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Avian Biodiversity in Two Zapotec Communities in Oaxaca: The Role of Community-Based Conservation in San Miguel Tiltepec and San Juan Mixtepec, Mexico

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Abstract Oaxaca is one of the most biologically and culturally diverse states in Mexico, which is in turn a world region of megadiversity. We document the rich avifauna of two indigenous Zapotec communities, San Miguel Tiltepec of the Sierra Norte and San Juan Mixtepec of the Sierra Sur. During several years of periodic ethnobiological field research in these communities, we have recorded a total of 313 species: 208 in San Miguel and 191 in San Juan (just 26.5 % of the total for both communities are shared), a list that includes approximately 40 % of endemic species and approximately 29 % of species of special concern known from the state of Oaxaca. The two communities contrast notably in their habitats but share deep roots in their local landscapes and traditions of conservative management of biological resources within their municipal boundaries. We also recorded data on Zapotec names and cultural beliefs and practices regarding birds and noted community attitudes and administrative practices that for centuries have sustained a rich mosaic of critical avian habitats. We suggest that indigenous communities in Mexico and elsewhere, given certain preconditions, may provide critical human resources for biodiversity conservation in the future.

Keywords Traditional resource management · Biocultural conservation · Avian diversity · Traditional ornithological knowledge · Zapotec · Mexico

Introduction

Mexico ranks third worldwide in biodiversity though fourteenth in land area (Ramamoorthy *et al*. 1993:xxxi). Within Mexico, the state of Oaxaca is exceptional. Oaxaca ranks first in bird diversity with 736 confirmed species plus 60 likely additional species not yet confirmed (Navarro-Sigüenza *et al*. 2014:486), over 70 % of the 1,100 species so far recorded for Mexico in just 95,364 km^2, 4.8 % of the national territory, approximately the size of the state of Indiana. This is almost as many species as recorded for all of North America north of Mexico.

Biodiversity is measured not only in terms of total species richness but also in terms of the proportion of species endemic with respect to various regional limits. Following González-García and Gómez-de Silva (2002), we count as endemics bird species that are restricted to within the borders of Mexico (61 such species occur in Oaxaca, of which 26 occur within our two communities). Of these, we recognize some as "regional endemics," which are species restricted to south-central Mexico, north of the Isthmus of Tehuantepec and south of the Trans-Volcanic Axis (10 species within our two communities). Finally, we note "quasi-endemics," which are species that are limited to Mexico except for highly restricted intrusions across Mexico's northern or southern borders (14 such

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species occur in Oaxaca, of which at least six occur in our two communities), and "semi-endemics," species whose winter ranges are limited to Mexico (González-García and Gómez-de Silva 2002). Endemic species are of special significance as indices of biodiversity in that they are vulnerable to more localized disturbance than are more cosmopolitan species. They also represent the special evolutionary potential of particular regions and habitats.

This exceptional biodiversity makes sense in terms of Oaxaca's location in the northern tropics astride a major bioregional divide between the Nearctic and Neotropical realms, which meet at the Isthmus of Tehuantepec and thus bisect Oaxaca. Oaxaca also bridges the Pacific and Atlantic slopes of the continent. Oaxaca's topography adds another dimension of diversity with elevations ranging from sea level to over 3700 m, with mountain ranges generating extreme rainfall regimes, supporting humid tropical rain and cloud forest to arid habitats supporting deciduous tropical forests to desert scrub.

However, Oaxaca's biodiversity is threatened by global trends, in particular, habitat destruction and climate change. Rapid loss and fragmentation of habitats has been documented in Mexico. From 2000 to 2007 there was annual forest loss of 534 707 ha. (Rosete-Vergés *et al*. 2014). Tropical deforestation generally results from conversion of forests to agricultural land and through timber extraction. Changes in land use in rural and indigenous communities have increased poverty, economic inequality, overall social polarization, over-extraction of natural resources, and have led to a high degree of social marginalization. All these factors have contributed to a "cascade effect" in terms not only of natural resource depletion but also of social and cultural impoverishment (Alcántara-Salinas 2011:9).

We argue here in favor of a strategy of biocultural diversity conservation (Boege 2008). Conserving biodiversity need not require setting land aside in preserves that exclude human occupation and use (MacKay and Carson 2004). Rather, sustainable management by local communities, in particular indigenous communities with subsistence economies that require deep ties to local landscapes and a commitment to *comunalidad* (Martínez-Luna 2013), can effectively conserve this global biotic heritage while simultaneously sustaining cultural diversity (Maffi 2001:8–12).

Two Zapotec Communities of Oaxaca

San Miguel Tiltepec is a settlement within the Ixtlán de Juárez municipality, population 417 (INEGI 2010), of which 77 % speak Zapotec as their first language (Fig. 1). The communal territory covers 130 km^2. The town center, at 1326 m elevation, is a nucleated settlement with household gardens. Nearby are *milpas* (fields for maize and beans), fruit orchards, forest patches where firewood and medicinal plants are harvested, and pasturage for domestic animals. The principal subsistence economic activity in San Miguel Tiltepec is maize agriculture, the "tortilla" – with beans, squash, and a variety of culinary herbs, notably chili peppers – constituting the staple diet. The residents complement their diet by collecting wild plants and mushrooms and hunting wild animals. They also cultivate coffee and sugarcane for local consumption and for sale in the regional market. A family's land is distributed over several plots to which the entire household moves in season.

San Miguel community lands encompass a substantial diversity of major habitat types. These include tropical evergreen forest between 800 and 1000 m, dominated by evergreen trees 30–40 m in height (cf. Wendt 1989). Beneath this forest canopy there are abundant lianas and epiphytes of tropical affinity. Montane cloud forest forms a band between 400 and 2250 m along the northern and eastern slopes of the Sierra Norte and the Sierra de Los Mixes. The temperature here is moderate, ranging between 14° and 20 °C, and humid, with a mean annual precipitation exceeding 2000 mm and reaching 6000 mm in some places (Rzedowski and Palacios-Chávez 1977). Dominant trees average 20–30 m in height. Evergreen and deciduous species bearing many epiphytes occur together with palms, tree ferns, ericaceous shrubs, and moisture-loving herbs (Paray 1951; Lorence and García-Mendoza 1989; Martin and de Ávila B. 1990). Floristically, this formation is a mixture of neotropical and holarctic elements, including affinities with South America and Asia. Also common are lianas and vines, such as *Lophospermum atrosanguineum* Zucc., endemic to Oaxaca (SEMARNAP 2000).

Pine forest occurs on basaltic substrates at 1600–2600 m. Six pine species dominate, with an average height of 25–40 m, and grasses dominate the lower stratum. Pine-oak forest is found between 2000 and 2800 m. The rare balsam firs (*Abies guatemalensis* Rehder and *A. hickelii* var. *macrocarpa* Martínez) are associated with these pines, mainly in ravines and above 2700 m. Fern diversity is exceptional, including rare tree ferns such as *Polystichum speciosissimum* (A. Braun ex Kunze) Copel. and *Dryopteris wallichiana* (Spreng.) Hyl. (Riba 1993). Oak forest is characteristic at relatively low elevations with a dry summer season. At least seven species of this genus are commonly encountered here. Other species are *Arbutus xalapensis* Kunth, *Calliandra* sp., and several species of orchid. This formation occurs westward (inland), towards the Río Grande Basin, where it gradually changes to shrub and/or low forest (Alcántara-Salinas 2011). More heavily modified habitats, such as in and around settlements, milpas, and roads and trails, adds diversity.

