services on which local people depend, including clean air, clean water, a cooler climate, fish stocks and other resources. Local people are becoming concerned about the health of the Lake. The lake water can no longer be used for drinking water due to pollution; the lake is silting up through abandoned floating gardens, and waste,

Fishers describe the steady decline of the Inle Lake fishery. Thirty years ago, one day's fishing would yield around 100 viss, (163 kg) of fish, with Inle Carp of up to 4 viss (6.52 kg) in size. Around 12 years ago tilapia began to appear in fish catches in numbers, and is now the main species caught. Typical daily catches are only 4-5 viss, (6.52 - 8.15kg). Oreochromis nilotica appears to have established a viable feral population and has even been observed in the clear water streams feeding into the northern end of the lake. This fish appears to be particularly well suited to the shallow eutrophic conditions now existing in the Lake.

6 TREND ANALYSIS OF RIVER HEALTH

Myanmar's rivers are under increasing pressure from human activities and development, and there is a generally considered view that their condition and state of health is declining. The trends in the state of health of the rivers in Myanmar is difficult to describe in any quantitative terms, and there are no consistent or comprehensive analyses of water quality or surveys of river condition with which to describe these trends, apart from a concern, expressed by both local villagers and government officials, that the state of health of the rivers is deteriorating.

An approach therefore has been developed for this SEA to describe the different human pressures upon the river systems and to provide a consolidated map that shows the river reaches that are most affected by the main human pressures. These include:

- **Urban development** reflecting the increase in human populations and the discharge of waste waters, solid wastes, industrial waste waters and urban run-off;
- **Rural populations** using the river and its natural resources - the higher the rural population density, the greater the pressures on these natural resources and the quality of the river reaches;
- **Deforestation** reflecting the progressive loss of tree cover in the catchments and riparian vegetation with subsequent soil erosion and loss of bank stability;
- **Mining activities** reflecting the increase in mineral extraction for gold, copper, precious stones, jade etc., especially when these occur within the rivers releasing sediments and the use of toxic materials for purification of the ores, e.g. use of mercury for gold;
- **Intensity of agriculture** reflecting the increasing use of land for two and three crops per year with increased use of agricultural chemicals such as fertilizers which add to the nutrient load in the rivers and herbicides and pesticides which increase the toxic load on the rivers;
- **Irrigation reservoirs** reflecting the increased use of water for irrigation, especially in the dry season, and subsequent reduction in both wet season and dry season flows down the river;
- **Existing hydropower projects** reflecting the barrier effect for migration of fish upstream and downstream and the changing flow patterns, reducing wet season and peak flows, and tending to increase dry season flows.

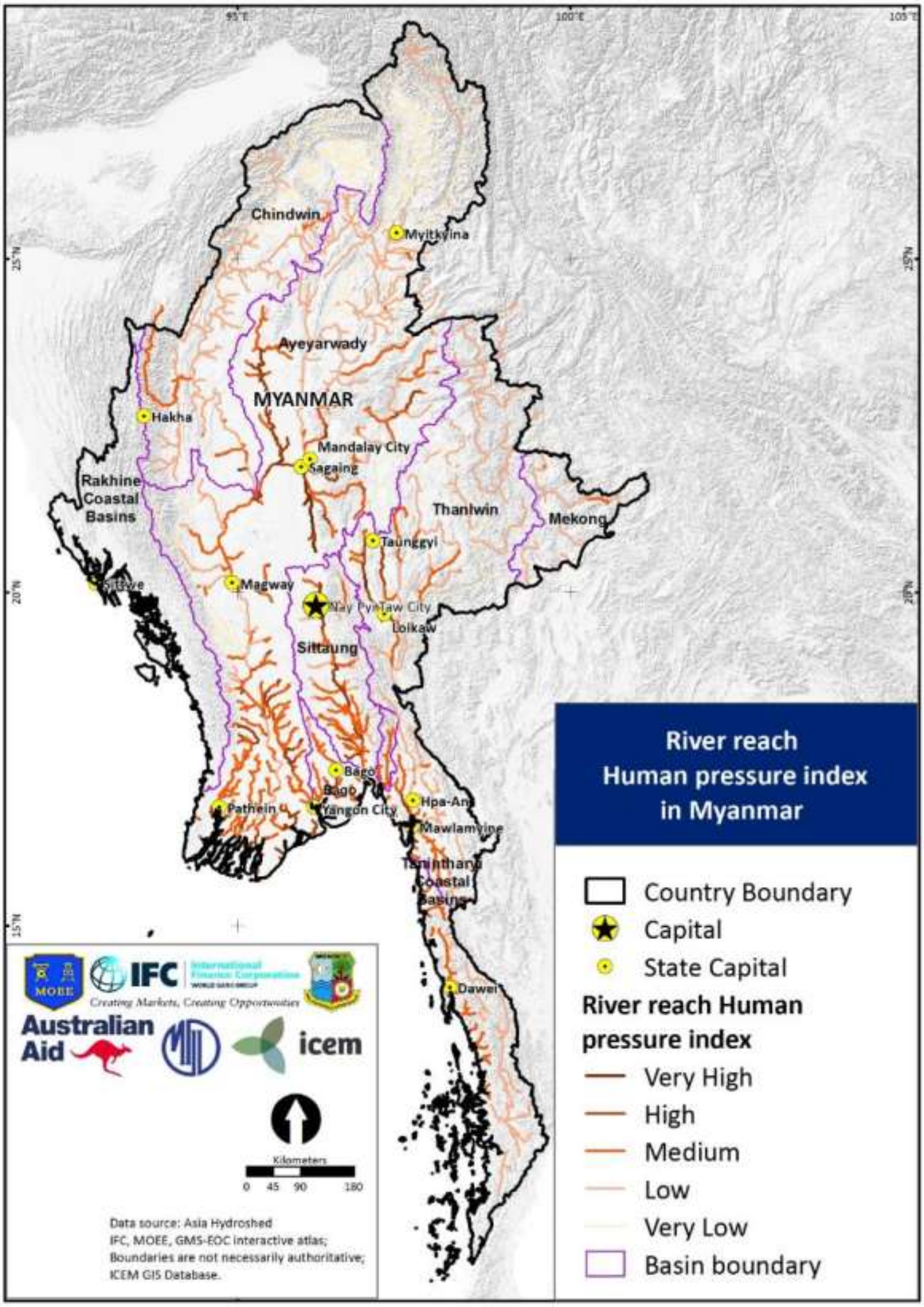
No attempt is made to provide a historical trend of how these pressures have developed, but a system of scoring the current level of these pressures has been provided. The pressures listed above can be mapped individually and their contribution to the combined index of pressure upon the river ecosystems scored. The scoring components are described in the following sections; basically, each river reach is accorded a negative score depending upon the intensity of the pressure. The process is described in Annex 1.

The scores for the eight parameters - urban wastes and run-off; rural population density; loss of forest cover; intensity of agriculture; density of road infrastructure; mining pressure, irrigation dams and reservoirs, and hydropower dams and reservoirs, are combined in Figure 6.1 with the pressure recorded in strengths from Very High, High, Medium and Low. Subsequent sections in this chapter describe these pressures and the trends in these human pressures are described in the Economics baseline report.

There is a clear hotspot of very high pressures on the Ayeyarwady downstream from Mandalay - largely caused by the influence of the urban population. There is also a hot spot in the Mu River flowing south to its confluence with the Ayeyarwady between Sagaing town and the confluence with the Chindwin. This is probably due to intensity of agriculture and irrigation in this sub-basin, which carries the large Thapanzeik reservoir. The Myitinge River near its confluence with the mainstem is also indicated as a hotspot, largely because of pressure from Yewa and Zawgyi dams. The Ayeyarwady delta area reaches also show high pressure, largely due to the intensity of agriculture.

On the Chindwin River, the pressures are relatively low except for the Uyu tributary high pressures due to the intensity of mining pressures. The Manipur River has medium pressure coming from India and due to construction of a dam in the lower reaches.

Figure 6.1: Human pressure index for river basins in Myanmar



On the Thanlwin, the Baluchaung River and Inle Lake valley is highlighted with high human pressure, due to a combination of the irrigation reservoirs and hydropower dams - the Baluchaung cascade has effectively isolated the sub-basin ecologically from the Thanlwin mainstem. Most of the mainstem Thanlwin currently shows low to medium pressures.

The Mekong catchment shows relatively low to medium pressures, especially along the Mekong itself, though there are pressures near the hydropower construction site on the Nam Lwe.

The Sittaung generally shows medium to high pressure due to the presence of irrigation and hydropower projects on its tributaries and the intensity of agriculture in the valley and in the lower reaches.

In the Tanintharyi coastal region, the coastal reaches of the rivers have higher pressure upon them due to the higher rural populations, road infrastructure and agriculture. The upland river reaches in this region have less pressure.

While a similar assessment has not been possible for the Rakhine coastal region, since the river reach data set is not available, the pattern of pressures will be very similar to the Tanintharyi coastal region, with less pressure on the shorter upland river reaches, and higher pressures from rural populations, road density and coastal agriculture. The Kaladan River coming in from India is likely to have similar pressures as the Manipur River.

6.1 Urban development

This indicator of pressure assumes declining water quality downstream from major urban areas from domestic waste waters, industrial waste waters and solid wastes. For the purposes of this assessment the areas of influence of urban areas are assumed to extend downstream proportionally to population size and river flow, as shown in Table 6.1. A larger river has a greater carrying capacity to absorb and deal with wastes from larger urban areas than a smaller river.

Table 6.1: Lengths of river downstream influenced by urban areas

Urban population	River size	Flow range	Length of downstream influence	Score
> 1 million people	Mainstem river	> 1,000 cumecs	50 km	-5
> 1 million people	Large river	100 - 1,000 cumecs	75 km	-5
> 1 million people	Medium river	10 - 100 cumecs	100 km	-5
100,000 - 1 million people	Mainstem river	> 1,000 cumecs	25 km	-4
100,000 - 1 million people	Large river	100 - 1,000 cumecs	50 km	-4
100,000 - 1 million people	Medium river	10 - 100 cumecs	100 km	-4
100,000 - 1 million people	Small river	1 - 10 cumecs	125 km	-4
10,000 - 100,000 people	Mainstem river	> 1,000 cumecs	10 km	-3
10,000 - 100,000 people	Large river	100 - 1,000 cumecs	25 km	-3
10,000 - 100,000 people	Medium river	10 - 100 cumecs	50 km	-3
10,000 - 100,000 people	Small river	1 - 10 cumecs	100 km	-3

Source: As proposed by WLE Healthy Rivers Project (ICEM/IWMI)

The urban centres used in this assessment are listed in Table 6.2 and shown in Figure 6.2.

Table 6.2: Urban centres and populations in Myanmar

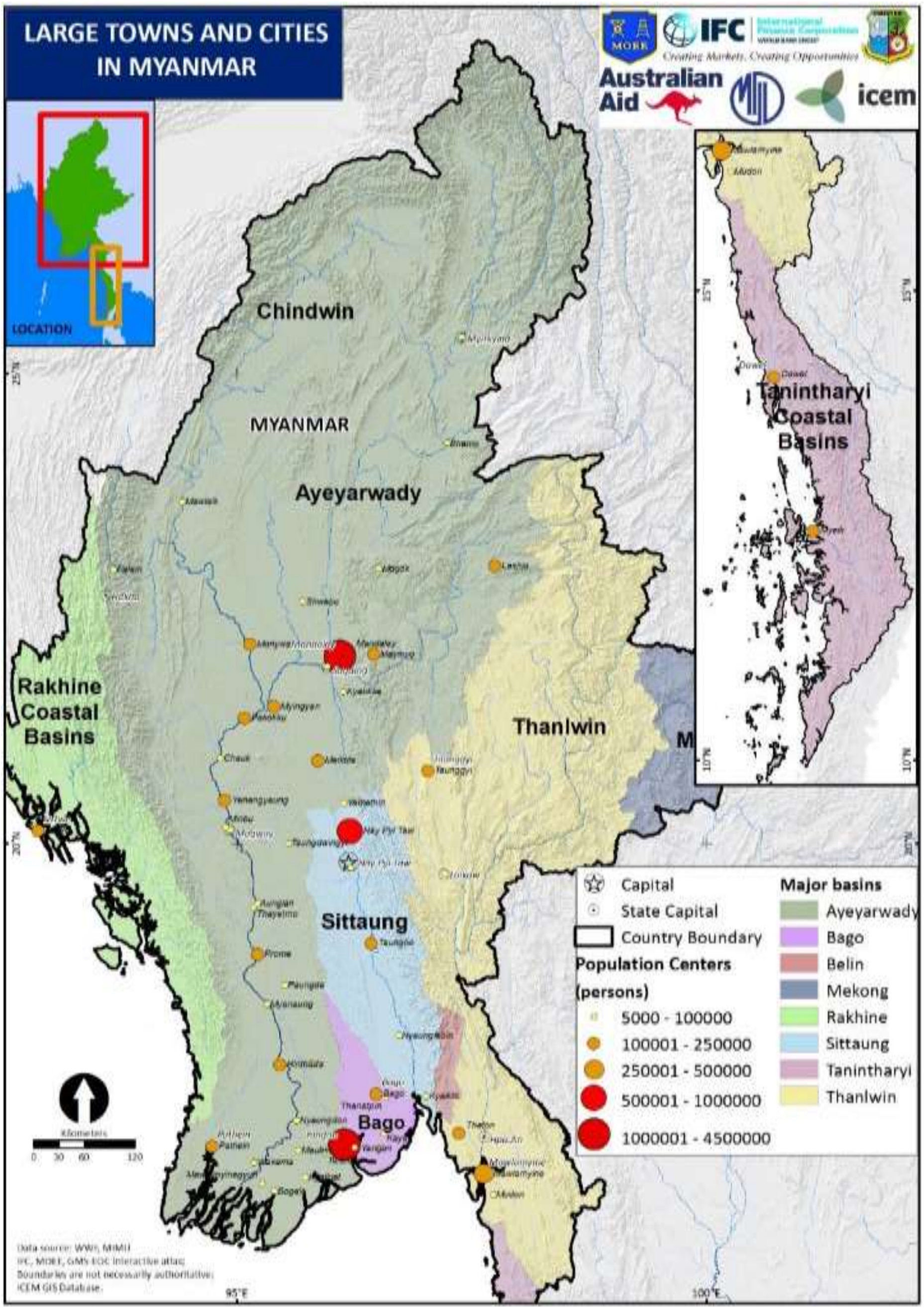
Rank	City	Population	Size	Catchment
1	Yangon	4,477,638	> 1 million people	Myit Ma Hka & Bago
2	Mandalay	1,208,099		Ayeyarwady
3	Nay Pyi Taw	925,000		Sittaung
4	Mawlamyine	438,861	200,000 - 1 million people	Tanintharyi
5	Bago	244,376		Myit Ma Hka & Bago
6	Pathein	237,089		Ayeyarwady
7	Monywa	182,011	150,000 - 200,000 people	Chindwin

