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Freshwater fishes and aquatic habitats in Peru: Current knowledge and conservation

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Peruvian freshwater fishes and their habitats were investigated by the Natural History Museum of San Marcos University (MHNSM) as part of a long-term project. Fishes were inventoried by sampling in main drainage basins, including coastal rivers, highland rivers, and Peru's Amazonian waters. To date, the MHNSM fish collection has approximately 300,000 specimens comprising 1000 valid species in 168 families and 8 orders. The greatest diversity lies within the Ostariophysi (80% of all species) with the dominant orders being Characiformes and Siluriformes. Characidae is the most diverse family with 22.5% of all species.

Protected areas (i.e. Parks, Reserved Zones or National Reserves) have been sampled intensively providing a reasonable estimates of their fish diversity. However, our knowledge is still poor for less accessible areas. More fieldwork is needed in all of the large river basins before we can have a fuller understanding of total fish diversity. As an example of ongoing efforts, we discuss specific fish inventories in both Peruvian coastal rivers and highlands and in river systems shared with neighboring countries.

In addition to Peruvian fish diversity; we discuss the state of aquatic resources and habitats in Peru's principal river basins, and current problems facing such aquatic systems (e.g. inland fisheries and extractive activities such as deforestation and gold mining). Near large cities, such as Iquitos and Pucallpa, fishing effort has increased considerably in the last decade, whereas catch per unit effort appears to have decreased considerably indicating that over-fishing has become locally problematic. An overview is presented of main conservation problems, including exotic species that confront aquatic ecosystems in Peru. Finally, an environmental education program is recommended to inform the general public about the value of freshwater fishes and aquatic ecosystems and the main problems such resources are facing.

Keywords: Taxonomy, fisheries, exotic species, Amazon basin

Introduction

The western Amazon has a great diversity of habitats and endemic species (Olson et al., 1998). Important components of this diversity are its thousands of water bodies and great variety of aquatic habitats. Due to its particularly high number of species and habitats, Peru is acknowledged as one of the 10 biologically mega-diverse countries of the world (CONAM, 1999). In total, there are 855 fish species currently recognized in Peru (Chang and Ortega, 1995); however, if undescribed and undiscovered species are taken into account, Peru's fish fauna is estimated to comprise at least 1200 species (Ortega and Chang, 1998). Peru's fishes are distributed across three main drainage systems:

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1) Pacific coastal rivers; 2) the Lake Titicaca basin; and 3) the Peruvian Amazon basin. Rivers which drain directly to the Pacific have approximately 45 species. In the highland waters above 1000 meters, 80 species have been recorded (Ortega, 1992). More than 50 of these coldwater species are endemic and belong mostly to the genera *Orestias, Astroblepus and Trichomycterus* (Parenti, 1984; Ortega, 1992; Ortega and Chang, 1998).

The majority of Peru's freshwater fish diversity, or more than 800 species, is restricted to the Amazon drainage (Ortega and Vari, 1986; Chang and Ortega, 1995). The most diverse group is the Ostariophysi (80%), represented by Siluriformes (39%), Characiformes (36%) and Gymnotiformes (5%). Nevertheless, despite such a wealth of fish biodiversity, there are numerous ecological problems confronting both the cold and warm waters of the country. Deforestation, gold mining, oil extraction activities, and inappropriate agriculture methods used in the lowland rain forest, are the main problems for Peru's aquatic habitats and fishes. Furthermore, at least 30 species of exotic fishes have been introduced for various purposes and these exotics present many problems for conservation of the native fish fauna (Ortega and Ramírez, 2000).

Most of our current knowledge regarding Peru's fish fauna comes from research activities and expeditions within the last 10 years. Many river systems have been surveyed in the southern and northern parts of Peru. Some of the principal areas surveyed were: (1) Tambopata-Inambari-Tahuamanu systems, including regions north of the Puno and Madre de Dios Departments; (2) Urubamba basin including the lower and upper rainforest from Cusco to Ucayali; (3) Cordillera Azul National Park, Ucayali—Loreto Departments; (4) upper portion of the Marañón River basin (Cajamarca—Amazonas Departments) and coastal rivers of the Pacific Ocean basin from Río Tumbes; (5) Río Santa; (6) and Río Locumba (Tacna Department) (Figures 1 and 2). We also surveyed relevant literature for the Lake Titicaca system and synthesized available data for all of Peru to more thoroughly describe the total fish diversity, present environmental conditions, changes in major habitats, and introduction of exotic species in the main aquatic systems of Peru.

Species were identified using taxonomic keys, original descriptions and recent taxonomic revisions (see Eschmeyer, 1998; Malabarba et al., 1998 for complete list of references). Higher-level classifications follow Reis et al. (2003). Bussing (1987) and Trewavas (1983) were consulted for exotic fishes such as poeciliids and cichlids.

Objectives

This work summarizes the current knowledge of Peruvian freshwater fish diversity, the state of conservation of Peru's main aquatic systems and the current impact of extractive activities and exotic fish species in Peru. We provide an overview of the uses of fish resources as well as Peru's main inland fisheries, and we make management suggestions for commercial fishing, fish culture and protection of aquatic habitats.

Overview of the freshwater resources, fish fauna, and inland fisheries

Freshwater resources

Approximately 53 rivers drain the western Andes to the Pacific along the Peruvian coast. These rivers change seasonally, from almost dry for half the year to flood for at least four months (December–March). Nearly all have permanent water to a lesser or greater extent and all are used by local peoples for direct consumption and for agriculture, farming and industry. Some rivers, mostly in the north of the country (i.e. Poechos, Gallito Ciego), have been dammed, creating reservoirs that are used especially for agriculture). Unfortunately, all of these rivers have also been used as conduits for urban waste water.

In the highlands, there are at least 10 000 lakes whose headwaters usually begin in the snow-clad mountains of the Andes as rain and snowmelt. Most of these lakes on the eastern Andean slopes and they themselves feed into streams that lead to larger rivers like the Ucayali, Marañón and Amazonas (Ortega, 1992). As in other Peruvian regions, urban waste water and other pollutants are discharged directly into these rivers.