San Juan Mixtepec is an independent municipality in the district of Miahuatlán in the Sierra Sur, population 711 (www.snim.rami.gob.mx/), of which 94 % speak an indigenous Zapotec language as their first language (Fig. 1). The

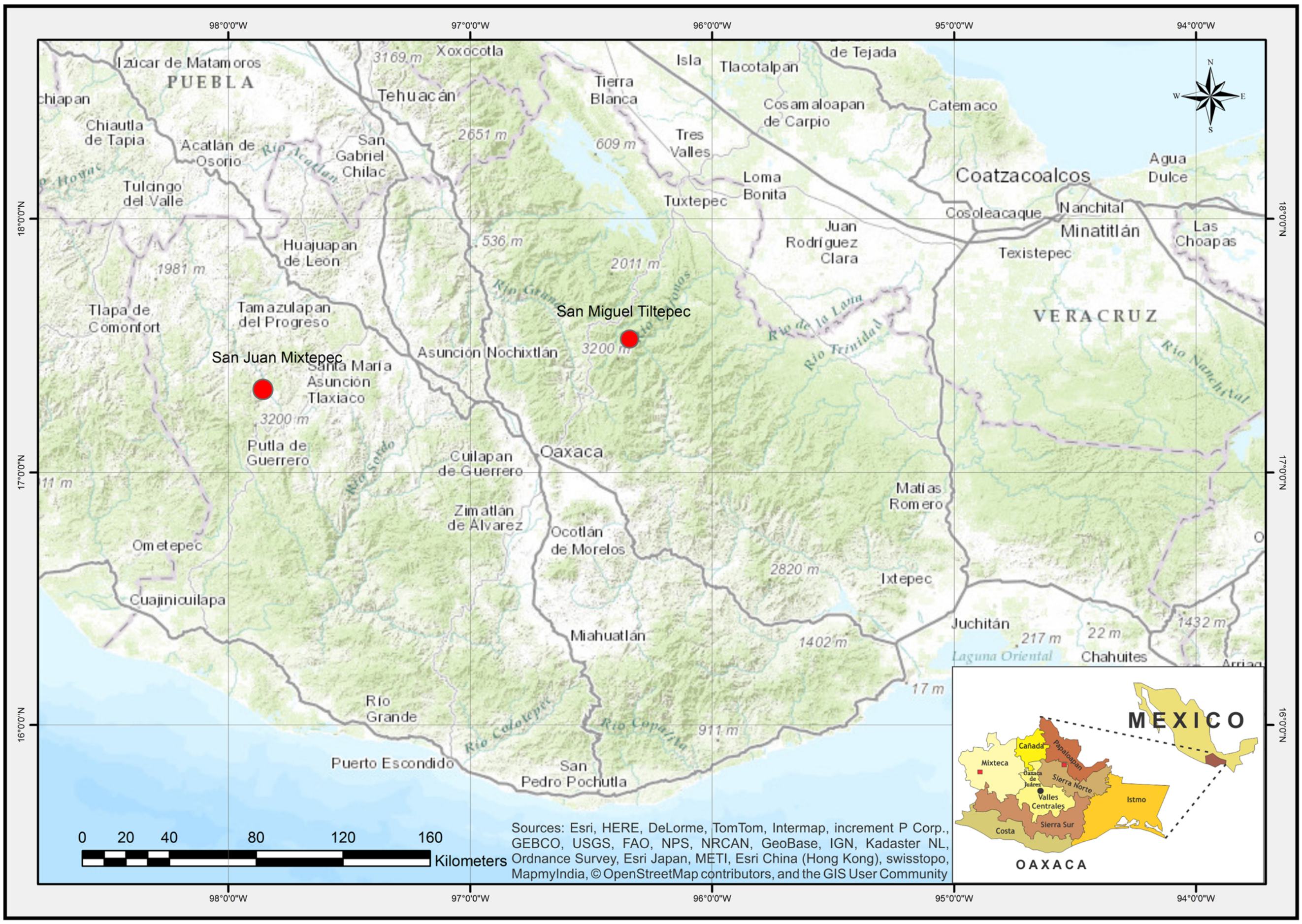

Fig. 1 San Miguel and San Juan locations

communal territory covers 58 km^2, plus 14 km^2 of high forest in dispute with a neighboring town. The town center is at 2050 m elevation. San Juan ancestors apparently sustainably farmed these same lands since Classic times (ca. 750 ACE) judging by local archaeological remains and local oral histories (Winter 1997; Hunn 2008).

San Juan has lost approximately 250 residents since 1990, mostly young men who have apparently opted to migrate north for wage work in preference to subsistence agriculture that has sustained the town population for over 1000 years within the immediate vicinity. However, the town remains to a substantial degree self-sufficient in basic food production, housing materials, and medical treatment, with some production of local clothing (Hunn 2008). A variety of "creole" cultivars of maize, beans, and squashes are sown in milpas cultivated by ox-drawn plows. These harvests are supplemented by a variety of greens, condiments, and fruits from household gardens and streamside orchards to meet the bulk of daily caloric and vitamin requirements, available land and weather permitting. Domestic chickens and turkeys provide meat and eggs, at least on special occasions. Goats and a few sheep are raised by some families for sale outside the community or for weddings, funerals, and other celebratory feasts. There is very little production for sale. The territory is too dry for commercial coffee.

Cultivated fields are interspersed with houses and gardens within the nucleated settlement and range for up to an hour's walk above and below the town on cleared land. Most farmers depend on rainfall during the rainy season, May or June through September. Relatively unmodified habitats occur at the lower elevations in the steep-walled canyons of the local streams and in the nearly unbroken pine-oak and pine forests between ca. 2400 and 3700 m. These forests are jealously guarded, with only very limited contract logging, hunting, and gathering of medicinal herbs (Hunn 2008). Communal boundaries are periodically patrolled by the local *Comisariado de Bienes Comunales*, a committee of local residents that is also responsible for allocating communal lands and resources to community members.

Highland pine forest above 3200 m are near uniform stands of *Pinus hartwegii* Lindl. with *Alnus jorullensis* Kunth var. *jorullensis* in clearings and along streams. *Agave atrovirens* Karw. ex Salm-Dyck is common on open ridges and in areas opened by crown fires (Hunn *et al.* 2001:15–16).

Humid pine-oak and pine-fir forest is found at 2700–3400 m. Balsam firs mixed with pines, oaks, alders, madrones, and the *manita de león* (*Chiranthodendron pentadactylon* Larreat.), the distinctive flowers of which attract a variety of hummingbirds, are found particularly in moist canyons. Epiphytic bromeliads (*Tillandsia* spp.) are common on oaks.

Arid pine-oak forest occurs below ca. 2200 m. These predominantly oak woodlands are rather open, though the pine canopy is enclosed above 2300 m. Mexican white-pine (*P. ayacahuite* C. Ehrenb. ex Schltdl.) is conspicuous above 2500 m. Seven species of oaks are common, the exact mix dependent on elevation. Hunn observed several pines and oaks at 2300–2900 m with diameters > 1 m, indicating the maturity of these forests. Clearings in these forests above 2300 m are typically associated with seepage areas and are ringed by up to 3-m tall *Baccharis heterophylla* Kunth shrubs.