Rank	City	Population	Size	Catchment
8	Sittwe	177,743		Rakhine
9	Meiktila	177,442		Ayeyarwady
10	Myeik	173,298		Tanintharyi
11	Taunggyi	160,115		Thanlwin
12	Myingyan	141,713		Ayeyarwady
13	Dawei	136,783		Tanintharyi
14	Prome	135,308		Ayeyarwady
15	Hinthada	134,947		Ayeyarwady
16	Lashio	131,016	100,000 – 150,000 people	Ayeyarwady
17	Pakokku	126,938		Ayeyarwady
18	Thaton	123,727		Sittaung
19	Maymyo	117,303		Ayeyarwady
20	Yenangyaung	110,553		Ayeyarwady
21	Taungoo	106,945		Sittaung
22	Thayetmo	98,185		Ayeyarwady
23	Pyinmana	97,409		Sittaung
24	Magway	96,954		Ayeyarwady
25	Myitkyinā	90,894		Ayeyarwady
26	Chauk	90,870		Ayeyarwady
27	Mogok	90,843		Ayeyarwady
28	Nyaunglebin	89,626		Sittaung
29	Mudon	89,123	50,000 - 100,000 people	Tanintharyi
30	Shwebo	88,914		Ayeyarwady
31	Sagaing	78,739		Ayeyarwady
32	Taungdwingyi	70,094		Ayeyarwady
33	Thanlyin	69,448		Sittaung
34	Bogale	68,938		Ayeyarwady
35	Pyapon	65,601		Ayeyarwady
36	Yamethin	59,867		Ayeyarwady

Rank	City	Population	Size	Catchment
37	Kanbe	58,146		Ayeyarwady
38	Aunglan	57,897		Ayeyarwady
39	Minbu	57,342		Ayeyarwady
40	Thayarwady	54,386		Ayeyarwady
41	Thongwa	52,496		Sittaung
42	Kyaiklat	52,425		Ayeyarwady
43	Maubin	51,542		Ayeyarwady
44	Kyaukse	50,480		Ayeyarwady
45	Kyaikto	48,658		Sittaung
46	Martaban	48,629		Sittaung
47	Kyaikkami	48,100		Ayeyarwady
48	Bhamo	47,920		Ayeyarwady
49	Twantay	46,516		Myit Ma Hka & Bago
50	Mawlaik	44,540		Chindwin
51	Wakema	42,705		Ayeyarwady
52	Myanaung	42,252		Ayeyarwady
53	Pyu	40,386	10,000 - 50,000 people	Sittaung
54	Kayan	40,322		Myit Ma Hka & Bago
55	Nyaungdon	40,092		Ayeyarwady
56	Mawlamyinegyun	39,115		Ayeyarwady
57	Thanatpin	39,000		Sittaung
58	Letpandan	38,936		Sittaung
59	Thanatpin	38,059		Sittaung
60	Paungde	36,971		Ayeyarwady
61	Loikaw	17,293		Thanlwin
62	Falam	5,404	> 10,000 people	Chindwin

Source: (ADB, 2013)*and Ministry of Immigration and Manpower. 2011.*

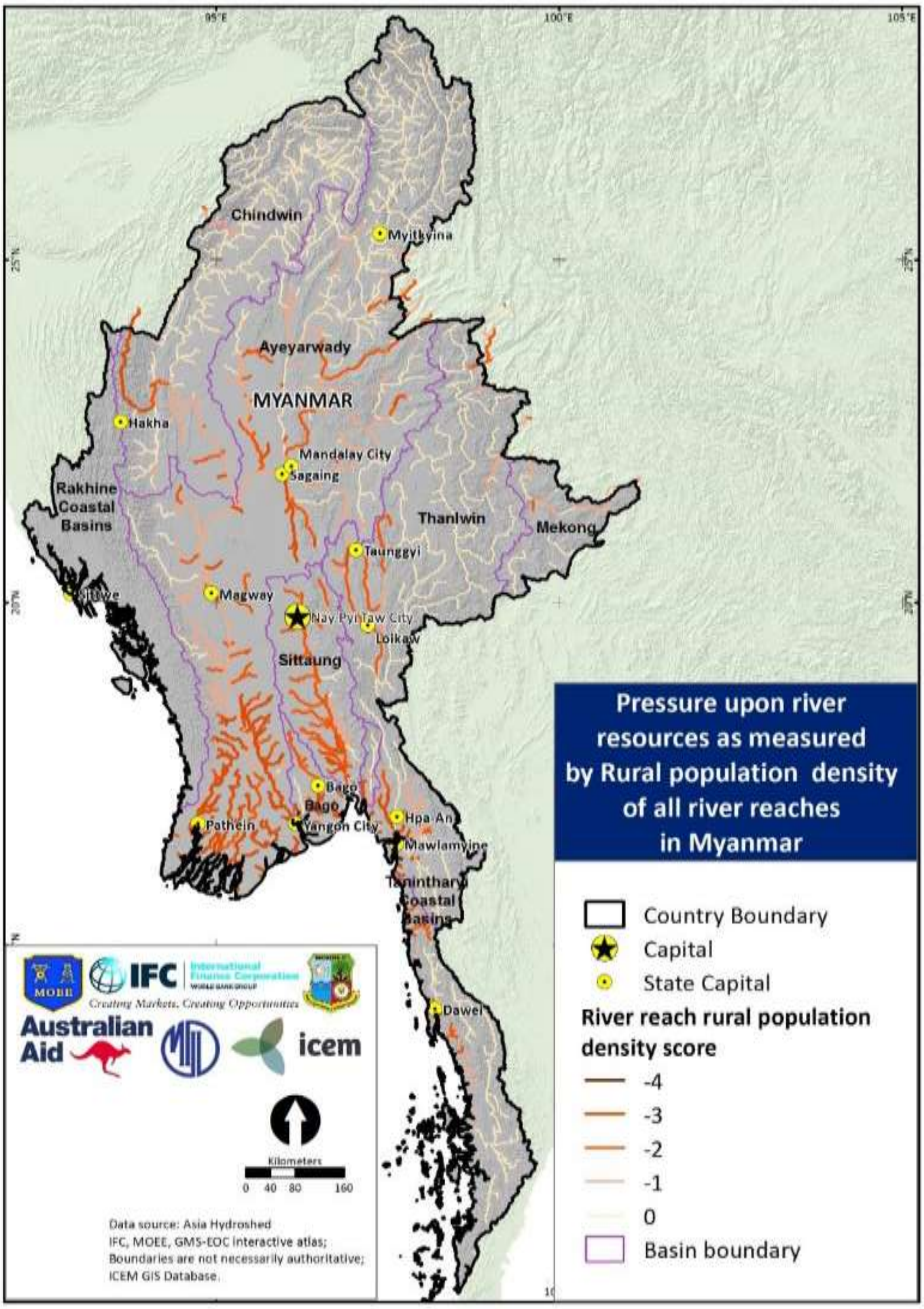
Figure 6.2: Large towns and cities in Myanmar



6.2 Rural population density

Rural population density is used as an indicator of the pressure upon natural river systems, for example as measure of the capture fishery and use of other natural resources. The data is taken from the WWF River reach classification and measures the population density upstream of any given river reach. It can be seen that the lowest densities and hence fishing pressure occurs in the upper reaches of the Ayeyarwady, Chindwin and in the Tanintharyi coastal region. Higher pressures from the rural populations occur along most of the Ayeyarwady below Mandalay, especially into the Delta, and in the Sittaung. Note that the Rakhine coastal region is not included in this analysis, because the data set is not available.

Figure 6.3: Pressure upon river resources as measured by Rural population density of all river reaches in Myanmar



6.3 Deforestation and loss of forest cover

Deforestation can be used as an indicator of pressure upon natural aquatic ecosystems, even if the loss of forest cover has occurred many years ago. The database used here comes from the WWF River reach classification database described in Section 2, which provides data for each river reach of the percentage of the upstream watershed covered with forest (based on GLC2000). Upstream watersheds are graded according to forest loss, and each river reach receives a pressure score as follows:

% forest loss	Pressure score
0 - 20%	-1
20 - 40%	-2
40 - 100%	-3

Trend - Over the past decade the rate of deforestation and change in land use from forest has been increasing throughout the country as described clearly in the biodiversity baseline report. The pressure of loss of forest cover will have intensified since that used for this assessment.

6.4 Intensity of agriculture

Agriculture imposes pressures upon aquatic ecosystems from abstraction of water for irrigation, allowing an increase in intensity of cultivation with two and even three crops per year. Increased intensity also brings increase in run-off with agricultural chemicals. An assessment of this pressure uses a method developed by the WLE Myanmar Healthy Rivers program (in preparation). In this method, all of the river reaches in the HydroBasins Level 6 database shown are considered to be affected by the intensity of the agriculture there.

An index for the intensity of the agriculture is calculated by multiplying the percentage of the cropping area in each HydroBasin, by the intensity of cropping (e.g. % multiple crop) x 1,000. The Landcover database has areas for the following types of cropping area:

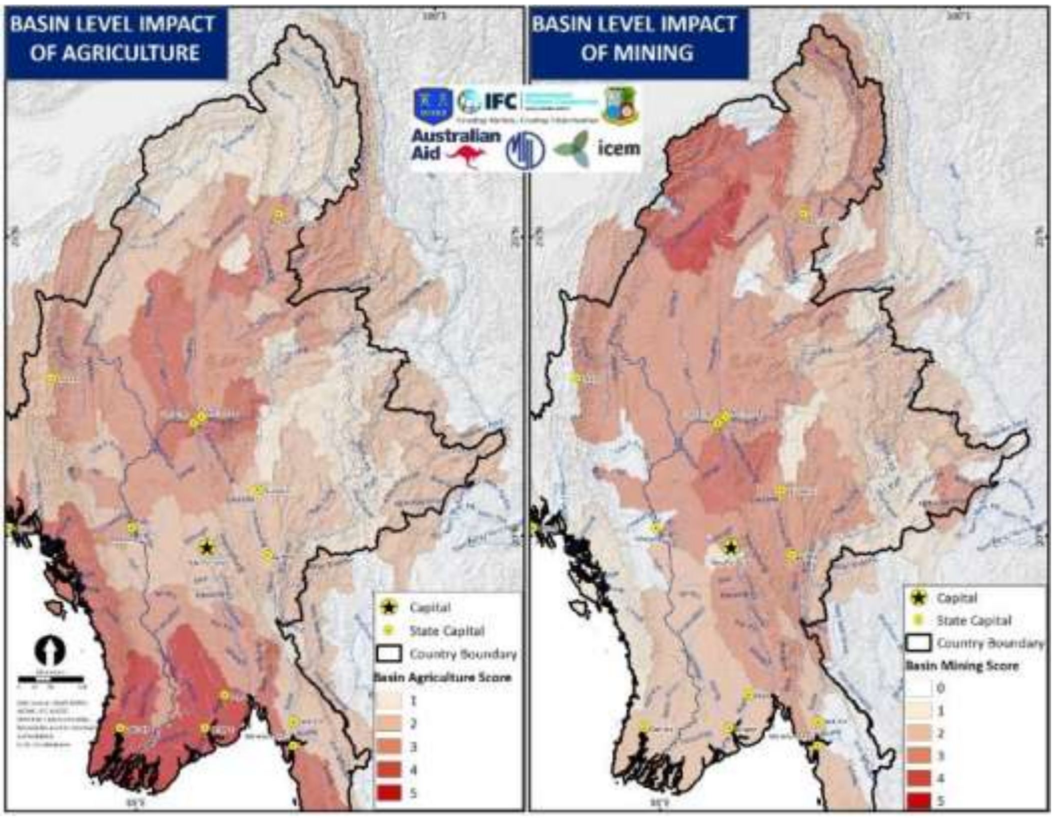
- Rainfed - Single
- Rainfed - Double
- Flood Plain - Single
- Flood Plain - Double
- Water Managed - Single
- Water Managed - Double
- Irrigated - Single
- Irrigated - Double
- Irrigated - Triple

The agricultural intensity index is then divided into five classes from Very high (5), High (4), Medium (3), Low (2) and Very low (1) according to a preset range shown below. This is shown in Figure 6.4.