In the high forest of the eastern Andean region, there are hundreds of small to medium-sized rivers flowing mostly to the east and north. Rivers such as the upper Apurímac, Araza, Izcozacin, Pichis and Mayo are good examples. The main headwater tributaries that originate in Ecuador flow mostly south until joining medium-to-large sized rivers that then become transportation arteries for neighboring towns and villages. It is likely that nearly all such rivers

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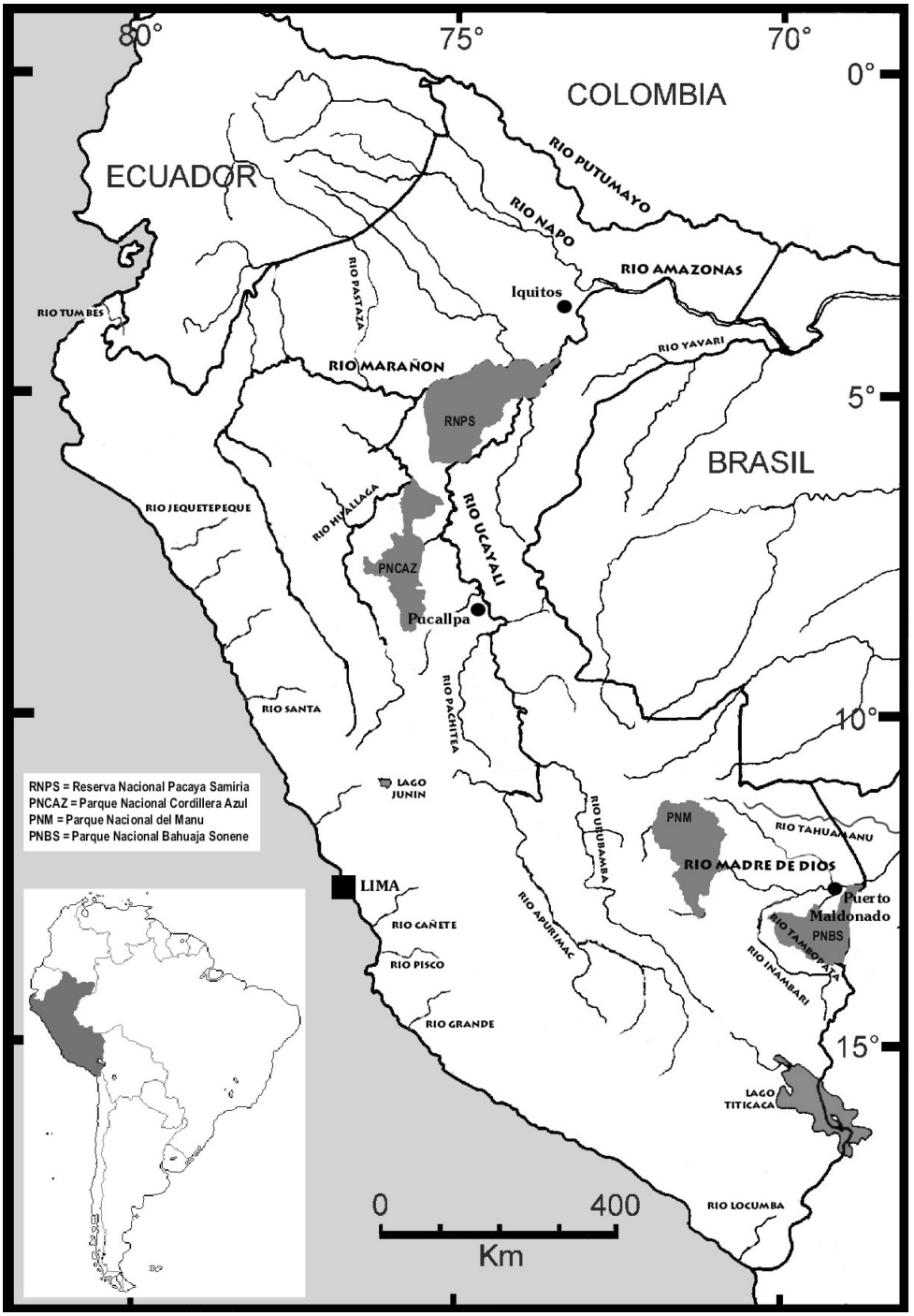

Figure 1. Geographic and hydrographic map of Peru showing main basins and localities for fish fauna inventories and inland fisheries.

are contaminated to some extent by urban waste discharged directly into them.

The lowland Amazonian forest occupies the greatest area in Peru (>50% by area) and all of the large rivers of Peru are confined to this region. In the northern Amazonas River drainage of Peru, for example, these rivers include the Urubamba, Marañón, Aguaytia, Ucayali, Napo, Putumayo, Yavari and