Oak scrub or chaparral is found on drier slopes at 2000–2300 m. These habitats are covered by dense and diverse stands of 2–3 m-high shrubs. The chaparral may be broken by scattered groves of pines, junipers, oaks, and madrones. Giant lily-like plants such as *Agave potatorum* Zucc., *Furcraea longaeva* Karw. et Zucc., and *Nolina longifolia* (Karw. ex Schult. f.) Hemsl., are locally common on steep slopes subject to fire.

Arid subtropical scrub and deciduous woodland is found below 2000 m, a mosaic of low deciduous forest and scrub vegetation dominated by well-armed species of *Acacia* and *Mimosa* and arborescent or columnar cacti, with a variety of copal trees (*Bursera* spp.) and agaves. Riparian groves are prominent below 2300 m where the closed pine-oak forest gives way to more open terrain. Characteristic trees of this zone are alders and willows. Bald cypress (*Cupressus* sp.) occurs below 1700 m. This zone is frequently planted with fruit trees.

Modified terrestrial habitats include gardens, orchards, hedgerows, and road and trail margins in and near town (at 1900–2200 m). Such areas are characterized by anthropogenic woody vegetation. Exotic ornamentals and fruit trees have been planted in town. Living fences are of agaves, copal trees, arborescent cacti, coral bean, ocotillo, and *Jatropha cordifolia* Pax. Weedy roadside shrubs include *Wigandia urens* (Ruiz & Pav.) Kunth, and *Solanum* spp.

Methods

Our research was first approved by communal authorities in each community. Our bird observations are based on extensive visits to each community at all seasons over several years. The San Miguel Tiltepec bird list was compiled by Alcántara-Salinas and Acuca-Vásquez during visits totaling 118 days (1997–2000). The San Juan Mixtepec bird list was compiled by Hunn and Acuca-Vásquez during 64 visits totaling 282 days (1996–2004) in the course of Hunn's ethnobiological research. An annotated list has been published in *Cotinga* (Hunn *et al*. 2001:14–15). Most observations were visual with binoculars and of vocalizations, though mist nets were employed in strategic locations and photographs taken of birds in the hand. Sound recordings documented nocturnal species. Point census counts were conducted in San Miguel (for methodological details see Acuca-Vásquez *et al*. 2014). Identifications were by reference to Howell and Webb's authoritative field guide (1995). Relative abundance, habitat preferences, breeding status, and seasonality were assessed over the course of our multi-year observations.

The authors and their colleagues recorded local Zapotec names for birds whenever possible by coordinating our visual and/or vocal observations with our local consultants (cf. Hunn 1977: 19–21). To confirm the referential equivalence of a native term with a Linnaean genus or species name we queried consultants as to the appearance, vocalizations, behavior, habitat preferences, and season of occurrence of the bird in question. However, it was not always possible to establish unambiguously if and/or how a particular bird species was named in the local language. In certain cases local consultants either did not recognize or name a particular species or "lumped" several similar species together under a more general term. In other cases consultants disagreed with one another. In our experience, this is to be expected and such complications should be carefully noted.

Both studies combined methods from anthropology, ethnobiology and biology. We practiced "participant observation" (Bernard 2006; Puri 2011) in both communities, accompanying local residents as they worked in their fields, herded their goats, or searched for medicinal herbs in their forests. In this way we thoroughly explored each communal territory at all seasons in the company of local guides. We interviewed knowledgeable residents about their knowledge, use of and attitudes toward local birds, with particular attention to how the local community and its government managed local natural resources.

Alcántara-Salinas collected data addressing causes of differences and similarities in the encoding of zoological knowledge, uses and classification by Zapotec individuals. She used informal interviews during the early stage of the research to identify more experienced and knowledgeable individuals and to establish networks of informants, including men, women, young people and children. In addition, formal structured interviews were conducted. Once rapport was established with bird experts in the field they were able to provide folk terminology, data on diet, breeding, hunting uses, symbolism. Overall Alcántara-Salinas conducted formal interviews with 112 individuals. Quantitative methods such as free listing helped define the bird domain. Questionnaires–365 questionnaires were conducted with 75 individuals varying in age and gender –generated quantitative data to compare Zapotec and Spanish bird names, to clarify bird habitat preferences and seasonality, and to document hunting stretaegies, symbolism and oral tradition. Pile sorts were used late in the fieldwork (*N*=28) (Alcántara-Salinas 2011; Alcántara-Salinas *et al.* 2013).

Hunn worked with 32 primary consultants in San Juan, including 19 men and 13 women. Consultants ranged in age from six to over 60, selected by an informal process of "snowball sampling," that is, asking authorities and other willing residents to recommend knowledgeable individuals who might be willing to help in the research, and in turn asking them for additional names. In addition, Hunn interviewed 23 San Juan residents using a questionnaire in the local Zapotec language designed to clarify local values and perspectives (e.g., are X [some species of plant or animal] "intelligent" and, if so, are some more "intelligent" than others?) on how people relate to plants and animals. This helped clarify the range of local opinion with respect to a range of animals, plants, and other natural phenomena. Hunn also laid out a "plant trail" in San Juan with a diverse sample of 55 plant species flagged. He accompanied 36 children, aged seven to 14, around this trail, asking each in Zapotec to name each plant and in a sample of cases to indicate how it was used (Hunn 2002, 2008: 231–236). Though Hunn was unable to apply statistical controls, the results clearly indicated that children as young as seven may command a vocabulary of several hundred plant names. Vocabulary depended more on motivation and learning opportunity than on age or sex.

Results

Indigenous Communities as Informal Bird Refuges

We list our observations (Table 1) in systematic order (AOU 2011, 2014) by community, noting for each species whether introduced, resident, winter visitor, summer visitor, passage migrant, or vagrant, and whether endemic or of special conservation concern. We list a total of 313 species (plus one well marked subspecies, *Troglodytes aedon brunneicollis*), of which all but two (*Columba livia* and *Passer domesticus*), both recorded in San Juan, are native North American species. San Miguel accounted for 208 species, San Juan for 191, with 85 species recorded for both communities. Included are 47 species that are present in our region only in migration or winter, breeding to the north. Two additional species are present only in summer, nesting in the region but wintering to the south. Five species are transients or vagrants (e.g., *Phalaropus lobatus*, blown in from the Pacific by a hurricane) and thus not of regular occurrence. Thus 260 species are resident. As of 2004 the official Oaxaca state list included 736 species, with an additional 60 species not yet verified (Navarro *et al.* 2004:391), 67 % of the total recorded for Mexico. Of the official Oaxaca list, 503 species are resident, thus our two

Table 1 Birds Reported for San Miguel Tiltepec (SMT) and San Juan Mixtepec (SJM) with Indices of Conservation Status (I), Seasonality/Origin (II), and Endemic Status (III)