Index	Agricultural Intensity score	Description	Pressure score
1	0 - 1	Very Low	-1
2	1 - 10	Low	-2
3	10 - 100	Medium	-3
4	100 - 1000	High	-4
5	1,000 - 3,000	Very High	-5

The Ayeyarwady delta scores very high, whilst the northern reaches of the Ayeyarwady and Chindwin score very low. The Mu and Myitinge HydroBasins score high, while other parts of the Lower Chindwin and Lower Ayeyarwady have Medium agricultural intensity index.

Figure 6.4: Pressures of agricultural intensity and mining sub-basins in the Myanmar river basins



6.5 Mining pressure

Mining can produce substantial pressure on aquatic ecosystems, especially alluvial gold mining. Other forms of mining can increase sediment loads in the water and release toxic materials from the rocks themselves or from ore processing, e.g. mercury used for extracting gold. The disturbance to aquatic ecosystems from mining is illustrated by the Google Earth image of the Uyu River which is also a Key Biodiversity Area (Figure 6.5).

There is a significant correlation with geology - most (65% by areas) are in the in recent (Cainozoic) sediments. These are likely to be alluvial gold, gems, tin; and the oil deposits. About 10% are in granites (probably tin - tungsten).

Figure 6.5: Google Earth image of mining disturbance of the Uyu River, a tributary of the Chindwin

The mining pressure on aquatic ecosystems has been mapped following a similar process used for the WLE Myanmar Healthy Rivers program for the Ayeyarwady and Thanlwin (in preparation). River reaches receive a score based upon the area and number of mines within each of the sub-basins. The area of mines from MIMU data set has been normalized by area of each sub-basin (HydroBasins Level 6). The minimum amount of mining occurring in each sub-basin is 10 ha/10,000 sq.km used as the cutoff for class 1, (Very low) and the other classes are scaled logarithmically as shown below.

Index	Mining Intensity score (Ha/10,000 sq.km)	Description	Pressure score
1	0 - 10	Very Low	-1
2	10 - 100	Low	-2
3	100 - 1,000	Medium	-3
4	1,000 -10,000	High	-4
5	>10,000	Very High	-5

The HydroBasins with the different scores are shown on Figure 6.4 (right). The Uyu River receives the highest score.

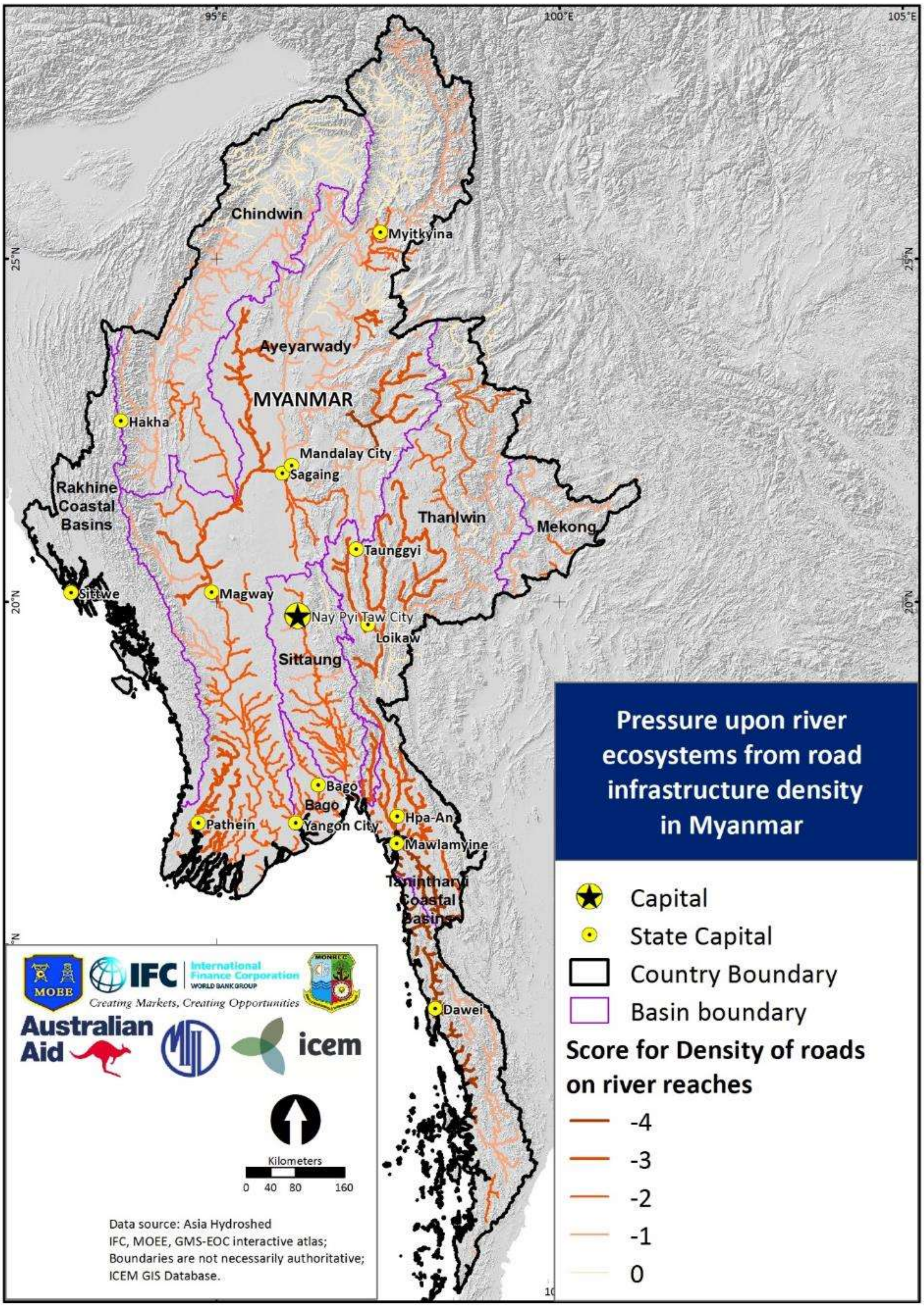
6.6 Road infrastructure

Roads create a pressure upon the river ecosystems in several ways. During the construction of roads and bridges, vegetation clearance, soil erosion and sediment release into the rivers is likely to increase, especially roads adjacent to the river banks. Bridges have a specific construction impact at the location of the river crossing. Road building materials (sand and gravel) may also be sourced from the river.

Once constructed roads provide improved access to the rivers, increasing ease of natural resource use and transport to markets. The density of the road infrastructure in relation to the area of each sub-basin has been calculated (i.e. length of major roads per square kilometer of sub-basin, HydroBasin Level 6). This indicator has then been applied to the river reaches within each sub-basin (see Figure 6.6).

As with rural population density, the road density is lowest in the upper reaches of the Ayeyarwady and along the Thanlwin increasing further downstream. The highest density of roads per sub-basin is found near the mouth of the Thanlwin near Mawlamyine, probably due to being relatively small sub-basin with many intersecting roads.

Figure 6.6: Pressure upon river ecosystems from road infrastructure density

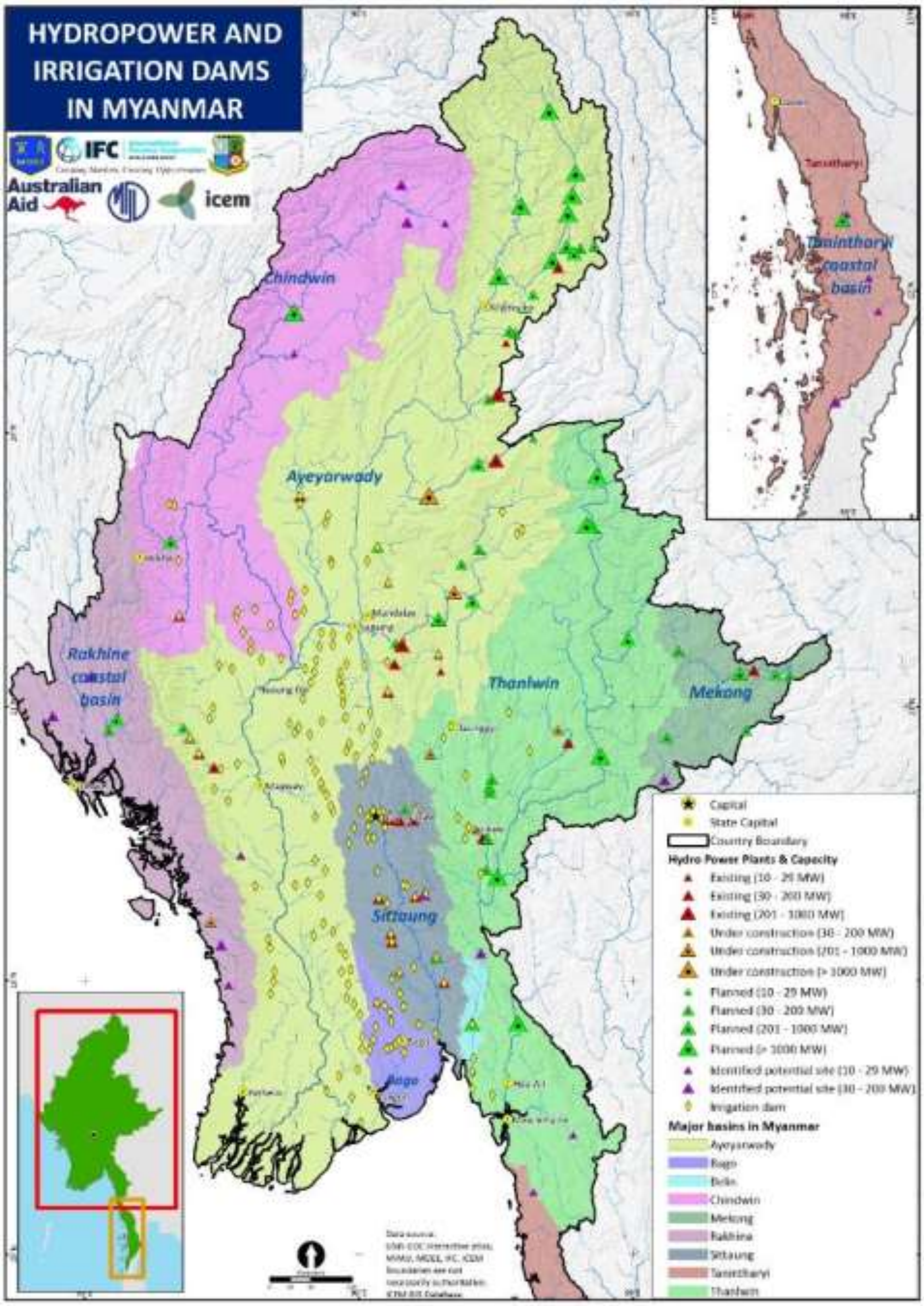


6.7 Irrigation reservoirs

Irrigation reservoirs exert pressure on the aquatic ecosystems - they present a barrier in the form of a low weir or a more substantial dam across the free-flowing river. The flows in the river will be changed, with water storage in the wet season and diversion of the water to the agricultural fields in the wet season for supplementary irrigation and in the dry season for second cropping. Unlike hydropower, the water stored is largely lost to the river system apart from flows draining the fields.

In assessing the pressure upon the aquatic ecosystems, the reservoir itself converts part of the river upstream of the dam or weir into a lacustrine environment, and downstream the impacts upon flow are taken down to the next confluence with a river of the same size. All river reaches lying within the irrigation reservoir are scored at - 5. All river reaches downstream of the irrigation reservoir down to the next confluence with a similar sized river score -3.