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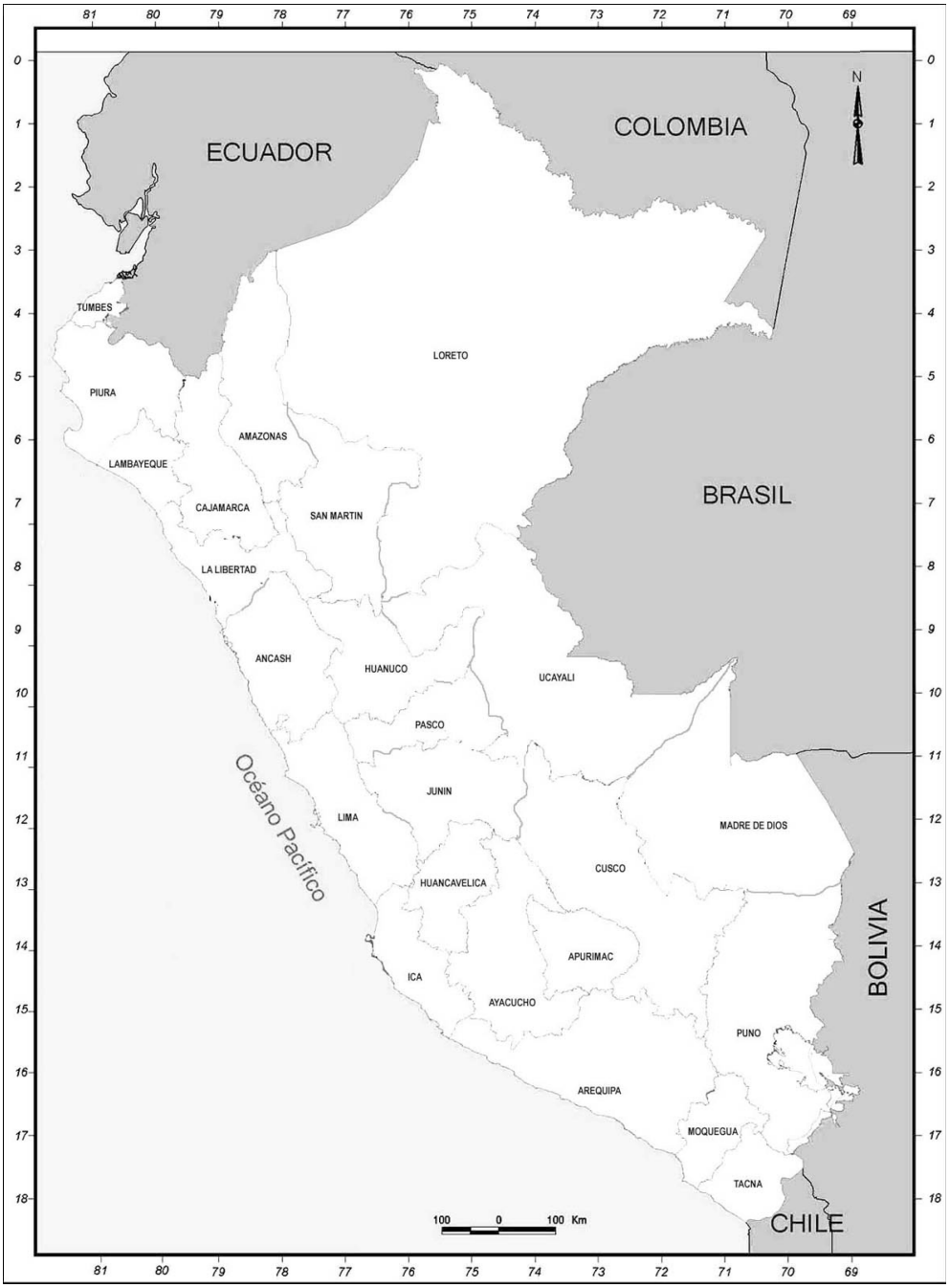

Figure 2. Political map of Peru showing departments.

Nanay. Rivers in this area are important for food, transportation and other economic activities. Near some of the large cities, such as Iquitos and Pucallpa, over-fishing appears to be an increasing problem and there are also indications that water pollution could be reaching alarming levels locally.

Freshwater fish fauna

855 valid freshwater species are currently recorded for Peru (Chang and Ortega, 1995). The total number of freshwater fish species in Peru, however, is estimated to comprise at least 1200 species

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(Ortega and Chang, 1998). Along the coast, from north to south, there are remarkable differences in the composition of the fish fauna. In northern Peru, the Tumbes River, whose headwaters originate in Ecuador, has tropical features and receives as much rain as the lowland forest. The Tumbes river and its tributaries contain 33 fish species, mostly Characiformes or Siluriformes, and including some marine families. Several endemic species are restricted to the Tumbes (Ortega, 1992). In the Santa river basin, that stretches from the high Andes to the Pacific Ocean in Ancash Department, 14 fish species have been recorded. Most of these are from the lower section. From the Andes, *Orestias* and *Astroblepus*, two genera that are important to the ecology of cold, running waters, and the second one have been found in the Tumbes river system (Sifuentes, 1992; Napravnik, 1998).

In the central, dry part of Peru, in Lima Department, only seven species of fishes are known and one of these is introduced. In the southern region of Tacna Department, near the Peruvian - Chilean border, only three fish species are known.

At altitudes above 1000 masl, approximately 80 species have been recorded (Ortega, 1992), mainly from the genera *Orestias, Astroblepus* and *Trichomycterus;* in addition, there are some small Characidae belonging to the genera *Ceratobranchia, Acrobrycon, Bryconamericus* and *Creagrutus.* Lake Titicaca, which is located at more than 4000 masl, is the most fish-diverse basin in the Andean highlands. Lake Titicaca has species-rich groups of closely-related species known as species flocks, and most of these are in the genus *Orestias.* Some species of *Orestias*, especially the larger ones, are seriously threatened and may be in danger of extinction (Treviño et al., 1991).

In the Peruvian Amazon, more than 800 species (84% of the total) have been recorded, and the majority of these (80%) are in the Ostariophysi, represented by Siluriformes (39%), Characiformes (36%) and Gymnotiformes (5%). Among the non-Ostariophysi, Perciformes, including the family Cichlidae, dominates with 9% of species and the remaining 5% are represented by a variety of orders mainly of marine origin (Table 1).

Manu National Park has 210 known species (Ortega, 1996) and the Tambopata-Candamo Reserved Zone has 232 known species (Chang, 1998). The Pachitea River, a tributary of the Ucayali, was surveyed with the cooperation of Earthwatch Institute during 2001 and 2002, and a total of 158 species are now known from this river (Ortega et al., 2003a). The Yavari river, at the Peruvian-Brazilian border, has 240 recorded species (Ortega et al., 2003b). The Ampiyacu – Apayacu-Yaguas and Middle Putumayo regions have 289 recorded species (Hidalgo and Olivera 2003). The Pastaza basin of Ecuador and Peru has 312 recorded species (P. Willink, Field Museum of Natural History, Chicago, pers. comm.). 250 species were observed in the Tahuamanu, in Madre de Dios Department, during Earthwatch expeditions in 2003 and 2004. The Lower Urubamba basin in Cusco and Ucayali Departments has 160 recorded species (Camisea Project, Pluspetrol & TGP; and H Ortega, MUSM, Lima, pers. comm).

Table 1. Number of Fish families, genera and species of freshwater systems of Perú.