I[a]	II[b]	III[c]	SMT	SJM	Latin Name
A			1		*Tinamus major*
A			2		*Crypturellus boucardi*
			3		*Ortalis vetula*
		E		1	*Ortalis poliocephala*
A			4		*Penelope purpurascens*
A			5		*Crax rubra*
A		E	6	2	*Dendrortyx macroura*
PE			7		*Odontophorus guttatus*
			8		*Dactylortyx thoracicus*
PE				3	*Cyrtonyx montezumae*
	V			4	*Bubulcus ibis*
			9	5	*Coragyps atratus*
			10	6	*Cathartes aura*
P			11	7	*Sarcoramphus papa*
PE	V			8	*Chondrohierax uncinatus*
P			12		*Spizaetus tyrannus*
	W			9	*Circus cyaneus*
PE			13	10	*Accipiter striatus*
PE	X			11	*Accipiter cooperi*
P	R		14		*Buteogallus solitarius*
			15		*Rupornis magnirostris*
PE			16		*Pseudastur albicollis*
				12	*Buteo brachyurus*
PE	W		17	13	*Buteo albonotatus*
			18	14	*Buteo jamaicensis*
	V			15	*Bartramia longicauda*
	V			16	*Phalaropus lobatus*
	I			17	*Columba livia*
			19		*Patagioenas flavirostris*
				18	*Patagioenas fasciata*
PE			20		*Patagioenas nigrirostris*
				19	*Columbina inca*
				20	*Columbina passerina*
			21		*Claravis pretiosa*
A			22		*Geotrygon albifacies*
				21	*Leptotila verreauxi*
			23	22	*Zenaida asiatica*
				23	*Zenaida macroura*
			24		*Piaya cayana*
			25	24	*Geococcyx velox*
				25	*Tyto alba*
				26	*Megascops trichopsis*
A				27	*Bubo virginianus*
A				28	*Glaucidium gnoma*
	X	QE		29	*Micrathene whitneyi*
			26		*Ciccaba virgata*
			27	30	*Chordeiles acutipennis*

Table 1 (continued)

I[a]	II[b]	III[c]	SMT	SJM	Latin Name
			28	31	*Antrostomus arizonae*
			29	32	*Cypseloides niger*
			30	33	*Streptoprocne rutila*
			31		*Streptoprocne zonaris*
				34	*Aeronautes saxatilis*
PE			32		*Panyptila cayennensis*
			33		*Phaethornis longirostris*
			34		*Phaethornis striigularis*
			35		*Campylopterus curvipennis*
			36		*Campylopterus hemileucurus*
				35	*Colibri thalassinus*
				36	*Eugenes fulgens*
			37	37	*Lampornis amethystinus*
		QE		38	*Lampornis clemenciae*
A			38	39	*Lamprolaima rhami*
		NE		40	*Calothorax pulcher*
	W			41	*Archilochus colubris*
		E	39	42	*Atthis heloisa*
		SE	40	43	*Selasphorus platycercus*
	W			44	*Selasphorus rufus*
		NE		45	*Cynanthus sordidus*
PE			41		*Abeillia abeillei*
			42		*Eupherusa eximia*
			43		*Amazilia candida*
			44		*Amazilia cyanocephala*
			45	46	*Amazilia beryllina*
A		E		47	*Amazilia viridifrons*
			46	48	*Hylocharis leucotis*
A			47		*Trogon massena*
			48		*Trogon melanocephalus*
			49		*Trogon caligatus*
				49	*Trogon elegans*
			50	50	*Trogon mexicanus*
PE			51		*Trogon collaris*
			52		*Momotus coeruliceps*
PE			53		*Aulacorhynchus prasinus*
PE			54		*Pteroglossus torquatus*
A			55		*Ramphastos sulfuratus*
			56	51	*Melanerpes formicivorus*
		NE		52	*Melanerpes hypopolius*
			57		*Melanerpes aurifrons*
	W			53	*Sphyrapicus varius*
			58	54	*Picoides scalaris*
			59		*Picoides fumigatus*
				55	*Picoides villosus*
			60		*Colaptes rubiginosus*
				56	*Colaptes auratus*
			61		*Dryocopus lineatus*
PE			62		*Campephilus guatemalensis*

Table 1 (continued)

I[a]	II[b]	III[c]	SMT	SJM	Latin Name
PE			63		*Micrastur ruficollis*
PE			64		*Micrastur semitorquatus*
			65	57	*Falco sparverius*
PE				58	*Falco peregrinus*
PE			66		*Eupsittula nana*
A		E	67		*Psittacara holochlorus*
VU, P				59	*Ara militaris*
P			68		*Pyrilia haematotis*
A			69		*Pionus senilis*
EN, P		QE	70		*Amazona oratrix*
PE			71		*Taraba major*
			72		*Thamnophilus doliatus*
			73		*Formicarius analis*
A			74		*Sclerurus mexicanus*
			75		*Sittasomus griseicapillus*
PE			76		*Dendrocincla anabatina*
			77		*Dendrocincla homochroa*
			78		*Xiphorhynchus flavigaster*
A			79		*Xiphorhynchus erythropygius*
			80		*Lepidocolaptes souleyetii*
		E		60	*Lepidocolaptes leucogaster*
			81	61	*Lepidocolaptes affinis*
				62	*Camptostoma imberbe*
				63	*Myiopagus viridicata*
			82		*Mionectes oleagineus*
			83		*Rhynchocyclus brevirostris*
PE			84		*Platyrinchus cancrominus*
			85		*Myiobius sulphureipygius*
PE/NT		NE		64	*Xenotriccus mexicanus*
			86	65	*Mitrephanes phaeocercus*
			87	66	*Contopus pertinax*
			88	67	*Contopus sordidulus*
	W		89		*Empidonax minimus*
	W			68	*Empidonax hammondii*
	W	SE		69	*Empidonax oberholseri*
		QE	90	70	*Empidonax affinis*
		SE	91	71	*Empidonax occidentalis*
	X		92		*Empidonax flavescens*
				72	*Empidonax fulvifrons*
			93	73	*Sayornis nigricans*
	W			74	*Sayornis saya*
			94	75	*Myiarchus tuberculifer*
				76	*Myiarchus nuttingi*
			95		*Myiarchus tyrannulus*
			96		*Pitangus sulphuratus*
			97		*Megarynchus pitangua*
			98		*Myiozetetes similis*
	S		99		*Myiodynastes maculatus*
			100		*Tyrannus melancholicus*

Table 1 (continued)

I[a]	II[b]	III[c]	SMT	SJM	Latin Name
		SE	101	77	*Tyrannus vociferans*
		QE		78	*Tyrannus crassirostris*
	W		102	79	*Tyrannus verticalis*
	W			80	*Tyrannus forficatus*
A			103		*Cotinga amabilis*
			104		*Ceratopipra mentalis*
			105		*Tytira inquisitor*
			106		*Tytira semifasciata*
PE			107	81	*Pachyramphus major*
			108	82	*Pachyramphus aglaiae*
				83	*Lanius ludovicianus*
		NE		84	*Vireo brevipennis*
			109	85	*Vireo plumbeus*
	W	SE	110	86	*Vireo cassinii*
				87	*Vireo huttoni*
		E		88	*Vireo hypochryseus*
			111	89	*Vireo gilvus*
			112		*Vireo leucophrys*
			113		*Hylophilus decurtatus*
		QE		90	*Vireolanius melitophrys*
P/VU		NE	114		*Cyanolyca nana*
			115		*Cyanolyca pumilo*
A			116		*Cyanolyca cucullata*
			117		*Cyanocorax yncas*
			118	91	*Cyanocitta stelleri*
			119	92	*Aphelocoma coerulescens*
A			120		*Aphelocoma unicolor*
			121	93	*Corvus corax*
				94	*Eremophila alpestris*
			122	95	*Stelgidopteryx serripennis*
	W			96	*Tachycineta thalassina*
	W			97	*Hirundo rustica*
			123	98	*Petrochelidon pyrrhonota*
		QE		99	*Poecile sclateri*
				100	*Baeolophus wollweberi*
			124	101	*Psaltriparus minimus*
				102	*Sitta carolinensis*
	X			103	*Sitta pygmaea*
				104	*Certhia americana*
				105	*Salpinctes obsoletus*
				106	*Catherpes mexicanus*
	W		125	107	*Troglodytes aedon*
		QE*	125	107	*Troglodytes a. brunneicollis*
			126	108	*Thryomanes bewickii*
			127		*Campylorhynchus zonatus*
		NE		109	*Campylorhynchus jocosus*
			128		*Pheugopedius maculipectus*
			129		*Henicorhina leucosticta*
			130	110	*Henicorhina leucophrys*