Figure 6.7: Distribution of existing and planned hydropower dams and irrigation reservoirs in Myanmar



6.8 Hydropower dams and reservoirs

There are 22 existing hydropower projects in Myanmar (Figure 6.7). Using an assessment of the Global Surface Water Database,[29] the reservoirs cover an area of 98,270 ha, with an average size of 4,467 ha. They fill up during the wet season and are drawn down during the dry season, covering 42,000 ha or about 43% of the total surface area.

Hydropower dams and reservoirs exert pressures on the aquatic ecosystem by changing the flow patterns in the river, reducing the peak flows in the wet season and increasing the dry season flows. There may be daily variations in flow if the hydropower plant operates on peak loading during the day, with minimum flow releases at night. They convert the area above the dam from a free-flowing river to a lacustrine environment, often increasing the depth considerably. They also may affect water quality especially during construction and initial filing of the reservoir. Dams will tend to trap sediments, unless special measures are put in place such as bottom flushing gates, so that the water released tends to have a lower sediment content. This may give rise to bed and bank erosion downstream, until the river has picked up enough sediment load for its stream power. One of the major impacts of hydropower dams is the barrier effect that the dams have for migratory species, especially for fish moving upstream for spawning and moving downstream as floating eggs, fry and small fish with returning larger fish.

Hydropower impacts have been incorporated into the human pressure scores for each reach by including the reaches inundated by the reservoir, and the downstream impacts upon flow down to the next confluence with a river of the same size. If the river reach lies within a hydropower reservoir, the score for the combined pressure index is -5; for downstream reaches the length of river impacted depends upon the size of hydropower plant, thus for HPP >100 MW, score downstream reaches down to the next confluence of similar size at -4, for HPP <100 MW score downstream reaches down to the next confluence of similar size at -3; for HPP <50 MW score downstream reaches down to the next confluence of similar size at -2.

[29] https://global-surface-water.appspot.com/

Case Study 1: Baluchaung 3

The Baluchaung No. (3) HPP (BLC-3) is located in Kayah State, (20) km south of the state capital of Loikaw. The project is located on the right bank of the lower Baluchaung River, its upstream end being located immediately downstream of, and connecting to, the tailrace area of the existing Baluchaung No. (2) Power Station (BLC-2),with the No.(3) Power Station being located some 5.25 km further downstream near the confluence of the Baluchaung River and the Nam Pawn River. The live storage provided by the Mobye Reservoir enables energy generation, by its downstream hydropower projects throughout the dry season, this being of significant importance to the overall energy generation of Myanmar. The foreseen installed capacity is 52 MW providing an annual energy of 334 GWh.

In February 2011, an Environmental & Social Impact Assessment study report was published for the Baluchaung No. (3) Hydroelectric Power Project, that included an assessment of fish species and fisheries livelihoods. The purpose of the Environmental Impact Assessment (EIA) was to provide information that contributed to the decision-making process in regard of design, cost and feasibility assessment.

The main findings related to fisheries and aquatic resources were as follows:

- 13 fish species identified in the Baluchaung River, including *Labeo calabasu; Cyprinus carpio; Cirrhina latia, Cirrhina mrigala; Puntius hexastich; Ophiocephalus striatus; Notopterus notopterus; Puntius apongon; Lepidocephalus; Monopterus albus & Colisa labiasa.*
- The fish found in the Baluchaung River were mainly the short-term migrating species. laying sticky eggs on river boulders
- The area has a long tradition of fishing and the local people have developed specialized equipment for the fishery. In recent years, single layer gill net, the double layer gill net, the trailing net, cast net, layer square net, the dragging net or the sinking hook, etc. Fishing is performed on bamboo rafts and wooden canoes.
- The peak fishing season is during the flood season, when the water level rises, the debris flow is serious, the water flow is strong and the fishing difficult is challenging. In the local economic structure, the fishery is only a supplementary livelihood, and there are no professional fishermen in the area.
- The ESA concluded that due to the weir construction at the planned site, the river environment would be divided into three different sections. (The channel segment above the reservoir tail, the reservoir area and the downstream waters of the weir). This fragmentation and loss of connectivity would result in the formation of meta-populations of different sizes, with the genes between populations not being exchanged, leading to a reduction in genetic diversity and the probability of population extinction.
- The water flow in the reservoir area would be slowed down, and the water depth increased, The functions of the water area deepening, the stream decelerating, wind currents and stratification in front of the weir would result in lake hydrodynamic characteristics appearing
- Aquatic weeds are likely to appear in the area upstream of the weir and in the branch stream areas after the operation of the power station, but an increase in the amount of aquatic higher plants is anticipated to be small, because the river bank is mainly rocky.
- The river section of the reservoir area was originally suitable for the many fish species which live and reproduce in the rapid stream conditions. As a result of the closure, the number of fishes in the main streams in the reservoir area will be reduced, whilst the number of fish species adapting to living in a soft stream environment will be increased, so these types of fish will likely become dominant in the reservoir area.
- Due to the increase in the volume of the water body in the reservoir, the activity space of the aquatic organisms and fishes will increase, and the total amount of the resources can be expected to increase.
- With the establishment of the small reservoir, the water area will not be so enlarged, and the productivity of aquatic organisms will not increase. The species composition of the fish catch will slowly change, with those fish adapted to rapid stream conditions, being reduced, and those fish better adapted to soft steam or quiescent water conditions will increase remarkably.

Case Study 2: Yeywa

The Myitnge River or Nam Tu, also known as Dokhtawaddy River is a major tributary of Ayeyarwady River (Irrawaddy) in Myanmar (Burma). The name Myitnge in Burmese and Dokhtawaddy in Pali both mean "little river", by contrast with the Ayeyarwady or "big river" In late 2001, the Burmese government announced plans for the Yeywa Dam and in 2004, Burma's Ministry of Electric Power (MEPE) signed an MOU with a consortium of Chinese companies for the construction of the Yeywa Dam with a planned capacity of 790 megawatts, making it the largest roller-compacted concrete (RCC) dam in the country and one of the biggest RCC dams in the world.

At that time, there were few studies or debate focused on the impact that the HPP might have on local biodiversity and livelihoods. The Yeywa dam created a reservoir of 75 km in length and 59km^2 in area. This will have changed the hydrological conditions above the dam considerably, affecting fish and other aquatic populations, including several species of endangered turtles that would have had their traditional nesting sites permanently flooded. The endemic Myanmar roof turtle, *Kachuga trivittata*, ranks as one of the most critically endangered turtles in the world, and faces almost certain extinction in nature without serious conservation efforts. The Wild Population Management Group ranked most urgent area for conservation efforts as being the Myitnge / lower Dokhthawady, followed by the Sittaung and Salween. WCS report that turtles have been extirpated from the Myitinge River due to inundation and hunting and consumption by construction workers

The area is also home to a number of endemic fish species. For example, a number of new loaches have been recently described by Jörg Bohlen and Vendula Šlechtová, including, *Schistura puncticeps* and *Schistura pawensis,* currently known only from the mouth of Nam Paw stream at its confluence with the Myitnge River.

In 2005 the *Myanmar Times* reported that three villages near the dam had been relocated. The villagers had depended on the Myitnge River for their fishing, farming and logging livelihoods, the sources of which will be flooded by the dam. Ancient cultural sites like the Sappa Sukha Htattaw Temple will also be flooded and forever lost. There is also local concern about continued development of the sub-basin. Protests regarding the construction of an Upper Yeywa HPP have voiced ecological concerns, including villagers living along the Namtu in Hsipaw who rely heavily on fishing in the river, where fish is caught mostly in June and July, when the river level is rising. Dried fish and traditional Shan pickled fish are staple sources of protein.

6.9 Degree of regulation and fragmentation by existing hydropower projects

Table 6.3 shows the calculations for the degree of regulation for the existing hydropower dams in Myanmar. This is based on the database of hydropower projects prepared by the SEA team with MOEE, and uses the average annual flows at each of the hydropower project river reaches from the WWF river reach database. It can be seen that many have very low degrees of regulation, while some on the smaller tributaries in the Sittaung have higher DOR's,[30] Dapein 1 and Shweli being downstream of cascades of dams in China have low DORs. The Baluchaung cascade has very low DORs since these are run-of-river dams. There is no storage but all flows are diverted through the power houses, so that the river channel between the cascades is effectively dry except during peak flows.

The Degrees of Regulation for each tributary that have several hydropower projects at the points of confluence with the mainstem are shown in Table 6.4. This table also shows the cumulative DORs for the mainstem at these confluences. It can be seen that the Myitinge River at the Ayeyarwady confluence has a DOR of 14.3%, since it has been dammed by the Yewa HPP, the Zawgyi River which has been dammed by the Zawgyi 1 and 2 and Myogyi HPPs, and the Panlaung Chaung which has been dammed at the Kinda HPP. After the confluence with Myitinge, the Ayeyarwady has a cumulative DOR of 1.27% and when the Mu River joins with its very large storage reservoir at Thapanzeic and a DOR of 26%, the Ayeyarwady has a cumulative DOR of 1.58%.

After the Chindwin River, which is currently unregulated, enters the Ayeyarwady and the Mone Chaung River, with a DOR of 28, due to large reservoirs at Mone Chaung HPP and Kyeeon Kyeewa HPP, joins

[30] The estimated storage capacity on these Sittaung dams need to be confirmed.

the Ayeyarwady, the cumulative DOR falls back to 1.00% considering all the existing hydropower projects (excluding any storage in China on the Dapein and Shweli).

The Sittaung River shows the highest Degrees of Regulation of all Myanmar rivers, as shown in Table 6.4. At the confluence with the Paunlaung, which has three hydropower projects, its cumulative DOR in the Sittaung is 28.4%. More regulated and unregulated tributaries join and the cumulative DORs range between 18 and 21% for most of its length, falling to nearly 14% by the time it reaches the coast.

The cumulative DORs for the Thanlwin are very low, with the low storage on the Baluchaung cascade and Keng Tawng HPP.

The Degree of Fragmentation caused by these dams has been estimated. Since these dams are located on tributaries rather than on the mainstems of the large rivers, the general pattern is that all the tributaries, where there are dams located, are significantly fragmented (usually 90 - 100%) up until the tributary meets the very much larger flows in the mainstems.

The Baluchaung cascade effectively cuts off the Baluchaung River and its upstream links with Inle Lake, from the Thanlwin mainstem. The only dams which cause significant DOF are Upper and Lower Paunlaung on the Sittaung and the effects of these can be noticed progressively decreasing down to the lower reaches of the Sittaung (Figure 6.8).

This measure of the Degree of Fragmentation is based upon the relative flows downstream and upstream of dams. A measure of the Connectivity of river ecosystems can be used to assess the barrier effect of hydropower and irrigation dams, assessing the numbers of different types of river reach that are connected in a river system. The loss of connectivity can be assessed by calculating the changes in river type connectivity after the construction of a dam. This impact will be done for the proposed dams.