	Order	Families	Genera	Species
1	Carchariniformes	1	1	1
2	Myliobatiformes	1	3	5
3	Lepidosireniformes	1	1	1
4	Osteoglossiformes	2	2	2
5	Clupeiformes	2	6	10
6	Cypriniformes	1	5	5
7	Characiformes	14	135	359
8	Gymnotiformes	5	21	52
9	Siluriformes	13	144	393
10	Salmoniformes	1	1	1
11	Batrachoidiformes	1	1	1
12	Beloniformes	1	2	4
13	Cyprinodontiformes	3	8	63
14	Atheriniformes	1	2	3
15	Synbranchiformes	1	1	2
16	Perciformes	8	40	91
17	Pleuronectiformes	1	6	6
18	Tetraodontiformes	1	1	1
	TOTAL	58	380	1000

Peruvian inland fisheries

Pacific coast

Almost none of the freshwater species from coastal rivers are exploited commercially. In the Tumbes River, *Brycon atrocaudatus* and *Chaetostoma microps* are captured occasionally by people living near the river. There is also some local fishing for *B. atrocaudatus* and small catfishes (*Astroblepus* and *Trichomycterus*) in the Jequetepeque River in Lambayeque Department.

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Highland waterbodies

Rainbow trout (*Onchorhynchus mykiss*) is the main species exploited in highland waters. This species has been widely introduced to coldwater Rivers ranging from the south in Puno Department to the north in Cajamarca Department. There are public and private trout fish farms in the departments of Puno, Cusco, Apurímac, Junín, Ancash and Cajamarca.

Higher forest streams

Some fishing is done for local consumption in several rivers such as the Perené and Satipo rivers in Junín Department, Huallaga at Tingo María in Huánuco Department, Aguaytía in Ucayali Department and Alto Urubamba at Quillabamba in Cusco Department. The main species exploited are small, (e.g. *Rhamdia*), but larger migratory fishes such as *Pseudoplatystoma fasciatum* and *Prochilodus nigricans*, are also captured when present.

Lowland Amazon Rivers

Commercial fisheries exist near larger cities located along the main rivers. These include Puerto Maldonado on the Tambopata and Madre de Dios in Madre de Dios Department, Pucallpa on the Ucayali in Ucayali Department, and Iquitos on the Peruvian Amazon, including the vicinity of the Ucayali and Marañón rivers in Loreto Department. More than 50 fish species are exploited in the Madre de Dios region, but 12 species account for more than 90% of total landings (Goulding et al., 2003). More than 90 percent of the total annual catch consists of migratory species, that include large catfishes such as *P. fasciatum*, *P. tigrinum*, *Brachyplatystoma rouseauxii*, *B. filamentosum*, *Phractocephalus hemioliopterus*, *Zungaro zungaro* and some medium-sized Characiformes, such as *Piaractus brachypomus*, *P. nigricans*, *Mylossoma duriventre*, and *Potamorhina altamazonica* (Goulding et al., 2003).

The annual average harvest of Pucallpa during a 12 year-period from 1980 to 1991 was approximately 3800 t and only 8 species represented 85% of the total annual catch (Riofrio, 1998). Nearby in Iquitos, available data indicate that about 10 species account for approximately 90% of the annual catch (Tello and Bayley, 2001). De Jesus and Kohler (2004) have recently characterized the current Peruvian Amazonian fisheries and their data indicate that there has been overfishing near Iquitos city. Iquitos fishermen are apparently expending greater fishing effort to maintain catches (recruitment overfishing) and the average size of fishes was reported to have decreased (growth overfishing). The fundamental ecology of these systems is being altered as larger, longer-lived species are replaced by medium and small fishes with shorter life cycles.

The current state of freshwater fish science in the country

Current state of knowledge of Peruvian freshwater fishes

The current knowledge of the Peruvian freshwater fish fauna began largely with the contributions of H. W. Fowler (1945) and has increased most rapidly in the period since 1972, mainly due to the collections of the MNHSM. Large-scale collections began in the Ucayali river basin near IVITA-Pucallpa, a Tropical Research Station of San Marcos University, and they were extended to the Madre de Dios and Loreto departments in the following decades. In the last decade, fieldwork has covered more new areas and the Fish Collection at MNHSM now has approximately 300 000 specimens, representing approximately 1000 species, mainly from the Amazon system. Recently, material from the highlands (Apurímac, Cusco and Puno Departments) and some from coastal rivers (Tumbes and Piura Departments) has been collected. In contrast, the Lake Titicaca fish fauna is poorly represented in the collection.

The list of Peruvian fishes continues to grow, particularly for the Amazon region, as newly discovered species are described. Species recently described from Peru belong to many different genera, such as *Creagrutus*, *Attonitus*, *Tyttocharax*, *Chilodus*, *Aposturisoma*, *Crossoloricaria*, *Otocinclus*, *Glanidium*, and *Bujurquina*. The first checklist of Peruvian fishes was published by Ortega and Vari in 1986, reporting 736 species. It was updated by Chang and Ortega (1995), who reported 855 valid Peruvian species of freshwater fishes. At the present time, we are preparing a new checklist and this tentatively has a total of 1000 freshwater fish species for Peru, including exotic species.

For all of Peru, 359 species (36%) are Characiformes, 393 species (39%) are Siluriformes, 52 species (5%) are Gymnotiformes and 97 species (8,7%) are Perciformes and Cyprinodontiformes (63 species, 6,4%) (Table 1). Other orders such as

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Myliobatiformes (5 species), Osteoglossiformes (2), Clupeiformes (10), Atheriniformes (8), and Pleuronectiformes (5) are also represented. The family with the greatest number of species is Characidae (225 species, 23%), followed by Loricariidae (125 species, 11,6%); Cichlidae (72 species, 7%), Callichthyidae (42 species, 4,3%); Pimelodidae and Doradidae (41,42 species, 4%), Heptapteridae (36 species, 3,9%) and Trichomycteridae and Curimatidae (28 species, 32,3%) (Table 2).

The Yavari basin, with 360 species, has the highest recorded fish diversity, and this was based on only two expeditions in 2003 and 2004; the Pastaza basin of Ecuador and Perú has 312 species; the Ampiyacu-Apayacu-Middle Putumayo region has 289 species; the Madre de Dios basin has 287 species; the Peruvian Napo basin has 242 species; the Tambopata-Candamo Zone has 232 species; and Manu National Park has 210 species.