Table 1 (continued)

I[a]	II[b]	III[c]	SMT	SJM	Latin Name
			131	111	*Polioptila caerulea*
PE			132	112	*Cinclus mexicanus*
				113	*Regulus satrapa*
	W			114	*Regulus calendula*
				115	*Sialia sialis*
PE			133	116	*Myadestes occidentalis*
A			134		*Myadestes unicolor*
			135	117	*Catharus aurantiirostris*
		E		118	*Catharus occidentalis*
A			136	119	*Catharus frantzii*
PE			137		*Catharus mexicanus*
	V		138		*Catharus fuscescens*
	W			120	*Catharus ustulatus*
	W		139	121	*Catharus guttatus*
	W		140		*Hylocichla mustelina*
			141		*Turdus grayi*
			142	122	*Turdus assimilis*
				123	*Turdus migratorius*
PE		E		124	*Ridgwayia pinicola*
				125	*Mimus polyglottos*
		NE		126	*Toxostoma ocellatum*
				127	*Toxostoma curvirostre*
A		E	143	128	*Melanotis caerulescens*
	W			129	*Anthus rubescens*
	W			130	*Bombycilla cedrorum*
		QE	144	131	*Ptilogonys cinereus*
				132	*Peucedramus taeniatus*
	W		145		*Seiurus aurocapilla*
	W		146	133	*Parkesia motacilla*
	W		147	134	*Mniotilta varia*
				135	*Oreothlypis superciliosa*
	W			136	*Oreothlypis celata*
	W		148	137	*Oreothlypis ruficapilla*
A	W		149	138	*Geothlypis tolmiei*
			150		*Setophaga pitiayumi*
	W		151		*Setophaga magnolia*
	W			139	*Setophaga coronata*
	W			140	*Setophaga dominica*
	W	SE		141	*Setophaga nigrescens*
	W		152	142	*Setophaga townsendi*
	W		153	143	*Setophaga occidentalis*
	W		154	144	*Setophaga virens*
			155		*Basileuterus lachrymosus*
		QE	156	145	*Basileuterus rufifrons*
			157	146	*Basileuterus belli*
			158		*Basileuterus culicivorus*
	W		159	147	*Cardellina pusilla*
	W	SE		148	*Cardellina rubrifrons*
		E	160	149	*Cardellina ruber*

Table 1 (continued)

I[a]	II[b]	III[c]	SMT	SJM	Latin Name
			161	150	*Myioborus pictus*
			162	151	*Myioborus miniatus*
PE			163		*Lanio aurantius*
			164		*Ramphocelus sanguinolentus*
			165		*Thraupis episcopus*
			166		*Thraupis abbas*
			167		*Tangara larvata*
	S		168		*Cyanerpes cyaneus*
			169		*Chlorophanes spiza*
			170	152	*Diglossa baritula*
			171		*Volatinia jacarina*
			172		*Sporophila corvina*
			173	153	*Sporophila torqueola*
			174		*Coereba flaveola*
			175		*Tiaris olivaceus*
			176		*Saltator coerulescens*
			177		*Saltator maximus*
			178		*Saltator atriceps*
			179	154	*Arremon brunneinucha*
		QE	180		*Arremonops rufivirgatus*
		E	181		*Atlapetes albinucha*
		E		155	*Atlapetes pileatus*
		E		156	*Pipilo ocai*
				157	*Pipilo maculatus*
			182	158	*Aimophila ruficeps*
		NE		159	*Melozone albicollis*
		NE		160	*Peucaea mysticalis*
				161	*Spizella passerina*
	W	SE		162	*Spizella pallida*
	W			163	*Pooecetes gramineus*
	W			164	*Ammodramus savannarum*
	W		183	165	*Melospiza lincolnii*
		QE	184	166	*Junco phaeonotus*
			185	167	*Chlorospingus flavopectus*
			186	168	*Piranga flava*
	W			169	*Piranga rubra*
	W			170	*Piranga ludoviciana*
			187		*Piranga leucoptera*
		E		171	*Piranga erythrocephala*
			188		*Habia rubica*
			189		*Habia fuscicauda*
			190		*Caryothraustes poliogaster*
		SE		172	*Pheucticus melanocephalus*
			191		*Cyanocompsa cyanoides*
			192		*Cyanocompsa parellina*
				173	*Passerina caerulea*
	W			174	*Passerina cyanea*
			193	175	*Dives dives*
				176	*Quiscalus mexicanus*
			194	177	*Molothrus aeneus*
			195		*Molothrus ater*
				178	*Icterus wagleri*
			196		*Icterus prosthemelas*
	W			179	*Icterus spurius*
				180	*Icterus pustulatus*
	W	SE		181	*Icterus bullocki*
A		QE	197	182	*Icterus graduacauda*
	W		198	183	*Icterus galbula*
			199		*Amblycercus holosericeus*
			200		*Euphonia affinis*
			201		*Euphonia hirundinacea*
			202	184	*Euphonia elegantissima*
PE			203		*Euphonia gouldi*
			204		*Chlorophonia occipitalis*
				185	*Haemorhous mexicanus*
				186	*Loxia curvirostra*
			205	187	*Spinus notatus*
			206	188	*Spinus psaltria*
	X	QE	207	189	*Coccothraustes abeillei*
	X			190	*Coccothraustes vespertinus*
	I			191	*Passer domesticus*

[a] SEMARNAT (2010): *PE Sujeta a protección especial*, *A amenazada*, *P en peligro de extinción*; BirdLife International (2014): *EN* endangered, *VU* vulnerable, *NT* near threatened

[b] *W* winter visitor, *S* summer only, *V* vagrant, *I* introduced, *X* range extension documented in these studies

[c] *E* endemic to Mexico, *NE* "near endemic," endemic to south-central Mexico, *QE* "quasi-endemic," range extends minimally beyond Mexican borders, *SE* "semi-endemic," winter range restricted to Mexico (in large part)

communities host 52 % of all the resident birds of the entire state, within just 200 km^2, or 0.2 % of the state's land area.

The two Zapotec communities we studied are roughly similar in size (San Miguel Tiltepec,130 km^2; San Juan Mixtepec, 72 km^2) and population (San Miguel Tiltepec, 417; San Juan Mixtepec, 711 in 2010), share common traditions, notably in their subsistence agricultural economies, speak related languages of the Zapotec family (San Miguel Tiltepec, 77 %; San Juan Mixtepec, 94 % native speakers, respectively), and share a common history of colonial and post-colonial occupation by a Spanish-speaking, Catholic imperial state. Both are likewise now engaged with a global economy that offers new options for livelihoods via migration.