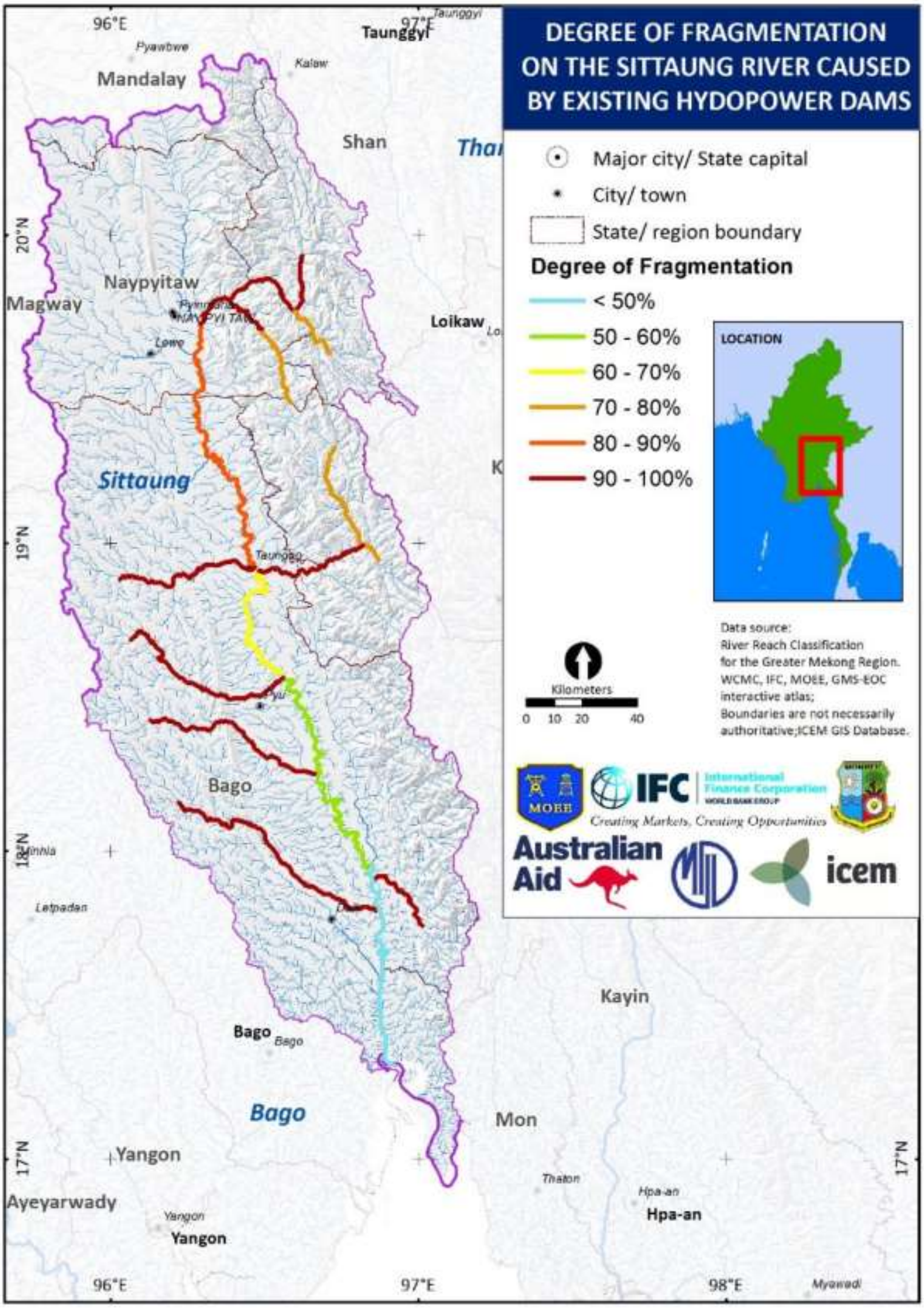
Table 6.3: Degree of Regulation analysis of existing hydropower plants on Myanmar Rivers

River	Hydropower project	Status	Installed capacity	Total upstream storage capacity	Mean annual flow	Total annual flow	Degree of Regulation (DOR)	Dam Height (m)	Total storage	Live storage	Retention period (days)	Reservoir Area (km2)	Reservoir Length (km)	Nearest KBA
			MW	cumecs	cumecs	cumecs			hm3	hm3				
Upper Ayeyarwady														
Chipwi Hka	Chipwi Nge	Existing	99	1,000,000	24.90	785,246,400	**0.13**	36	1	-	0.46	0.10	0.70	Mai Hka
Middle Ayeyarwady														
Dapein	Dapein 1	Existing	240	15,000,000	319.30	10,069,444,800	**0.15**	46	22	15	0.54	0.35	-	Ninety-six Ins and Ayeyarwady Bhamo section
Shweli	Shweli PRC x 8 HP	Existing												
	Shweli 1	Existing	600	24,000,000	562.80	17,748,460,800	**0.14**	47	24	24	0.49	1.30	10.50	
Sedawgyi	Sedawgyi	Existing	25	344,000,000	133.60	4,213,209,600	**8.16**	57	448	344	29.80	40.45	-	Taung Kan at Sedawgyi, Irrawady Dolphin
Myitinge	Yeywa	Existing	790	1,608,000,000	505.20	15,931,987,200	**10.09**	132	2,607	1,608	45.06	59.00	-	Mehon upstream reservoir, Myaleik Taung downstream (Peleik In)
Zawgyi	Zawgyi I	Existing	18	NA	27.30	860,932,800	-	-	-	-	-	-	-	
	Zawgyi II	Existing	12	516,000,000	42.80	1,349,740,800	**38.23**	44	639	516	139.54	38.47	-	
	Myogyi	Existing	30	274,000,000	70.10	2,210,673,600	**12.39**	79	444	274	45.24	22.72	-	
Panlaung Chaung	Kinda	Existing	56	871,000,000	35.70	1,125,835,200	**77.36**	72	1,078	871	282.38	28.57	-	Panlaung Pyadalin Cave
Mu	Thapenzeic	Existing	30	3,072,000,000	209.20	6,597,331,200	**46.56**	33	3,552	3,072	169.96	397.05	-	Chatthin
Lower Ayeyarwady														
Mone Chaung	Mone Chaung	Existing	75	642,000,000	105.00	3,311,280,000	**19.39**	61	832	642	70.77	42.00	-	
	Kyeeon Kyeewa	Existing	74	571,000,000	26.90	848,318,400	**67.31**	50	571	571	245.68	33.00	-	Shwesettaw, Mone Chaung
Sittaung														
Paung Laung	Paunglaung (U)	Existing	140	1,251,000,000	60.10	1,895,313,600	**66.00**	98	1,286	1,251	240.92	11	-	Paunlaung Catchment
	Nancho	Existing	40	4,000,000	20.00	630,720,000	**0.63**		9	4	2.31	0		Paunlaung Catchment
	Paunglaung (L)	Existing	280	338,000,000	95.00	2,995,920,000	**11.28**	131	678	338	41.18	15		Paunlaung Catchment
Ka Baung Chaung	Ka Baung	Existing	30	1,135,000,000	36.10	1,138,449,600	**99.70**	61	1,468	1,135	363.89			
Tauk Ye Khat	Thank Ye Khat (2)	Existing	120	148,000,000	50.10	1,579,953,600	**9.37**	94	444	148	34.19	60		
Phyu Chaung	Phyu Chaung	Existing	40	727,000,000	37.40	1,179,446,400	**61.64**	75	780	727	224.98	16		Central Bago Yoma
Kun Chaung	Kun Chaung	Existing	60	1,135,000,000	34.90	1,100,606,400	**103.12**	73	1,468	1,135	376.41			Central Bago Yoma
Shwegyin	Shwegyin	Existing	75	693,000,000	39.80	1,255,132,800	**55.21**	57	2,078	693	201.53	59	-	
Yenwe	Yenwe	Existing	25	NA	39.10	1,233,057,600	-	77	-	-	-	-	-	Central Bago Yoma
Bago														
Bago	Zaungtu	Exisitng	20	NA	56.40	1,778,630,400		-	-	-	-	14.93	-	
Salween														
Baluchaung	Baluchaung 1	Exisiting	28	2,000,000	149.60	4,717,785,600	**0.04**	-	2	-	0.15	-	-	
	Baluchaung 2	Exisiting	168	-	150.50	4,746,168,000	**0.00**	-	-	-	-	-	-	
	Baluchaung 3	Exisiting	52	-	151.20	4,768,243,200	**0.00**	-	-	-	-	-	-	
Keng Tawng	Keng Tawng	Existing	54	52,000,000	203.10	6,404,961,600	**0.81**	27	61	52	2.96	11.63	-	
Mekong														
	Nam Lwe 001	Existing		NA	46.30						-			
	Nam Lwe 002	Existing		NA	275.10						-			

Table 6.4: Combined Degrees of Regulation on tributaries and at mainstem confluences

River	Dam	Storage	Combined storage	Flow at confluence	Annual flow	DOR of tributary	Flow after confluence with mainstem	Annual flow	DOR of mainstem
		Cubic metres		cumecs	cubic metres		cumecs	cubic metres	
Upper Ayeyarwady									
Chipwi Hka	Chipwi Nge	1,000,000		33	1,040,688,000	0.10	1180.1	37,215,633,600	0.003
Middle Ayeyarwady									
Dapein	Dapein 1	15,000,000		372.8	11,756,620,800	0.13	5721.9	180,445,838,400	0.01
Shweli	Shweli PRC x 8 HP	NA							
	Shweli 1	24,000,000		1020	32,166,720,000	0.07	7282.9	229,673,534,400	0.02
Sedawgyi	Sedawgyi	344,000,000		166.7	5,257,051,200	6.54	8061.1	254,214,849,600	0.14
Myitinge	Yeywa	1,608,000,000							
Zawgyi	Zawgyi I	NA							
	Zawgyi II	516,000,000	3,269,000,000	723.6	22,819,449,600	14.33	9037.3	285,000,292,800	1.27
	Myogyi	274,000,000							
Panlaung Chaung	Kinda	871,000,000							
Mu	Thapenzeic	3,072,000,000		375.5	11,841,768,000	25.94	9416.9	296,971,358,400	1.58
Lower Ayeyarwady									
Mone Chaung	Mone Chaung	642,000,000	1,213,000,000	136.8	4,314,124,800	28.12	15258.2	481,182,595,200	1.00
	Kyeeon Kyeewa	571,000,000							
Sittaung									
Paung Laung	Paunglaung (U)	1,251,000,000							
	Nancho	4,000,000	1,593,000,000	99.6	3,140,985,600	50.72	177.6	5,600,793,600	28.44
	Paunglaung (L)	338,000,000							
Ka Baung Chaung	Ka Baung	1,135,000,000		54.5	1,718,712,000	66.04	459.8	14,500,252,800	19.83
Tauk Ye Khat	Thank Ye Khat (2)	148,000,000		58.8	1,854,316,800	7.98			
Phyu Chaung	Phyu Chaung	727,000,000		41.5	1,308,744,000	55.55	534	16,840,224,000	21.40
Kun Chaung	Kun Chaung	1,135,000,000		62.7	1,977,307,200	57.40	654.7	20,646,619,200	17.45
Shwegyin	Shwegyin	693,000,000		94.8	2,989,612,800	23.18	864.1	27,250,257,600	19.93
Yenwe	Yenwe			67.7	2,134,987,200	-	962.2	30,343,939,200	17.90
Sittaung							1238.6	39,060,489,600	13.90
Bago									
Bago	Zaungtu			327.8	10,337,500,800	-			
Salween									
Keng Tawng	Keng Tawng	52,000,000		334.1	10,536,177,600	0.49	3167.1	99,877,665,600	0.05
Baluchaung	Baluchaung 1	2,000,000							
	Baluchaung 2	-	3,000,000	402.3	12,686,932,800	0.02	3786.3	119,404,756,800	0.05
	Baluchaung 3	-							
Mekong									
	Nam Lwe 001								
	Nam Lwe 002			28.9	911,390,400		2033.7	64,134,763,200	

Figure 6.8: Degree of Fragmentation on the Sittaung River caused by existing hydropower dams



6.10 Summary

There is a general recognition that the state of health of the rivers in Myanmar is deteriorating, coming both from government officials and from local villagers living by and using the rivers. There is a concern that conditions are changing quite rapidly. However, there are no comprehensive surveys or analyses of water quality or river health. An approach has been taken to complement the ecological value of the river with a mapping of the river reaches according to the intensity of human pressures upon the rivers. This includes the development of urban areas which affect downstream reaches through the addition of domestic and industrial waste waters, and solid wastes. The rural population density reflects a pressure of river and natural resource use - with increasing density it is possible that unsustainable uses are being reached. Similarly, deforestation in the watershed and clearance of riparian vegetation tends to increase the sediment erosion and transport by the rivers, and change their character. The intensity of agriculture has been mapped covering the areas of single and multiple cropping within each sub-basin. Mining activities, especially for jade and alluvial gold create very negative conditions within certain river reaches, and these have been mapped according to sub-basin. The construction of roads can create adverse conditions in the rivers, and increase access to the natural resources - the density of roads by sub-basin is used as an indicator of this human pressure on the river. Irrigation reservoirs store water for the consumptive use of water for agriculture. There are over 180 irrigation reservoirs in Myanmar covering just over 100,000 ha, which will have an impact upon seasonal flow patterns and reducing connectivity. There are 22 existing hydropower projects with reservoirs covering nearly 100,000 ha. These also affect seasonal and daily flow patterns, retain sediments and may affect water quality. The distribution of these human pressures upon the river systems has been mapped to identify those river reaches where the trends in deteriorating river health are expected to be high. The existing hydropower dams and reservoirs have been analysed for their impacts upon the rivers by estimating the degree of regulation and the degree of fragmentation of the river flows.

7 CONCLUSIONS

This baseline report on the aquatic ecology and fisheries of the main river basins in Myanmar has provided an overview of the diversity of the river ecosystems and aquatic natural resources. It has provided an initial process for identifying the river reaches that are important and are ecologically sensitive. This is a first step in identifying those parts of the river systems that should be protected or otherwise safeguarded in the development in the development process,

It has also provided an overview of the pressures upon these river systems from a variety of human activities. The general trend is that these pressures are increasing and the health of the river systems is declining.

This description and baseline assessment of the aquatic ecology and fisheries is limited by lack of adequate data, both in terms of the river habitats and their river health status, and in terms of the aquatic biodiversity and natural resources they contain. Recent surveys of fish, of turtles and amphibians provide an indication that earlier biodiversity assessments have been significantly underestimated, and that the aquatic biodiversity and endemicity is much richer than originally described. Indeed, a positive trend is that efforts to research and survey the different rivers of Myanmar are being strengthened, so that some of the gaps in knowledge will be filled over the next few years and further areas of aquatic sensitivity and importance will be identified for protection and safeguards.