Above 1000 masl, 80 fish species have been recorded, mainly in the genera *Orestias, Astroblepus* and *Trichomycterus* (Ortega, 1992). Along the coast, 14 species were recorded from the Santa River, ranging from the mouth to more than 5000 masl, a distance of greater than 350 km. Samples were taken in many of the Santa's tributaries during both the rainy and dry seasons of 1989 and 1990. Nine of the 14 species live in the lower elevations below 300 masl (Sifuentes, 1992).

The Rio Cañete, the most important river in Lima Department, located 150 km south of Lima, is wider than the Santa, and has clear water for nearly seven months a year. Eight fish species are known from the Cañete, including *Orestias* in headwaters, *Mugil* near the mouth and the exotic species *Poecilia reticulata*.

Fish surveys were carried out between 1987 and 1993 in the lowland forest area of Manu National Park. These surveys included the Reserved Zone along the Manu river and tributaries near Pakitza station, at 350 m elevation. A total of 210 species were recorded (Ortega, 1996), which were mainly Characiformes and Siluriformes, these were found in white, clear and black water streams as well as in the main channel of the Manu river.

In the Tambopata-Candamo Reserved Zone, 232 species were recorded (Chang, 1998). Recently, 287 species have been recorded from the Madre de Dios and Los Amigos in the area near the confluence of the two rivers (Barthem et al., 2003).

In southeastern Peru between the departments of Puno and Madre de Dios, there is a large area that is drained by the Tambopata, Inambari, Madre de Dios and Tahuamanu rivers. This area is composed of a wide variety of habitats visible as one drives along the road from Cusco to Iñapari, including clear, black and white water streams and rivers. Recent fieldwork (July–August, 2003 and 2004) recorded more than 250 fish species from this area. These results could be used as baseline with which to monitor the impacts of the new Transoceanic Highway between Brazil and Perú. This highway cuts through the Madre de Dios rainforest close to the Peruvian border with Bolivia, and heads into the Andes of Cusco and Puno Departments to eventually reach the Pacific coast in Arequipa and Ica Departments.

The Urubamba River begins as the Vilcanota river at Quillabamba, Cusco Department and ends at the town of Atalaya where it becomes the Ucayali, Ucayali Department. Urubamba tributaries include the Cumpirosiato, Comberciato, Shimaá, Timpia, Camisea, Mishahua, Tambo and Sepahua rivers. The fish fauna in the Urubamba river basin was surveyed during both low and high water seasons in different years between 1996 and 2004. A total of 160 fish species have been recorded from the Urubamba basin. Assessments of 15 water bodies in the Urubamba basin in 2003 determined that the Urubamba is important for transportation and food resources for several native communities.

Habitats in the Pachitea River basin between 400 and 800 masl were sampled during two low water periods from 2000 to 2002. A total of 158 species were recorded in this area. (Ortega et al., 2003a).

In the department of Ucayali there are hundreds of water bodies. From the Aguaytía river basin alone nearly 250 fish species have been recorded (M. Hidalgo, MUSM, Lima, unpubl.). In the lower Ucayali River, near Contamana, Loreto Department, a single survey carried out in one week (June, 1996) recorded 154 fish species (H. Ortega, MUSM, Lima, Peru, unpubl.).

In Pacaya-Samiria National Reserve, 240 fish species were recorded (James Albert, NHM of University of Louisiana, Lafayette, pers. comm.). 102 species of predominantly small-bodied fishes were recorded from the blackwater, forest streams near Requena (Jenaro Herrera) in January, 2004 (W. Crampton, University of Central Florida pers. comm.).

Systematic revisions of many groups are ongoing; for example, the family Astroblepidae (Siluriformes) is being revised by Scott Schaefer of the American Museum of Natural History; the

Table 2. Freshwater fishes of Perú. Number of genera and species by Orders and Families.

ORDER	Families	Genera	Species
CARCHARTINIFORMES	CARCHARINIDAE	1	1
MYLIOBATIFORMES	POTAMOTRYGONIDAE	3	5
LEPIDOSIRENIFORMES	LEPIDOSIRENIDAE	1	1
OSTEOGLOSSIFORMES	ARAPAIMATIDAE	1	1
	OSTEOGLOSSIDAE	1	1
CLUPEIFORMES	ENGRAULIDIDAE	3	6
	PRISTIGASTERIDAE	3	4
CYPRINIFORMES	CYPRINIDAE	5	5
CHARACIFORMES	ACESTRORHYNCHIDAE	1	9
	ANOSTOMIDAE	9	23
	CHARACIDAE	8	225
	CHILODONTIDAE	2	4
	CRENUCHIDAE	10	13
	CTENOLUCIIDAE	1	3
	CURIMATIDAE	8	32
	CYNODONTIDAE	4	4
	ERYTHRINIDAE	3	4
	GASTEROPELECIDAE	3	6
	HEMIODONTIDAE	3	7
	LEBIASINIDAE	6	23
	PARODONTIDAE	2	3
	PROCHILODONTIDAE	3	3
GYMNOTIFORMES	APTERONONTIDAE	9	18
	GYMNOTIDAE	2	15
	STERNOPYGIDAE	4	7
	HYPOPOMIDAE	4	6
	RHAMPHICHTHYIDAE	2	6
SILURIFORMES	ARIIDAE	5	7
	ASPREDINIDAE	5	11
	ASTROBLEPIDAE	1	19
	AUCHENIPTERIDAE	14	28
	CALLICHTHYIDAE	7	42
	CETOPSIDAE	4	10
	DORADIDAE	19	40
	HEPTAPTERIDAE	13	36
	LORICARIIDAE	35	124
	PIMELODIDAE	23	41
	PSEUDOPIMELODIDAE	3	5
	SCOLOPALACIDAE	1	1
	TRICHOMYCTERIDAE	14	28
SALMONIFORMES	SALMONIDAE	1	1
BATRACHOIDIFORMES	BATRACHOIDIDAE	1	1
BELONIFORMES	BELONIDAE	2	4
CYPRINODONTIFORMES	CYPRINODONTIDAE	1	38
	RIVULIDAE	3	19
	POECILIDAE	4	6

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Table 2. Freshwater fishes of Perú. Number of genera and species by Orders and Families *(Continued)*.