However, they occupy quite distinct ecological zones, as shown by the fact that of the 313 species of birds we recorded in the two communities, only 27 % are shared. This contrast is clearly due to their respective geographic positions: San Miguel occupies a lower average elevation in a more humid climate compared to San Juan. San Miguel includes substantial areas of humid tropical and montane cloud forest largely absent in San Juan, while San Juan encompasses extensive tropical dry forest with its notably distinct flora and fauna. Taken together, the two communities encompass the most biodiverse terrestrial habitats to be found in Mexico. The Sierra Norte (San Miguel) is aligned more with Neotropical fauna derived from South America while the Sierra Sur (San Juan) has strong affinities with Nearctic fauna. The dominant bird families in each are quite different (cf. Escalante *et al.* 1993). Also San Juan is more important as a refuge for North American migrants than San Miguel. Of the 47 species in our lists that winter here while breeding to the north, 43 winter in San Juan while just 19 winter in San Miguel. In short, our two communities provide a refuge for two quite distinct avifaunas.

Our community bird lists are also rich in endemic species. Of the 104 Mexican endemic bird species (González-García and Gómez-de Silva 2002:1809–182), 61 are found in Oaxaca, plus 17 of Mexico's 47 "quasi-endemic" species, that is, those that mostly nest in Mexico, but also within limited regions beyond Mexico's borders (González-García and Gómez-de Silva 2002:183–184). Of these, 25 endemics (43 % of the total for Oaxaca, including 10 "regional endemics," those nesting only within the southern highlands of Mexico) and 11 additional quasi-endemic species are found in our two communities. It is noteworthy that San Juan, with a smaller total avian inventory than San Miguel, hosts many more endemic species, 22 (including nine near endemics and nine quasi-endemics). By contrast, San Miguel hosts just seven endemics, one regional endemic, and eight quasi-endemics. This is largely attributable to the concentration of endemics in arid tropical forests, habitat absent from the more humid Sierra Norte. One may also distinguish "semi-endemics," defined as bird species that winter exclusively or to a very large extent within Mexico (González-García and Gómez-de Silva 2002:185–186). Of 46 such species, 13 occur in San Juan and three of these also in San Miguel. This contrast is due to the far greater affinity of the San Juan avifauna with North America, the source of most such "semi-endemics." In sum, these two indigenous Zapotec communities offer essential refuge for a substantial number of endemic species, both resident and migratory, which are of particular concern for bird conservation.

Our communities also shelter a substantial number of the 195 Oaxacan species judged of special concern (including those judged *amenazada* ['Threatened'] and *en peligro de extinción* ['In danger of extinction'] by SEMARNAT (2010) and of the 26 such species included in the list of endangered and threatened species of BirdLife International (2014)). Of these, we have recorded 60 (31 %) species, including 24 threatened and seven in danger of extinction. We recorded four species that are on the BirdLife International watch list (15 %), including one considered endangered (*Amazona oratrix*), two considered vulnerable (*Ara militaris*, *Cyanolyca nana*), and one "near threatened" (*Xenotriccus mexicanus*). The Military Macaw (*Ara militaris*) is known from San Juan only to older people who report that it has not been seen in many years; it is nearly extirpated from Oaxaca, likely due to the depredations of the pet trade (cf. Howell and Webb 1995:337), though there remains an isolated population in the La Cañada region on the Atlantic slope.

It is noteworthy that in contrast to the patterns of endemism, San Miguel harbors twice as many species of special concern than does San Juan: 47 compared to 22, including 13 versus seven considered threatened and four versus two in danger of extinction. Many of these species are restricted to cloud forests, a habitat of limited extent in Mexico that is threatened by logging and the development of coffee plantations. In short, our two communities provide critical refuge for the conservation of biodiversity in this megadiverse region.

Traditional Environmental Knowledge, Cultural Values, and in situ Conservation

Traditional Environmental/Ecological Knowledge (TEK) may be seen as a necessary though not sufficient foundation for the local conservation of birds and their habitats. The TEK of the citizens of San Miguel and San Juan does not focus on birds. For example, San Juan Mixtepec Zapotec TEK emphasizes knowledge of the local flora. Hunn recorded over 700 named plant taxa in San Juan (Hunn 1998), which local residents use to refer to a local vascular plant inventory estimated at over 1000 species. By contrast, Hunn recorded approximately 100 distinct bird names for San Juan. Bird nomenclature is less highly elaborated, perhaps because wild birds play a quite limited economic role in San Juan Mixtepec.

Hunn recorded 72 distinct named "generic" bird categories (cf. Berlin 1992) in Mixtepec Zapotec. Twenty-one of these are polytypic, that is, they include two or more "specific" subcategories. Thus there is a total of 105 "terminal taxa" (the sum of monotypic generic taxa and specific taxa) recognized in San Juan. Zapotec folk taxa may correspond to scientific species one-to-one (66 %) or they may be under-differentiated, that is, the Zapotec category may encompass more than one scientific species (27 % of the Zapotec folk taxa). Various hummingbirds, flycatchers, and wood warblers are "lumped" into a few rather poorly demarcated categories. Thirty-five additional species were observed by local consultants but not named (abstracted from Hunn 2008:109–116). In sum, San Juaneros attend selectively to the birds in their experience, largely ignoring the smaller species, particularly those that are present only seasonally. This pattern is also typical of other well-documented ethno-ornithological inventories in Mexico, such as Tenejapa Tzeltal (Hunn 1977), Yucatec Maya (Anderson and Medina-Tzuc 2004), and Northern Piman (Rea 2007). Of course, their observations are "naked eye." Nevertheless, they appreciate avian diversity and have noted the recent demise of such conspicuous rarities as the King Vulture and Military Macaw.

The situation in San Miguel Tiltepec is similar (Alcántara-Salinas 2011:159, 193ff; though we lack ethnobotanical data for that community). The 208 species of birds recorded in San Miguel were classified in the local Zapotec within 30 named “folk generic” taxa, 11 of which were further differentiated into 77 “folk specific” subcategories, and of these six were further subdivided into 11 “folk varietal” taxa (cf. Berlin 1992) for a total of 102 terminal taxa, coincidentally exactly comparable to the 102 such taxa recorded for San Juan. In both communities phylogenetic relationships were recognized in a large majority of cases, with a few not unreasonable deviations from contemporary ornithological opinion, e.g., lumping of swifts (Apodidae) with swallows (Hirundinidae) and of tinamous (Tinamidae) with quail (Odontophoridae). In San Miguel the King Vulture (*Sarcoramphus papa*) and the Great Curassow (*Crax rubra*) were treated as closely related, apparently due to their superficial similarity in size and shape coupled with their extraordinary distinctiveness *vis-à-vis* other species of their families. Similar patterns of “lumping” of the smaller and/or migratory species were noted in both communities. Such species are named *vigini win* or *chëbete* in San Miguel and *wǐt* or *yěets* in San Juan. These may be targeted by children practicing hunting skills using slingshots, to complement their diet. These classificatory deviations aside, the folk ornithological taxonomies of both communities clearly demonstrate close attention to detail and intimate familiarity with the local avifauna.

Quail, partridges, and guans were prime targets of hunters in both communities, though traditional hunting in San Miguel plays a larger role in the local subsistence economy and community identity than is the case for San Juan. Although we have no quantitative data on the rate of hunting per year, in the case of San Miguel we can affirm that local hunters have a deep knowledge of the breeding biology and habitat requirements of prey species, and of the optimal times to hunt. Hunting involves a considerable degree of organization and hunters spend several days n the forest. Local authorities allow only a select group of men to hunt per year. Hunting is significant not only for food, but also for maintaining high social status. Successful hunters mount heads or antlers, traditionally preserved, on the entrance to their houses.