This baseline report looks forward to the next step of the SEA in which the ecological sensitivity of the river reaches described here will be analysed to give the inherent ecological value of each of 40 sub-basins. These sub-basins include those where hydropower projects are being proposed as well as other sub-basins where no hydropower is currently being proposed. The purpose of this process is to identify those sub-basins which have a high ecological value from an aquatic ecology perspective, and which can then be combined with their geomorphological and terrestrial ecology values. High value sub-basins identified will require additional safeguards and environmental management if they are to be developed for hydropower and irrigation dams and for other activities such as mining. All sub-basins will be described in terms of their characteristics and level of human pressures to indicate trends in river health. The impacts of the clusters of hydropower projects will then be assessed on those sub-basins in which hydropower is being proposed to identify the increased pressure upon those sub-basins.

REFERENCES

ADB. (2013). *Myanmar: Urban Development and Water Sector Assessment, Strategy, and Road Map.* Manila, Phillipines: Asian Development Bank.

Allen, D. M. (2010). *The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya.* Cambridge, UK and Gland, Switzerland: and Coimbatore, India:: IUCN, and Zoo Outreach Organization.

Allen, D. S. (2012). *The Status and Distribution of Freshwater Biodiversity in Indo-Burma.* Cambridge, UK and Gland, Switzerland: IUCN.

Davies, J. S. (2004). *A Wetland Inventory for Myanmar.* . Ministry of Environment, Japan.

Grill, G. a. (2016). *Hydropower development options and their environmental impact in the Greater Mekong Region for different energy development scenarios.* WWF - Greater Mekong Program.

Ilya. (2016). *Freshwater mussel observations in Myanmar in December 2016.* FFI unpublished.

IUCN. (Downloaded on 01 May 2017.). The IUCN Red List of Threatened Species. Version 2016-3. <www.iucnredlist.org>. .

Kottelat, M. (2015). *Fish species observed in Lake Indawgyi and its basin; December 2014 update,* . Yangon: Report No. 44 of the Myanmar Conservation and Development Program, a joint initiative of Fauna & Flora International (FFI) and the Myanmar Government. FFI,.

Kottelat, M. (2015). *Fish Species Observed In Lenya River Drainage in Tanintharyi Region, in November 2014,* . FFI, Ya: Report No.28 of the Tanintharyi Conservation Program, a joint initiative of Fauna & Flora International (FFI) and the Myanmar Government.

Kottelat, M. (2015). *Fish species observed in Mali Hka River and tributaries in Putao area, Kachin State, in November–December 2014,* . Yangon: Report No. 45 of the Myanmar Conservation and Development Program, a joint initiative of Fauna & Flora International (FF.

Kottelat, M. (2015). *Fish Species Observed In Tanintharyi Drainage in April–May 2014,* . FFI, Yangon: Report No.27 of the Tanintharyi Conservation Program, a joint initiative of Fauna & Flora International (FFI) and the Myanmar Government.

Lehner, B. a. (2014). *River reach classification for the Greater Mekong Region.* WWF Greater Mekong.

Mekong River Commission. (2015). *Identification of ecologically sensitive sub-basins for sustainable hydropower development in Mekong tributaries.* Vientiane, Lao PDR.: MRC Initiative on Sustainable Hydropower.

Ramsar Convention. (Downloaded April 2017). http://www.ramsar.org/wetland/myanmar.

Reeves, R. J.-C.-B. (2008). *Orcaella brevirostris. The IUCN Red List of Threatened Species 2008: e.T15419A4579987.* Retrieved from http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T15419A4579987.en. Downloaded on 26 May 2017.

UNESCO. (Downloaded April 2017). https://aseanup.com/unesco-world-heritage-sites-myanmar/.

Wogan, G. e. (2008). NEW COUNTRY RECORDS AND RANGE EXTENSIONS FOR MYANMAR AMPHIBIANS AND REPTILES. *Hamadryad Vol. 33, No. 1,* ,, pp. pp. 83 - 96.

ANNEX 1: SCORING METHOD FOR IDENTIFYING ECOLOGICALLY SENSITIVE RIVER REACHES AND HUMAN PRESSURES

Introduction

The base layer for the analysis was the WWF Greater Mekong Program River Reach Classification for the Greater Mekong Region (Lehner and Dallaire 2014).[31] The basic spatial unit of this classification is 'River Reach'. A river reach is a linear unit that represents a stretch of river located between two consecutive confluences. Lehner and Dallaire's (2014) classification applies a range of hydrological, physio-climatological and geomorphological classifications to the river reaches. In addition, this analysis applied a set of geospatial variables linked to ecological sensitivity to the River Reaches of the Ayeyarwady and Thanlwin River basins' river reaches to create an overall measure of river reach ecological sensitivity, River Reaches were classified as having low, medium, high or very high ecological sensitivity. Another set of geospatial variables related to negative human pressures was applied to the Ayeyarwady and Thanlwin River basins' river reaches to develop a combined score for human pressure, river reaches with a negative score for human pressure that was below a defined threshold were classified as under either low, medium, high or very high human pressure.

Ecological Sensitivity

River Reach Rarity

The total length of the river reaches within each of Lehner and Dallaire's (2014) Combined classes was calculated for the basins. The Combined class is an aggregate of a range of hydrological, physio-climatological and geomorphological classifications. The total length of the river reaches within each of the constituent Simple Hydrological classes was also calculated for the basins. The percentage of the total length of each Simple Hydrological class that each Combined class occupied was then calculated. This percentage was used to score each reach for rarity. The rarest reaches, Combined class reaches occurring in 0-5% of their constituent Simple Hydrological class were given a rarity score of 4, 5-10% were given a score of 3, 10-20% were given a score of 2 and the remainder, 20-71%, the most common Combined classes, were given a score of 1.

Combined Class Description	Sum Reach Length (Km)	Percentage Simple Hydrological	Rarity Score
Large river, in dry broadleaf forest region, with floodplains	0.63	0.01	4
Medium river, in dry broadleaf forest region, with low gradient	18.74	0.09	4
Large river, in mangrove region	8.50	0.12	4
Large river, in montane region, with low gradient	12.16	0.17	4
Medium river, in montane region, with high gradient	145.32	0.73	4
Large river, in moist broadleaf forest region at high elevation, with low gradient	56.07	0.78	4
Medium river, in mangrove region	185.76	0.93	4
Medium river, in moist broadleaf forest region at low elevation, with high gradient	245.39	1.23	4
Large river, in dry broadleaf forest region, with floodplains and sediment	108.99	1.52	4
Medium river, in moist broadleaf forest region at high elevation, with high gradient	325.86	1.64	4
Medium river, in karst within montane region	347.02	1.74	4

[31] Lehner B., & Ouellet Dallaire C., 2014. River reach classification for the Greater Mekong Region. Final report on behalf of WWF Greater Mekong Program.

Combined Class Description	Sum Reach Length (Km)	Percentage Simple Hydrological	Rarity Score
Medium river, in moist broadleaf forest region at high elevation, with floodplains	363.43	1.83	4
Medium river, in coniferous region, with high gradient	422.47	2.12	4
Large river, in moist broadleaf forest region at high elevation, with floodplains	169.94	2.37	4
Main stem, meandering channel with alluvium	112.68	2.39	4
Medium river, in dry broadleaf forest region, with floodplains	493.92	2.48	4
Large river, in moist broadleaf forest region at low elevation, with floodplains and sediment	204.91	2.86	4
Large river, in karst region at high elevation	206.21	2.88	4
Large river, in karst within montane region	251.70	3.51	4
Large river, in moist broadleaf forest region at high elevation, with sediment	353.20	4.93	4
Medium river, in coniferous region, with low gradient	1172.14	5.89	3
Medium river, in montane region, with low gradient	1239.07	6.23	3
Large river, in large delta region	448.08	6.25	3
Medium river, in large delta region	1284.07	6.45	3
Main stem, large delta	304.58	6.47	3
Medium river, in moist broadleaf forest region at high elevation, with low gradient	1305.72	6.56	3
Large river, in moist broadleaf forest region at low elevation, with low gradient	506.75	7.07	3
Medium river, in karst region at high elevation	1436.37	7.22	3
Large river, in moist broadleaf forest region at low elevation, with sediment	634.06	8.85	3
Large river, in coniferous region, with low gradient	1033.71	14.42	2
Medium river, in karst region at low elevation	2980.58	14.98	2
Medium river, in moist broadleaf forest region at low elevation, with floodplains	3215.01	16.16	2
Main stem, anastomose channel	959.36	20.38	1
Large river, in moist broadleaf forest region at low elevation, with floodplains	1585.62	22.12	1
Large river, in karst region at low elevation	1587.79	22.15	1
Medium river, in moist broadleaf forest region at low elevation, with low gradient	4719.35	23.72	1
Main stem, rock cut river channel	3330.83	70.76	1

Endemic Areas

Polygons delineating the presence of Endemic species were delineated based upon the literature, e.g. (Allen D. M., 2010) and from consultation with organizations such as FFI and WCS. River Reaches intersecting these areas were given a score of 3.

Key Biodiversity Areas

Polygons delineating Key Biodiversity Areas were obtained from the World Database of Key Biodiversity Areas.[32] These areas were further classified as Riverine & Wetlands, recognized as

[32] BirdLife International (2017) The World Database of Key Biodiversity Areas. Developed by the Key Biodiversity Areas Partnership: BirdLife International, IUCN, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Global Wildlife Conservation, NatureServe, Royal Society for the Protection of Birds, World Wildlife Fund and Wildlife Conservation Society.

globally important (Ramsar and World Heritage sites, and wetlands identified under 2004 wetland inventory), other important riverine and wetland KBAs, Terrestrial KBAs on River valley, Terrestrial KBAs only. River Reaches intersecting these areas were given the following scores:

KBA Classification	Score
Riverine & Wetlands, recognized as globally important	5
Other important riverine and wetland areas	4
Terrestrial KBAs on River valley	3
Terrestrial KBAs only	2

Confluences

River confluence points were identified by reviewing the reach classification dataset. Buffer zones of varying sizes were applied to each point to create an expert defined area of influence. River Reaches intersecting these areas of influence were given the following scores.

Confluence Type	Buffer Size	Score
Large River Confluence with Large River	10Km	2
Large River Confluence with Main Stem	20Km	3

Karst Geology

River Reaches classified as Karst environments by Lehner and Dallaire 2014 were given a score of 3.

Presence of threatened fish and other aquatic organisms

The predicted presence of Critically Endangered, Endangered and Vulnerable species of fish and other aquatic organisms in each sub-basin is taken from the IBAT/Redlist Freshwater assessment. River reaches within those sub-basins are scored as follows:

Reach intersects with a basin polygon with where the presence of Red List fish species has been indicated	Vulnerable Fish	Endangered Fish	Critically Endangered Fish
Score	3	4	5
Reach intersects with a basin polygon with where the presence of Red List species (not fish) has been indicated	Vulnerable Aquatic Sp. (not fish)	Endangered Aquatic Sp. (not fish)	Critically Endangered Aquatic Sp. (not fish)
Score	3	4	5

Combined Ecological sensitivity scoring

A combined Ecological Sensitivity score was then calculated for each river reach. The ecological sensitivity scores for all reaches ranged between +1 and +23.

- Reaches with a score of less than or equal to 4 were classified as Low sensitivity,
- reaches with a score between +4 and +9 were classified as Medium sensitivity,
- reaches with a score between +9 and +13 were classified as High sensitivity,
- reaches with a score greater than +13 were classified as Very High sensitivity.

Human Pressures

Deforestation

Lehner and Dallaire's (2014) river reach classification included a measure, derived from the Global Land Cover 2000 project, of the percentage of the upstream watershed covered with forest. A low percentage was considered a valid proxy for deforestation. The following scores were applied to river reaches depending on the value for upstream forest cover.

Deforestation	Upstream Forest Cover	Score

Low	40-60%	-1
Medium	20-40%	-2
High	0-20%	-3

Agriculture & Mining

An expert assessment of the impact of agriculture and mining was carried out for both basins. Scores were applied to each HydroBASINS level 6 sub-basin. HydroBASINS is a series of polygon layers that depict watershed boundaries, the hierarchically nested sub-basins follow the topological concept of the Pfafstetter coding system. River Reaches intersecting the sub-basins were given a score of between -1 and -5 for both impact of mining and agriculture depending on the expert assessment of the impact within the sub basin.