ORDER	Families	Genera	Species
ATHERINIFORMES	ATHERINOPSIDAE	2	3
SYNBRANCHIFORMES	SYNBRANCHIDAE	1	2
PERCIFORMES	CICHLIDAE	26	72
	SCIAENIDAE	3	7
	GOBIIDAE	5	5
	GERREIDAE	2	2
	MUGILIDAE	1	2
	GOBIESOCIDAE	1	1
	OSPHRONEMIDAE	1	1
	POLYCENTRIDAE	1	1
PLEURONECTIFORMES	ACHIRIDAE	6	6
TETRAODONTIFORMES	TETRAODONTIDAE	1	1
18	58	380	1000

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sub-family Hypostominae (Siluriformes: Loricariidae) is being revised by Jonathan Armbruster at Auburn University; and the genus *Chaetostoma* (Siluriformes: Loricariidae) is the subject of a doctoral thesis by Norma Salcedo at Texas Tech University. There are also several new species descriptions underway.

A workshop sponsored by Instituto Nacional de Recursos Naturales (INRENA) in 2003 helped prepare data for the Red Book on Peruvian fauna. At least 30 freshwater fish species were considered for special conservation status. Some species were considered to be threatened with extinction, such as a few species of *Orestias* and *Trichomycterus* from Lake Titicaca. Furthermore, it was resolved that some of the large, commercially exploited fish species need protection, such as *Arapaima gigas* from lowland forests (Appendix II) and catfishes that are heavily exploited near Pucallpa and Iquitos, Ucayali and Loreto Departments, respectively.

Fish ecology

Ecological studies of freshwater fishes in Peru are in their infancy. The majority of this data is currently unpublished but available as university theses and institutional and consultant's reports. There are also several ongoing research projects. For example, there is an ongoing investigation of the reproduction and ontogeny of large migratory catfishes, including "dorado" (*Brachyplatystoma rouseauxii*; Cañas, C. ACCA, pers. comm.). H. Ortega (MUSM, Lima, unpubl) is examining the seasonal composition and distribution of fishes in different types of streams in Manu National Park. There are studies of the "giant otter" (*Pteronura brasiliensis*) and its prey fishes (L. Davenport, Duke University, pers. comm.). There is some information on feeding, growth, reproduction and behavior of some Peruvian Amazonian commercial fish species, such as *Cichla monoculus*, *C. macropomum*, *P. nigricans*, *P. brachypomus*, *Triportheus* spp., *Brycon* spp., *Leporinus trifasciatus* and*Schizodon fasciatus* (López, 1998; Tuesta, 1999; Riofrio et al., 2000; Briones, 2005).

Current status and features of inland fisheries and aquaculture

Commercial fisheries do not exist in the coastal rivers. In the highlands, there are small-scale, mostly subsistent, fisheries for a few species of Characiformes and Siluriformes. There was a very successful fishery based on rainbow trout (*Oncorrhynchus mykiss*, Salmonidae) for five years (1968 to 1972) in Lake Titicaca (Everet, 1973). At present, there is a relatively important commercial fishery in Lake Titicaca based on another introduced species from Argentina, "pejerrey" (*Odonthestes bonariensis,* Atherinidae). Both introduced species compete with and predate upon native fishes such as *Orestias cuvieri* and*Trichomycterus rivulatus*, both of which are now almost extinct. Fishes from Lake Titicaca are sold in Cusco, Puno (Perú) and La Paz (Bolivia).

Important inland fisheries are limited to the main white water rivers in the Peruvian Amazon and are

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largely artisanal, seasonal and multispecific. Annual total fish landings for the Peruvian Amazon are estimated to be approximately 80 000 t, with 75% obtained from subsistence fishing and 25% from commercial fisheries. In Loreto, however, commercial fisheries represent 75% of the total catch and in Ucayali 25% (Tello and Bayley, 2002). Subsistence fishing takes place mostly near riverine towns and villages. Commercial fishing in the Ucayali River is mainly near Pucallpa (Riofrio, 1998). In the Tambopata and Madre de Dios rivers, commercial fishing is centered on Puerto Maldonado in Madre de Dios; in the Peruvian Amazonas River commercial fishing is mostly near Iquitos (Cañas, 2000; Tello, 2002; Barthem et al., 1995; Tello and Bayley, 2001; De Jesus and Kholer, 2004).

The total annual commercial catch for Iquitos, Loreto Department, is estimated to be 30 000 t; 12 000 t for Pucallpa, Ucayali Department; and 290 t for Tambopata province (Madre de Dios); according to Barthem et al., 1995; Riofrio, 1998; Cañas, 2000. The most important commercial fish species for the Peruvian Amazon is *P. nigricans*, which accounts for approximately 30% of the total annual catch (Riofrio, 1998). This species, along with three curimatids (detritivores), represent almost 55% of the total catch (Riofrio, 1998). These species are also important prey for large piscivorous catfishes such as: *P. fasciatum, P. tigrinum, B. vaillanti, B. filamentosum* and *B. rouseauxii*. Fruit- and seed-eaters, such as *Colossoma macropomum* and *P. brachypomus*, are also seasonally important to commercial fisheries.

The commercial species-selection trend over the next 10 years will probably be towards medium-sized migratory fishes that have a fast growth rate and relative short life cycle (e.g. *P. nigricans*, *P. altamazonica*, *M. duriventre*). On the other hand, large catfishes (*Pseudoplatystoma* spp.and *Brachyplatystoma* spp.) and large characids (*Colossoma* and *Piaractus*) will probably become scarcer in the commercial fisheries, according to Welcomme (1988) and De Jesus and Kholer (2004), because currently there is overfishing for these species and the total average size has become shorter than a few years earlier.

Aquaculture

Freshwater shrimp farming in Peru uses mostly *Macrobrachium rosembergii*, the Malasian shrimp, which is produced widely in San Martín Department. Fish farming is much more important, however, and tilapias are the preferred species throughout the department of San Martín. There are also numerous fish ponds in the department of Ucayali along the road from Pucallpa to Aguaytía, and in Loreto Department along the road from Iquitos to Nauta, where several native species are also used, especially paiche (*Arapaima gigas*). It appears that aquaculture is promising for Peru, considering problems with overfishing and poor fisheries management implementation throughout the Amazon. Farming of native species, such as *C. macropomum*, *P. brachypomus*, *B. cephalus*, *C. monoculus* and *P. nigricans*, can be implemented in both lowland and high forest areas. There is already sufficient technology and know-how in some regional institutions, such as the Instituto de Investigaciones de la Amazonia Peruana (IIAP) in Iquitos and the IVITA Institute in Pucallpa, to promote and develop fish farming activities using native fishes.