In both communities, birds were recognized as playing key ecological roles and supporting environmental values. For example, the King Vulture, known as *brhudi*, that is, in San Miguel Zapotec ‘priest,’ is said to be the first to locate a dead animal. It first eats the eyes and the tongue of the carcass. Local people believe that this action “blesses” the dead animal while alerting other vultures in the vicinity. San Miguel residents value all vultures, as they together “keep the forest clean.”

Birds are often considered to be like humans, willful, intelligent, and environmentally sensitive. In San Juan and San Miguel, owls and the Mexican Whip-poor-will (*Caprimulgus arizonae*) are widely considered to be ill omens, foretelling illness or death if they call near the house. Red-tailed hawks (*Buteo jamaicensis*) or other raptors circling overhead calling may also portend misfortune. In San Miguel Sharp-shinned and Zone-tailed hawks (*Accipiter striatus*, *Buteo albonotatus*) foretell bad news if seen flying frequently around a particular house. But a Solitary Eagle (*Buteogallus solitarius*), White Hawk (*Pseudastur albicollis*), or Black Hawk-Eagle (*Spizaetus tyrannus*) foretell good news when suddenly encountered or heard in the forest.

Curiously, in San Juan the Canyon Wren (*Catherpes mexicanus*) is feared. They often nest in abandoned houses in town and thus are associated with death. By contrast, in San Miguel House Wrens (*Troglodytes aedon*) are considered to be “housekeepers,” cleaning houses of irritating insects, though these wrens may also steal bits of tortilla from the main table “as a reward,” a form of symbiosis. Swifts and swallows foretell the timing of the onset of the rainy season or predict the quality of imminent rainfall. In San Miguel guans, quail, and their relatives (Cracidae, Odontophoridae) foretell the onset of changeable weather. If encountered on a sunny day, the next day will be rainy.

Very few birds have medicinal applications. We noted only toucans, used to treat complications of birth, and hummingbirds, which may be eaten to cure ‘fright’ (*espanto*, *susto*, or *mal del ataque* in Spanish; *dzéb* in Mixtepec Zapotec). Onomatopoetic names are common, and some bird songs are interpreted as Zapotec phrases or incorporated in the local bird name. Such names demonstrate close attention to bird behavior, despite their limited material value, which in San Miguel involves the use of toucan (*Ramphastos sulphuratus*) or curassow (*Crax rubra*) heads to decorate dancers' costumes or the door of a house to signify high social status. The shinbone (*rhita lunia-ba*) and femur (*rhita kutzi*) of the curassow, chachalaca (*Ortalis vetula*), and Crested Guan (*Penelope purpurascens*), important game birds, are used to shell maize, while wing and tail feathers are used to fan the kitchen fire.

However, does this detailed appreciation of avian diversity within these communities translate into behavior that might be interpreted as “conservation”? Beyond the indirect evidence that these communities have for many centuries lived sustainably within their local habitats, preserving space for a substantial diversity of bird species, we may note that there is a widely shared attitude toward birds and elements of the local natural environment more generally which has been termed “animistic.” That is, local residents think of birds in anthropomorphic terms rather than simply as “objects to be used.” As noted above, many birds are considered intelligent. In San Juan Zapotec, they are considered to be “sharp, intelligent” (*guièl̲-bìinî*), though how “sharp” they are varies by species, with turkeys ranked just above frogs. The Great Horned Owl was considered exceptionally “intelligent,” given its powers of foresight (Hunn 2008:100). Hunn surveyed a small local sample of opinion with respect to whether people should keep birds in cages, for example, White-winged Doves. Some said it was fine, as the birds were beautiful and could thus be admired, an anthropocentric judgment, but an equal number opposed the practice on the grounds that, "God would be sad" to see his creatures so confined and that might bring "bad luck, " a "biocentric" moral evaluation (Hunn 2008:101).

Alcántara-Salinas pursued similar questions about local cultural values. She reported that "smart behavior," "intelligence" and even "wisdom" were attributed to birds as well as other animals. Birds were also thought to exhibit amongst themselves such human attributes as "friendship," mutual help, and "virtue". A number of species were judged to be capable of exerting "magical power" over people, notably among the birds of prey, cuckoos, and the roadrunner. Alcántara-Salinas documented a system of folk zoological classification that emphasized ecological and behavioral properties that included not just birds but all animals (Alcántara-Salinas *et al*. 2013).

Discussion and Conclusions

These explicit cultural values might not ensure the conservation of local habitats (and thus local avian diversity) had there not been a relatively stable balance between the subsistence requirements of the local population and the local resource base. In the past, this might have been due to higher mortality rates. In San Juan in recent decades a pattern of "circular migration" has helped maintain this balance. A substantial number of "citizens" of the town live outside, mostly in nearby cities, but they retain their "citizenship" and commitment to their home community, returning periodically, often for fiestas, bringing an infusion of cash, commodities, and information about the regional and national context. One might say that the global economy "subsidizes" the local, indigenous community, facilitating continuing sustainable husbanding of local land and resources and an intense loyalty to the home community. Thus these communities are not "isolated" but rather "insulated" from the more destructive impacts of globalization. This insulation is in part a consequence of a strong preference for *endogamy*, marriage within the community. In fact, as of 2000 there were just a handful of marriages in conflict with this rule. It is also noteworthy that San Juan rejected coercive efforts by the Mexican federal government in the 1960s to suppress the local Zapotec language in favor of Spanish. San Miguel resisted the prohibition of Zapotec promoted by a primary school teacher in 1970. The town authorities expelled the teacher from the community.

Other social changes that might affect traditional-ecological knowledge in San Miguel are the growing popularity of Protestant churches in the region. Protestants actively discourage Zapotec traditional practices as "Catholic festivities." This undermines the *cargo* and *tequio* systems of community service as well as the Zapotec language, all central to a powerful sense of community or *comunalidad*. Government welfare programs such as *Oportunidades* (now *Prospera*) also devalue traditional environmental knowledge while fostering a sense of paternalism and dependency. For example, the *Prospera* program requires that pregnant women rely only on the services of the government clinic, avoiding traditional midwives. Toucan beaks and feathers – important for traditional therapeutic rituals accompanying birth – are prohibited. A final example of state interventions is the sale of imported US maize through government stores. This creates dependence on imported food, discouraging local production.

San Juan is currently 10 % Protestant, but so far has avoided debilitating sectarian conflict. Local farmers consider government maize inferior to local *creole* varieties in taste and reliability. Thus, local communities are not helpless "victims of progress" but able to adapt and evolve on their own terms.

We surmise that the *comuneros* of these indigenous communities do not "conserve biodiversity" for its own sake, whether avian or otherwise, but rather are motivated to protect their homeland for future generations. Community membership is a birthright that has substantial value - material, social, and cultural. Their land provides for their basic subsistence needs for food, materials, and medicines. It also is the center of their social world and the foundation for their identity. This commitment to ones local community of birth, or *comunalidad*, has been proposed as a distinctive and powerful cultural force of resistance characteristic of Oaxaca's indigenous communities (Martínez-Luna 2013). They will not lightly abandon this heritage. In both indigenous communities the continued transmission of these cultural values and perspectives from parents to children is key. That transmission in turn depends upon preserving the local language and the traditional subsistence economic engagement with local natural resources.