Agricultural intensity is calculated from the area of agricultural land within each sub-basin, factored by the area of double and triple cropping. Land use data has been taken from an IWMI database. The index calculation takes the percentage of the area in the sub-basin which is cultivated and multiplies this by the percentage of the agricultural land which is double or triple cropped multiplied by 1000. For all the sub-basins this index ranges between 0 to over 3,000. Each of the river reaches within the sub-basin is then given a score as follows:

Agricultural intensity index ranges	Score
0 - 25	1
25-250	2
250-750	3
750 - 3,000	4
>3000	5

Mining intensity is calculated from the mining area dataset from MIMU (Myanmar Information Management Unit). This dataset is overlaid on the HydroBasins level 6 and the mining intensity index calculated by dividing the area of mines in hectares divided by the area of each hydrobasin in sq.km. multiplied by 1000. This gives a range of indices between 0 and 25,000 and the river reaches in each sub-basin are then scored as follows:

Mining intensity Index ranges	Score
0 - 25	1
25 - 250	2
250 - 2500	3
2,500 - 10,000	4
>10,000	5

Urban Population centres

The location and population of the major urban areas in Myanmar was obtained from the Myanmar Information Management Unit.[33] Areas of influence were then delineated downstream of the population centre. The size of the area of influence was dependent on the size of the population centre and the size of the river affected by the population centre. River reaches intersecting the area of influence from a population centre were given a negative score depending on the size of the population centre. See below table for details of the sizes of areas of influence and scoring.

Urban population centres	River size	Length of downstream influence	Score
> 1 million people	Mainstem river	50 km	-5

[33] Myanmar Town Points. Available at: http://geonode.themimu.info/layers/geonode%3Amyanmar_town_points#more

> 1 million people	Large river	75 km	-5
> 1 million people	Medium river	100 km	-5
100,000 - 1 million people	Mainstem river	25 km	-4
100,000 - 1 million people	Large river	50 km	-4
100,000 - 1 million people	Medium river	100 km	-4
100,000 - 1 million people	Small river	125 km	-4
10,000 - 100,000 people	Mainstem river	10 km	-3
10,000 - 100,000 people	Large river	25 km	-3
10,000 - 100,000 people	Medium river	50 km	-3
10,000 - 100,000 people	Small river	100 km	-3

Rural Population density

The rural population density is used as a measure of pressure from rural populations upon the aquatic natural resources. The data comes from WWF Greater Mekong Program River Reach Classification for the Greater Mekong Region (Lehner and Dallaire 2014), which incorporates a field of population density above each river reach.

Rural Population density	Numbers of people per sq km above each river reach				
Reach has a Rural Population Score of	<= 25	> 25 AND <= 50	> 50 AND <= 100	> 100 AND <= 500	> 500
River reach score	0	-1	-2	-3	-4

Road infrastructure density

The road infrastructure overlay has been obtained from MIMU (Myanmar Information Management Unit). This is correlated with the sub-basins and the density of the road infrastructure calculated by the area of each sub-basin. The road density index for all river reaches within each sub-basin is then estimated as follows:

Road density	Length of road per area of sub-basin (km/sq.km)				
Reach intersects with a basin polygon with a Road index	0.0-0.025	0.025-0.05	0.05-0.075	0.075-0.1	0.1 - 0.224
River reach score	0	-1	-2	-3	-4

Dams Downstream

A database of hydropower and irrigation dam locations was obtained from the database developed for this project, see Hydropower theme baseline report. This database was then used to generate areas of influence for each dam. Areas of influence stretched downstream from each dam location up to the next confluence with a river reach with a higher hydrological class. River Reaches intersecting a dam area of influence were given the following scores:

Dam Type	Score
irrigation	-3
hydro >100 MW	-4
hydro <100 MW	-3
Hydro <50 MW	-2

Reservoirs

The extent of dam reservoirs was ascertained from the Global Surface Water[34] database. River reaches intersecting a dam reservoir (irrigation or hydropower) were given a score of -5.

Combined human pressure index

A combined Pressure score was then calculated for each river reach. River reach pressure scores ranged from -1 to -24.

- reaches with a score between -1 to -5 were classified as Very Low Pressure,
- reaches with a score between -5 and -10 were classified as Low Pressure,
- reaches with a score between -10 and -15 were classified as Medium Pressure,
- reaches with a score between -15 and -20 were classified as Very High pressure,
- reaches with a score between -20 and -24 were classified as Very High pressure.

[34] Jean-Francois Pekel, Andrew Cottam, Noel Gorelick, Alan S. Belward, High-resolution mapping of global surface water and its long-term changes. Nature 540, 418-422 (2016). (doi:10.1038/nature20584)

ANNEX 2: RIVER REACH CLASSIFICATION FOR MYANMAR'S MAIN RIVER BASINS

This section describes and compares the main river basins in Myanmar using the WWF river reach classification scheme (Lehner, 2014). The classification scheme identifies small reaches within each river basin according to hydrological class, physio-climatic classes and geomorphological classes. The purpose of this approach is to illustrate the characteristics and differences between the rivers, and identify within each river system reaches that may be relatively rare with distinctive ecology and biodiversity. The classification system identifies 5 sizes of stream and river reaches based upon the average annual flows:

1. Mainstem, >1,000 m^3/sec
2. Large rivers, 100 - 1,000 m^3/sec
3. Medium rivers, 10 - 100 m^3/sec
4. Small rivers, 1 - 10 m^3/sec
5. Small headwater streams, 0.1 - 1.0 m^3/sec

The river reach compositions are different for Myanmar's rivers and the analysis helps to highlight the character of each river. These are summarized in Table 0.1, and Figures 0-1 to 0-5, show that whilst the total lengths of the river reaches are different ranging from over 70,000 km for the Middle Ayeyarwady to 10,741 km for the Myit Ma Hka & Bago and 17,158 km for the Sittaung, the proportions of the different sizes of reach are quite similar, with about 62 to 67% of the total lengths comprising the small headwater streams, 22 to 26% small rivers, 6 to 9% medium sized rivers, 1.6 to 3.2% large rivers and 1.2 to 3.5% in the mainstem reaches. Only the Ayeyarwady, Chindwin and Thanlwin have mainstem reaches with average flow more than 1,000 m^3/sec. Thanlwin has a higher proportion of the mainstem reaches (3.5%) and large reaches (3.2%) than the other rivers as is to be expected from such a river with a narrow catchment and relatively fewer tributaries. Proportionately it has fewer Medium-sized and small rivers.

The Chindwin shows a lower proportion of headwater river reaches than the others, but higher proportion of small river reaches. The three Ayeyarwady catchments show higher proportions of mainstem river reaches coming downstream (1.21%, 1.63%, 1.71%), with lower proportions of large river reaches in the Lower Ayeyarwady compared to the upstream catchments. There is a lower proportion of medium sized river reaches coming downstream (7.85%, 7.58%, 7.48%).

When comparing the proportion of river reaches with karst limestone, the Upper and Middle Ayeyarwady, are the only ones to have significant proportions of montane karst. The Upper Ayeyarwady has a lower proportion of low elevation (<750 masl) and higher proportion of high elevation (>750 masl) karst reaches compared to the Middle Ayeyarwady. The proportion of karst river reaches on the Chindwin lies between these two. The Lower Ayeyarwady has no high elevation karst reaches, and the Sittaung, Myit Ma Hka & Bago and Tanintharyi are predominantly low elevation rivers. The Thanlwin shows a similar split between high and low elevation as the Upper Ayeyarwady, with 40% low elevation and 33% high elevation with a small proportion of montane karst.

Considering the physio-climatic classification, all the rivers are predominantly lying in moist broadleaf forest regions, with small proportions of reaches in dry broadleaf forest regions in the Middle Ayeyarwady, the Thanlwin and Sittaung. River reaches running through karst are significant in the Upper and Middle Ayeyarwady and the Thanlwin, with smaller proportions of karst reaches in the Sittaung and Tanintharyi. The Upper Ayeyarwady and Chindwin are the only rivers where reaches run through coniferous forest regions.

Considering the river reaches with geomorphological features such as floodplains, sediment, and floodplains and sediment, the smaller catchments of the Sittaung, Myit Ma Hka and Tanintharyi have the highest proportion of floodplain reaches, followed by the Middle Ayeyarwady and Chindwin. The Lower Ayeyarwady has lower proportions of floodplain, largely because most of its length lies in the large delta region and mangrove areas.[35] The Thanlwin has about 2% of its river reaches with floodplains and just under 1% with sediment.

Figure 0.1: Lengths of different sized river reaches for Myanmar rivers

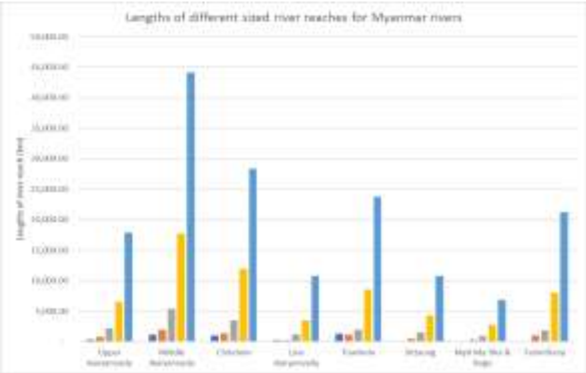


Figure 0.2: Comparison of river reach sizes for Myanmar rivers

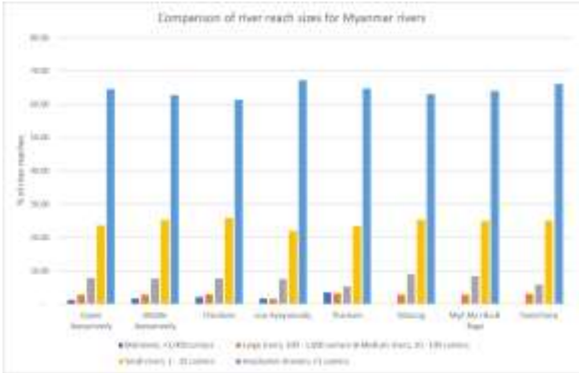


Figure 0.3: Comparison of elevations of Myanmar rivers

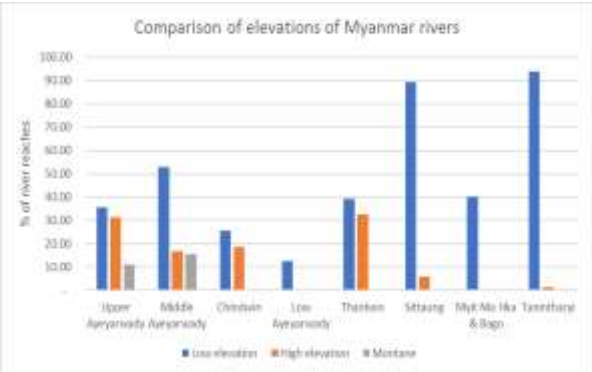


Figure 0.4: Comparison of Physio-climatic classifications for Myanmar rivers

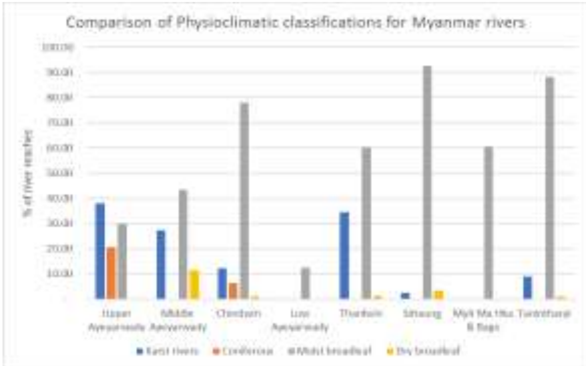
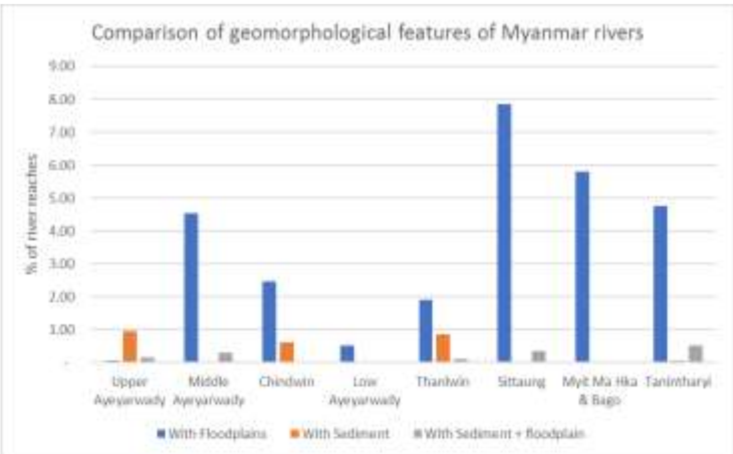


Figure 0.5: Comparison of geomorphological features for Myanmar rivers



[35] Note that if a river is classified in a delta region, it does not have an additional floodplain classification.