About aquarium trade, there are more than 164 species included; mainly collected around Iquitos, Loreto Department and most of them are Characiformes and Siluriformes (IIAP & Prompex, 2006).

Current status of freshwater habitats

The condition of aquatic habitats in Peru varies greatly and usually depends on their proximity to civilization, such as towns, roads, airports and extractive industries. Several relatively large rivers are in nearly pristine condition, such as Manu River in Manu National Park. Relatively pristine conditions can also be found in remote areas such as: Megantoni National Sanctuary; upper Timpia and Picha rivers of the Urubamba river basin; Yavari (Peruvian and Brazilian border); Ampiyacu (next to Putumayo River); Comainas (next to the border with Ecuador); and Cordillera Azul National Park. These rivers are located in remote areas where there are usually only small villages and fishing is limited mostly to subsistence practices.

Several large river basins have been moderately modified, especially near towns and cities. Examples include areas in Quillabamba, Satipo, Tarapoto or Bagua provinces. There are many environmentally degraded areas, such as nearly the entire Vilcanota River in Cusco that receives huge quantities of urban waste from the city of Cusco, Cusco Department. During an expedition in July 2004, we

found no fishes in the main channel of the Vilcanota River; fishes were only found in small tributaries. There is little aquatic life in the Huaypetue and Caychihue Rivers of the Inambari basin, near Mazuco because of large-scale gold mining activities in that basin. Rivers and streams in this area are often toxic and highly sedimented. Even streams such as Dos de Mayo near Mazuco, which used to be an important source of drinking water, recreation and local fishing, were found to be dry during our visit in August, 2004, because of gold mining activities. This type of situation will only worsen and, regrettably, the government is doing nothing to curtail the use of mercury in gold processing in Madre de Dios department (Goulding et al., 2003). Another serious problem is deforestation for non-sustainable agriculture in the lowland forested regions. Deforestation is leading to increased erosion and a consequent increase in suspended solids and turbidity in clear water rivers and streams that can result in massive fish mortalities (Goulding et al., 2003).

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Exotic fishes in aquatic systems

In the continental waters of Peru, there are exotic fishes adapted to both cold waters (e.g. *Oncorhynchus mykiss*) and warm waters (e.g. *Oreochromis niloticus*) (Ortega and Chang, 1998). In some cases, exotic species have reduced native species range distributions and abundances, principally by competition and predation, and sometimes by habitat displacement. Exotic fish species were introduced into Peruvian waters for a variety of purposes: fishing, fish culture, human health and the aquarium trade. The most frequently captured species in coastal rivers is *Poecilia reticulata* Ancash, Lima and Ica Departments (Sifuentes, 1992). Only a few exotic species have been collected in high forest waters, such as *Cyprinus carpio*, *O. niloticus* and *P. reticulata* in the Huallaga River basin (Ortega and Ramírez, 2000).

Survey of freshwater fish management in Peru

Legislative and regulatory treatment of fisheries

For fishing in Peru, there are national regulations for fishing in Peru, such as the Fishing Law (Ley de Pesca, 1994), but they are mainly relevant to marine fisheries. Few realistic regulations for fishery management have been implemented for freshwater fishes and Amazonian habitats. The most important is for protection of paiche (*Arapaima gigas*), which is in the IUCN Appendix II. For paiche, there are regulations protecting habitats, limiting exploitation during the breeding season and placing restrictions on minimum size and weight for capture. There are regional regulations for fisheries of five species in Ucayali Department and proposed measures for the Puerto Maldonado commercial fishing fleet (Riofrio, 1998; Cañas, 2000; Tello, 2002). Flores (1995) proposed a plan to implement preliminary general regulations for Amazonian fisheries. The main recommendations include the use of "official" common names in order to improve the fisheries data and not to use juveniles of food fishes as ornamentals. There are also regional regulations for the ornamental fish trade in Loreto related to some species as *Osteoglossum bicirrhosum* and some catfish species which become larger. At least 160 species are involved in this activity and exports of some species (e.g. tetras) are greater than one million individuals each year (Barthem et al., 1995).

Linking biodiversity conservation with ecosystem management

Pacaya – Samiria National Reserve is the largest protected wetland in Peru (2.5 million ha) and encompasses a variety of aquatic habitats found in the lowlands. This reserve was created several decades ago to protect the paiche (*Arapaima gigas*), the largest scaled freshwater fish in the world, as well as turtles and caimans, which were heavily hunted by local people. There is now a Master Plan for the management of natural resources of Pacaya- Samiria (INRENA, 2000). As for fishes, the main concern is *Arapaima gigas*, their size catching, annual volumes, and the breeding season.

Another good conservation example is the Bahuaja-Sonene National Park (Madre de Dios), which conserves large wetland areas together with native communities that practice subsistence fishing. Recently, the Cordillera Azul National Park was created (2001). This park contains a very diverse biota, numerous aquatic habitats such as Pauya and Pisqui rivers and its tributaries, and probably many endemic species (Alverson et al., 2001). One of these probably endemic fish species, *Hypostomus fonchii*, was recently described from the Cordillera Azul National Park (Weber and Montoya-Burgos, 2002).

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During 2003, rapid biological inventories developed by biologists from both the Field Museum of Natural History and from the Museo de Historia Natural (MNH-USM), were carried out in the Yavari and Ampiyacu areas to evaluate the floral and faunal richness and determine conservation measures that would be important for local communities to implement. The first assessment was in the lower Yavari River along the Peruvian and Brazilian border at the end of rainy season (Ortega et al., 2003b); the second assessment was near the Putumayo river (Peruvian – Colombian border) during the dry season (Hidalgo and Olivera, 2004). These studies informed the Peruvian government which created a Communal Reserve to protect primary forest and several species of mammals as well as the paiche (*A. gigas*).