Global attention has focused since the 1970s on the fact that the earth's resources on which all life depends are strictly finite. Conservation biologists fearing the pending extinction of a substantial fraction of contemporary species have called for the establishment of protected areas, national parks or wildlife preserves, to minimize the destructive impact of a burgeoning human population and the geometric growth in per capita consumption around the world. Critics, however, document how such preserves may displace and impoverish long resident local or indigenous populations that are dependent on the resources of these territories, not only for their basic subsistence livelihood but also for their cultural identity and mental health (Neumann 2000; Poirier and Ostergren 2002; Hunn *et al*. 2003; MacKay and Carson 2004). In response, and in recognition of the value of biocultural diversity

(Maffi 2001), Oaxaca has promoted the concept of *áreas comunitarias protegidas* (communal protected areas) for which San Miguel and San Juan should be eligible.

Our ethno-ornithological research in two Zapotec communities spanning key terrestrial habitats of Oaxaca contributes to the debate on the most effective and just means to conserve global biodiversity while respecting the communities living within the most biodiverse regions. We believe that the best way to conserve biodiversity is not to lock people out of their traditional homes, but rather to support local communities in their efforts to conserve their traditional livelihoods. Official Mexican policy in this respect has been inconsistent. On the one hand, there is support for communal protected areas, but on the other, the Mexican government has restricted traditional hunting, a practice intrinsic to the ecology of indigenous community lands, where prey species have co-evolved with human populations over millennia.

The current Wildlife Management Law (LGVS, www.semarnat.gob.mx) strictly prohibits hunting of just a few "charismatic species," but regulates hunting, including for subsistence, limiting quantities allowed and requiring that local community authorities assure compliance with conservation principles. Federal enforcement by SEMARNAT subjects local communities to external control rather than engaging them in collaborative management. Traditional hunting can be seen as a product of adaptive co-management of natural resources through time. The fact that the local ecological balance is an historic product of predation and harvesting by humans is often ignored, as is the fact that bird hunting is an important context for transmitting ethnobiological and ethno-ornithological knowledge.

Conservation biologists may be skeptical that local communities will be able to resist the seduction of commercialization of their local resource base and thus willing to conserve local biodiversity for the long term. However, we may cite in support of such local control an example from near San Miguel Tiltepec in the Sierra Norte of Oaxaca. A 25-year logging concession was imposed on indigenous communities of the Sierra Norte in 1955. This contract was not renewed upon its expiration in 1980 following vigorous coordinated opposition by indigenous community leaders. Control of logging concessions has reverted to those communities (Vigueras 2003:212). These Zapotec communities are governed not in the interest of profitability but rather, and more profoundly, by a commitment to *comunalidad* that inspires a "moral economy" of sustainability through collective environmental stewardship (Alcorn 1993; Toledo 2001; Berkes 2008; Boege 2008). Eight local communities involved in this opposition received commendations in 2002 of *El Regalo para la Tierra* (Gifts for the Earth) by the World Wildlife Fund (Galindo-Leal 2004:16) in recognition of their efforts at community-based conservation.

The world's megadiverse "hotspots" very often coincide with where the greatest diversity of indigenous languages survives (Maffi 2001). The fact that the two Zapotec communities featured here have lived in situ for hundreds, if not more than a thousand years – over 500 of those years under colonial domination – with no loss of avian diversity proves that it is not necessary to remove the people from the land in order to conserve biodiversity. Nor are San Miguel and San Juan isolated special cases; they are but two of hundreds of indigenous communities in Oaxaca and thousands throughout the world who live *with the land*, not just *on* or *off* it (Hunn 1999).

Our ethnobiological and ethnoecological research also clearly demonstrates that these indigenous *campesinos* are not accidental conservationists (Hunn and Williams 1982; Smith and Wishnie 2000). They have not failed to overexploit the natural resources under their control by virtue of low population and/or technological incapacity. Rather, they are sophisticated observers of natural history, formally recognizing a substantial fraction of the plants and animals within their traditional lands, first by naming several hundreds of plant and animal species and recognizing phylogenetic relationships among them, then by appreciating their value not only as food, material, or medicine, but also for the ecological roles they play in the economy of nature.

Yet the balance between the citizens of these indigenous communities and their natural environment is delicate. Clearly, if these local communities are to continue to conserve local biodiversity their populations must not exceed local "carrying capacity," given local subsistence strategies. On the other hand, the vitality of the local communal culture may be undermined if too many young people emigrate, choosing to abandon their local attachments, a process that may be underway in San Juan. Other threats to the integrity of local communities – a precondition for their success as stewards of local biodiversity – include varieties of commercial development that displace subsistence agriculture. The divisive social impact of commercial coffee production in one indigenous Sierra Sur community in Oaxaca is detailed by Hernández-Díaz (1987). We should note also the destructive logging of Zapotec communal lands in the Sierra Norte during the 1970s and 1980s. In both cases, local communities were manipulated by outside political interests. It is noteworthy that the Sierra Norte communities subsequently refused to extend logging contracts promoted by the state and federal governments in favor of local control and a more conservative forestry practice. As noted above, San Juan has jealously guarded "their forests," strictly limiting or prohibiting altogether commercial harvests. The quality of their local forests is witness to their ecological values.

In sum, indigenous and local subsistence-based communities in Oaxaca, Mexico, and around the world may prove to be most effective allies in our efforts to conserve biodiversity. However, not every such community will survive intact for the long term. Critical to their survival – and therefore to their value as communal protected areas – are such factors as noted by Smith and Wishnie in their theoretical analysis of the preconditions for community conservation (2000:505–6): 1) controlled or exclusive access (stable land rights); 2) distinct or confined resource populations, 3) resilient resource populations, 4) low discount rates, such that the value of sustained yield exceeds the value of immediate yield, 5) social parameters (e.g., small group size and stable membership) and institutions (monitoring and sanctioning) that counter free-riding.

The two communities we have studied meet all these criteria. First, the Mexican constitution guarantees local governmental control, according to customary usage (*usos y costumbres*), particularly with respect to the key environmental resources on which biodiversity depends, notably, local forests. With respect to the second and third conditions cited by Smith and Wishnie, we note that the great majority of bird species are resident in our two communities and thus secure within local habitats. Migratory birds are an exception, as their fate depends on the dangers they face not only in their breeding territories but also in migration and on the security of their winter habitats, to which tropical indigenous communities contribute. Their fourth constraint, we believe, is met by the fact that local citizens seem strongly motivated to preserve their communities intact for the foreseeable future. This commitment might be undermined if economic opportunities outside the community subvert the value of community membership, which to date involves a near guarantee of basic subsistence as well as a sense of collective identity and well-being. Finally, with regard to their fifth requirement, social sanctions restrain antisocial behavior most effectively in stable, face-to-face communities, such as our two indigenous towns. San Juan, for example, is quite strictly endogamous, which assures that all citizens are from local families with multi-generational ties to the town. The local town government, by collective consensus, imposes penalties on citizens for failure to meet specific community obligations, including environmental protection. The exploitation of communal resources, such as wildlife and timber, is formally regulated by a town citizen committee, the *Comisariado de Bienes Comunales*.

It is in the interest of all those committed to biodiversity conservation to support the continuing viability of these communities as they struggle to maintain their independence. The concept of a Wildlife Management Conservation Unit (UMA, *Unidades de Manejo para la Conservación de la Vida Silvestre*) was initiated under Mexican law in 1997 (www.semarnat.gob.mx/). Most Mexican UMAs are held by owners of private land, and very few by indigenous communities. However, both Zapotec communities described here would be suitable for a UMA, and if implemented this would expand the role that indigenous cultural and linguistic minorities currently play in government-sponsored conservation efforts. Other supportive initiatives might include ecotourism projects and employing local community "experts" in biodiversity monitoring programs (Alcántara-Salinas 2011:268–277).

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