Table 0.1: Comparison of the characteristics of river reaches for the main river catchments in Myanmar

	Upper Ayeyarwady		Middle Ayeyarwady		Chindwin		Low Ayeyarwady		Thanlwin		Sittaung		Myit Ma Hka & Bago		Taninthanyi	
	km	%	km	%	km	%	km	%	km	%	km	%	km	%	km	%
Mainstem, >1,000 cumecs	336.66	1.21	1,143.76	1.63	979.85	2.12	273.83	1.71	1,280.44	3.49						
Large rivers, 100 - 1,000 cumecs	769.94	2.78	1,966.94	2.79	1,367.36	2.96	253.19	1.58	1,166.37	3.18	467.23	2.72	302.37	2.82	962.88	2.99
Medium rivers, 10 - 100 cumecs	2,176.72	7.85	5,334.88	7.58	3,535.33	7.65	1,200.31	7.48	1,938.47	5.28	1,528.02	8.91	890.54	8.29	1,889.11	5.88
Small rivers, 1 - 10 cumecs	6,541.50	23.58	17,773.01	25.25	11,955.05	25.87	3,532.48	22.02	8,567.21	23.36	4,355.91	25.39	2,675.83	24.91	8,062.52	25.08
Headwater streams, <1 cumecs	17,911.53	64.58	44,163.77	62.75	28,371.58	61.40	10,780.54	67.21	23,729.01	64.69	10,807.05	62.98	6,872.17	63.98	21,237.01	66.05
Total length of reaches	**27,736.35**		**70,382.36**		**46,209.17**		**16,040.35**		**36,681.50**		**17,158.21**		**10,740.91**		**32,151.52**	
Karst rivers	10,558.41	38.07	19,291.73	27.41	5,630.23	12.18			12,714.38	34.66	425.02	2.48			2,875.66	8.94
Coniferous	5,753.14	20.74			2,976.31	6.44										
Moist broadleaf	8,328.11	30.03	30,545.62	43.40	36,049.86	78.01	2,013.39	12.55	22,163.25	60.42	15,882.97	92.57	6,515.40	60.66	28,384.65	88.28
Dry broadleaf			8,192.79	11.64	572.92	1.24			523.43	1.43	604.10	3.52			365.84	1.14
Low elevation	9,917.07	35.75	37,178.99	52.82	11,817.65	25.57	1,995.89	12.44	14,438.54	39.36	15,318.56	89.28	4,323.23	40.25	30,127.90	93.71
High elevation	8,706.22	31.39	11,804.32	16.77	8,648.05	18.72	17.50	0.11	11,950.12	32.58	989.43	5.77			464.36	1.44
Montane	3,035.42	10.94	10,980.96	15.60					13.53	0.04						
With Floodplains	13.14	0.05	3,187.82	4.53	1,144.15	2.48	81.62	0.51	703.89	1.92	1,346.11	7.85	623.39	5.80	1,526.66	4.75
With Sediment	265.42	0.96	24.58	0.03	288.92	0.63			320.42	0.87	1.39	0.01			18.93	0.06
With Sediment + floodplain	44.00	0.16	215.86	0.31	12.84	0.03			40.36	0.11	60.91	0.35			170.88	0.53
Within delta areas			208.43	0.30			10,247.78	63.89					3,257.33	30.33		
Within mangrove areas							3,779.18	23.56			53.47	0.31	968.18	9.01	525.37	1.63

ANNEX 3: POTENTIALLY IMPORTANT WETLAND SITES SURVEYED AS PART OF 2004 WETLAND INVENTORY

Basins	No.	Sites	Division
Ayeyarwaddy main river and associated wetland	1	Ayeyarwaddy River (first floodplain Stage)	Kachin
	2	Ayeyarwaddy River (first gorge)	Kachin
	3	Ayeyarwaddy River flow first gorge (outwash plain & floodplain)	Kachin
	4	Ayeyarwaddy River (second gorge)	Kachin
	5	Ayeyarwaddy River from Kattha upstream to Modalay Village	Mandalay
	6	Ayeyarwaddy River from Kattha downstream to Tagaung	Mandalay
	7	Ayeyarwaddy River from Tagaung downstream to Thabeikkyin	Mandalay
	8	Ayeyarwaddy River downstream of Singu	Mandalay
	9	Ayeyarwaddy River upstream of Nyaung-U	Mandalay
	10	Ayeyarwaddy River downstream of Nyaung-U	Mandalay
	11	Ywwa Thit Inn	Kachin
	12	Pee Le Inn	Kachin
	13	Le Pine Tin Inn	Kachin
	14	Modalay Inn	Sagaing
	15	Mahananda Kan & Canal	Mandalay
	16	Khu Le Inn	Mandalay
	17	Ayeyarwaddy River Downstream from Min Hla to Mone	
Ayeyarwaddy River Basin (Mogaung Chaung Sub-basin)	18	Indawgyu Kan	Kachin
	19	Indawgyu Chaung	Kachin
	20	Mogaung Chaung upstream from Mogaung	Kachin
	21	Lower Mogaung Chaung	Kachin
	22	Gway Byat Inn	Kachin
Ayeyarwaddy River Basin (Moe Le Chaung Sub-basin)	23	Lower Moe Le Chaung	Kachin
	24	Ka Lauk Inn	Kachin
	25	Oat Ma Inn	Kachin
Ayeyarwaddy River Basin (Tapaing Chaung Sub-basin)	26	Nampar Inn	Kachin
	27	Shwe China Inn	Kachin
	28	Tapain Chaung Oxbow/Cut-off	Kachin
Ayeyarwaddy River Basin (Chindwin River Sub-basin)	29	Chindwin River at Homalin	Sagaing
	30	Nat E Zu Chaung (in Htamanthi WS)	Sagaing
	31	Nga Yant Inn	Sagaing
	32	Ahlome lake	Sagaing
	33	Kanthaya Inn	Sagaing
	34	Khaung Khan Inn	Sagaing
	35	Komeywa dam	Sagaing
	36	Shwegu Taung In	Sagaing

Basins	No.	Sites	Division
Ayeyarwaddy River Basin (Mu River sub-basin)	37	Indaw lay kan (lake)	Sagaing
	38	Kyi Ni	Sagaing
	39	Kabo weir	Sagaing
	40	Thanpanseik dam	Sagaing
Ayeyarwaddy River Basin (miscellaneous small river sub-basins)	41	Sedawgyi reservoir	Mandalay
	42	Wa Shang dam	Kachin
	43	Kinda dam	Mandalay
	44	Chuangmagyi Reservoir	Mandalay
	45	Alaung sithu Reservoir	Mandalay
	46	Taungpulu reservoir	Mandalay
	47	Kyet Mauk Taung Reservoir	Mandalay
	48	Thitson reservoir	Mandalay
Ayeyarwaddy River Basin (unclassified sub-basins)	49	Kyee-Ni Inn	Mandalay
	50	Me Aung Lake	Mandalay
	51	Min Hla lake	Mandalay
	52	Nyaung Yan Kan	Mandalay
	53	Yemyet Inn (Padu Inn)	Sagaing
	54	Ye Khar Inn	Sagaing
	55	Yewai Lake	Mandalay
	56	Yit Lake	Mandalay
	57	Yin Saw	Mandalay
	58	Myinzin Kan	Mandalay
	59	Paleik Lake	Mandalay
	60	Taung Kan	Mandalay
	61	Tuangtaman Lake	Mandalay
	62	Kaung Hmu daw	Sagaing
	63	Ptaungbya Reservoir	Mandalay
	64	Beckthano lake	
	65	U to lake	Yangon
	66	Wetthikan Lake	Magwe
	67	Gyo Phyu Lake	
	68	Khatlan dam	Mandalay
	69	Kyeo lake (Kyeoh Aoe Kyi lake)	
	70	Let Pan Pya dam	
	71	Myauk Na Win dam	
	72	Ngamoeyeik lake	
	73	Pantawa lake	
	74	Phu Gyi lake	
	75	Shauk Taw Yoe lake	Mandalay

Basins	No.	Sites	Division
Ayeyarwaddy River Basin (unclassified sub-basins)	76	Shwe Yaungdaw lake	
	77	Taung Na Win dam	
	78	Hlawga Park Lake	
	79	Hlawga Reservoir	
Ayeyarwaddy River Basin (Delta Region)	80	Bobakone swamp island	
	81	Gadongalay (Kadonkalay) island	Ayeyarwaddy
	82	Gyatgyi (Gayetgyi Kyun)	Ayeyarwaddy
	83	Letkokkon	Ayeyarwaddy
	84	Malatto Inn	Ayeyarwaddy
	85	Meinma Hla Kyun Wildlife Sanctuary	Ayeyarwaddy
Sittaung River Basin	86	Moeyungyi Wildlife Sanctuary	Bago
	87	Htein Inn	Mandalay
	88	Kanma Inn	Bago
	89	Ngalaik Reservoir	Mandalay
	90	Yezin Reservoir	Mandalay
Thanlwin (Salween) River Basin	91	Inle Lake	Shan State
	92	Balu Chaung	Shan State
	93	Nadi Kan	Shan State
	94	Sagar Kan	Shan State
	95	Heho Kan	Shan State
	96	Inya Kan	Shan State
Rakhine Coastal Region	97	Byaing Kyun	Rakhine state
	98	Kyeintali Chaung	Rakhine state
	99	Satthwa Chaung	Rakhine state

Source: (Davies, 2004)

ANNEX 4: FISH BIODIVERSITY & LIVELIHOOD UTILIZATION IN SELECTED HYDROSHEDS

River	Code	IBAT code	Reach	# IBAT fish species	# Least concern	# Near threatened	# Endangered	# Data deficient	# Commercial	# Subsistence	# Ornamental (potential)	# Un utilized
Ayeyarwaddy	1	EUR 61382	Lower mainstem	79	67	5	0	7	23	34	7	15
Ayeyarwaddy	2	EUR 61568	Lower mainstem	51	45	2	0	4	20	18	4	9
Ayeyarwaddy	3	EUR 61382	Lower mainstem	79	67	5	0	7	23	34	7	15
Ayeyarwaddy	4	EUR-60619	Middle mainstem	75	63	5	0	7	20	34	7	14
Ayeyarwaddy	5	EUR-60146	Middle mainstem	74	62	5	0	7	20	33	8	13
Ayeyarwaddy	6	EUR60181	Tributary	64	55	5	0	4	20	28	7	9
Ayeyarwaddy	7	EUR60181	Tributary	64	55	5	0	4	20	28	7	9
Ayeyarwaddy	8	EUR_59640	Middle mainstem	80	65	6	0	9	20	32	11	17
Ayeyarwaddy	9	EUR59716	Upper mainstem	77	62	6	0	9	22	32	11	12
Ayeyarwaddy	31	EUR-57623	Upper mainstem	70	48	5	0	17	16	29	10	15
Ayeyarwaddy	37	EUR-56760	Upper mainstem	51	37	4	0	10	15	25	3	8
Chindwin	40	EUR57651	Upper mainstem	58	48	5	0	5	17	25	5	11
Chindwin	43	EUR59226	Middle mainstem	69	55	6	0	8	18	31	8	12
Chindwin	45	EUR59406	Lower mainstem	71	57	6	0	8	17	33	8	13
Sittaung	75	EUR61094	Lower mainstem	71	59	3	0	9	20	28	5	18
Sittaung	78	EUR61012	Lower mainstem	61	49	3	0	9	14	28	6	13
Sittaung	80	EUR60717	Middle mainstem	72	60	4	0	8	18	33	8	13

River	Code	IBAT code	Reach	# IBAT fish species	# Least concern	# Near threatened	# Endangered	# Data deficient	# Commercial	# Subsistence	# Ornamental (potential)	# Un utilized
Thanlwin	68	EUR59295	Upper mainstem	26	16	3	0	7	13	4	1	8
Thanlwin	51	EUR61080	Middle mainstem	91	71	3	1	16	17	35	13	26
Thanlwin	57	EUR60297	Inle Lake	42	28	4	0	10	11	21	6	4
Thanlwin	49	EUR61440	Lower mainstem	56	43	2	0	11	15	21	6	14
Tanintharyi	91	EUR62511	Middle mainstem	44	32	2	1	9	12	17	8	7
Tanintharyi	86	EUR62025	Lower mainstem	42	34	2	1	5	12	17	6	7
Tanintharyi	88	EUR62463	Upper mainstem	46	33	2	1	10	10	20	10	6
Rakhine	46	EUR_60846	Middle mainstem	36	28	3	0	5	15	3	12	4
Rakhine	48	EUR61078	Lower mainstem	35	29	3	0	3	16	11	3	5
Rakhine	47	EUR60152	Upper mainstem	37	30	3	0	4	18	12	3	4

[i] Soe, K., Baran, E. and Simpson, V. et al (2013). *Myanmar Inland Fisheries, Ayeyarwady Delta And Central Dry Zone 2003 -2013*. "Improving research and development of Myanmar's inland and coastal Fishery" (MYFish), Worldfish& Myanmar Department of Fisheries.
[ii] Southeast Asian Fisheries Development Center (SEAFDEC), (2012). *The Southeast Asian State of Fisheries and Aquaculture*. [online] Bangkok. Available at: http://www.seafdec.org/download/sea-state-of-fisheries-and-aquaculture-2012/

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