Several ongoing studies are monitoring regional fishing and hydrobiology in the lower Urubamba River (Cusco) as they relate to the Camisea Gas Project (www.camisea.com.pe). These studies revealed that of the approximately 160 fish species, almost one third are used as food by the native communities. Aquatic habitats in the Urubamba River basin are almost exclusively lotic. Ecological assessment of the Urubamba fish communities and habitats were carried out during both the rainy and dry seasons, and included five sites to evaluate local fishing pressure, fish diversity and related limnological parameters of the Shihuaniro, Timpía, Camisea, Picha, Sepahua rivers or Pitoniari, Charapa, Shimbillo, Kumarillo streams, among others.

Nearly all of the national protected areas have been studied and information on their main biotic components is being used in support of conservation tasks. Lately, research efforts have centered on regional cooperative projects that involve biologists from Peru, Bolivia, Brazil and the USA, with major support from the World Wildlife Foundation (WWF), the MacArthur Foundation, and the Gordon and Betty Moore Foundation.

Examples of success stories regarding freshwater fishes

Just a few decades ago, there was only a small population of paiche remaining after decades of heavy exploitation, but now the population has increased considerably because of their protection in the Pacaya-Samiria National Reserve. Regional plans for the management of paiche are being implemented and there is an ambitious program for aquaculture of this species in Loreto and Ucayali.

The use of native species for fish culture programs deserves comment as well. Aquaculture of *C. macropomum* and *Piaractus brachypomus* are examples of successful directed breeding under controlled conditions. Directed breeding has allowed the regional fisheries administration to expand fish culture based on native species.

Conclusions

The aquatic habitats in Peru provide examples of different degrees of impacts from pristine habitats in remote, isolated, and protected areas; moderate in rural areas with sparse population, and degraded in places with large-scale extractive industries or high densities of human settlement.

Peru has a diverse fish fauna with nearly 1000 known species (949 thus far recorded, but more awaiting description and discovery). There are a variety of threats to habitats and fish diversity. Among them, deforestation, gold mining and other extractive industries are the main threats to water quality and aquatic habitat conservation.

Our knowledge of fish biodiversity in Peru is progressing steadily with many new surveys in remote areas. Museum fish collections are also expanding and becoming more thoroughly representative of the Peruvian fish fauna. There are numerous research efforts underway that should greatly increase our understanding of fish biodiversity and ecology in the next decade.

In general, commercial fisheries in the Peruvian Amazon are increasing, especially near major cities located on rivers. There are signs of over-fishing of some of the larger species. Detritivorous fishes are becoming more important in commercial fisheries and replacing the larger piscivorous species in importance. In this context, aquaculture is considered an important alternative or supplement to fisheries to supply animal protein in highland and lowland forest areas where there is a dependence on fish as an important food source.

Science and management are intimately linked because biotic inventories are an important first step to assess faunal abundance and/or the commercial value of aquatic resources. For example, the fish fauna assessment carried out in the Reserva Nacional Pacaya-Samiria (Loreto) formed the scientific basis for the management of paiche (*Arapaima gigas*). On several occasions, biological assessments

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conducted in special areas gathered enough data to support the designation of new protected areas in Peru. The most recent example was in 2001when the Parque Nacional Cordillera Azul was created as a direct result of a biotic assessment carried out there by biologists of the Field Museum and Natural History Museum of San Marcos. Furthermore, biota assessments nearly always reveal new and endemic species. Recently, the Rapid Biological Assessment in the Megantoni Area in Cusco (August, 2004) resulted in a new National Sanctuary to protect pristine areas and their special biota.

As a long-term project, the Peruvian freshwater fish faunal inventory is a priority. There are currently many remote areas where our knowledge is minimal. Many of these will require travel either by helicopters, or long trips by boats and canoes. Examples include: headwaters of the Yanachaga-Chemillén (Pasco) and Cordillera Azul (Ucayali-Loreto-San Martín) National Parks; the lower Putumayo River basin between Perú and Colombia; several rivers arising in Ecuador in the north of Perú (Amazonas); the Santiago-Comainas Reserved Zone and the Alto Mayo river basin (San Martín); and, the Alto Purús Reserved Zone near the Peruvian and Brazilian border. In the higher forest areas of Ayacucho, Apurímac, Huánuco, Junín and Puno, Departments, there are also problems with the illegal drug trade that often make scientific expeditions dangerous.

Peruvian freshwater ichthyology needs greater official support so that a national inventory program can be carried out and a new building for the National Fish Collection can be built.

Future trends for Peruvian Amazon fisheries are uncertain if over fishing continue to increase.

Fish culture programs could be a solution to meet the fish demand in the high and lowland forest, especially for riverine communities such as those along the Urubamba River. There is an also potential opportunity for ornamental fishes, if some species could be raised in fish ponds, as well as, with controlled breeding work or improved management.

Conservation programs targeting wetlands need to include environmental education from primary schools to the universities, as well as participation of local authorities, NGOs and other stakeholders.

Peruvian aquatic ecosystems now face major degradation from pollution and habitat destruction from deforestation, mining, oil extraction, fishing with plant toxics and the illegal drug trade (Ortega and Chang, 1998). The effects of exotic species on lentic water bodies can be complex. The introduction of *O. mykiss* and *O. bonariensis* in the Lake Titicaca may have already driven at least two species to extinction:*Orestias cuvieri* and a catfish that is the largest species in the family Trichomycteridae (*Trichomycterus rivulatus*; Treviño et al, 1991).

The introduction of native species outside of their range is apparently uncommon in Peru, but some spectacular examples exist. For example, *A. gigas* was introduced from Loreto Department into Sauce Lagoon, San Martín Department in 1962 and *P. reticulata* was subsequently introduced in 1965 because the native fish fauna was insufficient to meet the food requirements of *A. gigas*. Later, after 1970, another exotic species, *O. niloticus*, was introduced for the same reason. Interestingly, tilapia proliferated to the extent that they could sustain a fishery in this lagoon.

A management plan for tilapia aquaculture should be implemented. Tilapia aquaculture continues to increase in the Peruvian Amazon, but often in inadequate, inappropriate conditions. A monitoring program for the presence and abundance of tilapia should be implemented in natural areas at highest risk, such as in the lower Huallaga river. Urban development and aquaculture have also modified freshwater environments. These alterations to natural habitats can favor exotic over native species (Ortega and Ramirez, 2000).

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