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Conserving the freshwater fishes of South America

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South America harbours the most diverse freshwater fish fauna in the world, and recent estimates point to between 6000 and 8000 species in the Neotropical region. Such fauna has diverse historical origins, either having invaded and diversified in fresh water from marine ancestors during the Palaeogene or being isolated on the continent since the end of the break-up of Gondwana in the Cretaceous. Taxonomic, morphological and ecological diversity of South American freshwater fishes is dramatic, as are the myriad freshwater habitats they inhabit. Unfortunately, many of these habitats are severely threatened by deforestation, water divergence for irrigation, industry and other uses by humans, hydroelectric damming, mining, pollution and invasive species. Despite these multiple threats, there are very few on-the-ground conservation initiatives in South America, although assessments of species-extinction risks have been produced at regional and subregional levels in different countries.

Key-words: biodiversity; endangered; fish diversity; Neotropical; systematic; taxonomy; threats; vulnerable; wetland habitats.

INTRODUCTION

The freshwater fish fauna of South America is the most diverse of all continents, with the estimated number of species above 4000. When the entire Neotropical region – which includes South America and part of Central America – is considered, the number of fish species jumps to above 5000, representing almost 10% of all known vertebrates (Lundberg *et al*., 2000; Albert & Reis, 2011a). The *Check List of the Freshwater Fishes of South and Central America* (CLOFFSCA) (Reis *et al*., 2003) listed 4475 valid species and estimated another 1550 species not yet described, based on authors' expertise or conjectures and knowledge about ongoing research, bringing the estimated existing fish species in the Neotropics to 6025. In the 9 years since the publication of CLOFFSCA, more than 900 additional freshwater fish species have been described from the region, at an average of one new species every 3·5 days, thus elevating the number of known species to around 5400 in 2012. At this pace of new species descriptions, the 6025 estimate of Reis *et al*. (2003) will be reached in another 6 years. As the curve of species descriptions is clearly not asymptotic, it can be expected that the final number of fish species in the Neotropical region may exceed the 8000 estimated by Schaefer (1998).

Besides being vast, the Neotropical freshwater fish fauna is ancient and has diverse historical origins (Albert *et al*., 2011). The marine ancestors of most of the smaller groups invaded and diversified in fresh waters of South America during the Palaeogene, primarily the Oligocene and Miocene. The incumbent groups, such as the Cichlidae and the Ostariophysi have been isolated on the continent since the end of the break-up of the Gondwana in the Cretaceous, roughly 100 million years ago.

Approximately, 340 freshwater species in 28 chiefly marine families contrast with

the 1080 cichlids, killifish and livebearers, and the almost 3800 ostariophysan fishes (characin, catfishes and knifefishes). Fishes in those 28 marine families are usually referred to as the peripheral division, which invaded and specialized for life in fresh waters. These groups range from 1 to around 100 species, and include freshwater stingrays, eels, sardines, anchovies, mullets, needlefishes, silversides, pipefishes, drums, gobies, flatfish and puffers, among others. The secondary division is composed of freshwater families that are closely related to marine groups, but are entirely confined to continental habitats, and include the cichlids (*c.* 480 spp), the highly threatened rivulids (*c.* 270 spp), anablepids (17 spp), cyprinodontids (59 spp) and poeciliids (*c.* 250 spp). In contrast, the primary division is composed of the Ostariophysii and four other small families that originated and diversified in freshwater habitats, the South American lungfish (Lepidosirenidae), the pirarucu, the largest freshwater South American fish (Arapaimidae), the two species of arowanas (Osteoglossidae) and half a dozen of leaf-fishes (Polycentridae). The Ostariophysii comprises *c.* 75% of all freshwater fishes worldwide. In this group are the tetras and their allies or Characiformes (*c.* 1700 spp), the knifefishes or Gymnotiformes (*c.* 180 spp) and the catfishes or Siluriformes (*c.* 1915 spp).

Diversity of morphological adaptations and ecological requirements are also dramatic across the South American fish fauna. The armoured catfishes or Loricariidae, the largest catfish family with above 800 species, includes remarkable examples. Some species live in highly oxygenated, fast-flowing mountain streams, while others dwell in almost anoxic lagoons in Amazonian lowlands and use their intestines as an accessory respiratory organ (Gee, 1976). At the same time, their premaxillae and dentaries are biomechanically decoupled (Schaefer & Lauder, 1986, 1996) showing bilateral independence and allowing them significant motion to scrape algae and periphyton very effectively from hard substrates. Loricariids also have a remarkable diversity in jaw morphology and associated trophic ecology, some species having spoon-shaped teeth, being highly specialized to feed on wood, while others developed long and acute premaxillary teeth, used to remove aquatic insects from crevices. Other amazing adaptations can be found among the catfishes, such as the phreatic habits of *Phreatobius*, a genus of a few species that live inside the soil in river banks and are most easily captured in existing water wells. Possibly the strangest feeding habits among South American fishes are those of the blood-sucking, parasitic candirus (*Vandellia* spp). These fishes are provided with special odontodes on their opercular area that allow them to attach firmly to the branchial arches of larger fishes and use their highly specialized premaxillary teeth to directly puncture the branchial artery of their hosts and feed on blood. These are the feared candirus that are known to enter mistakenly the human urethra causing painful complications. Also highly feared is the poraquê (*Electrophorus*), one of the almost 200 Gymnotiformes (Neotropical electric eels and knifefishes) of South America. Most of the species in this order are small and use their electrogenic abilities to generate an electromagnetic field around themselves to communicate and to perceive the neighbourhood electrically. In contrast, the *Electrophorus* grows to almost 2 meters long and can deliver electric shocks of up to 600 volts that are used to stun their prey.

HABITATS

This astonishing diversity of fish fauna lives in an equally wide range of aquatic habitat types across South America including many of the largest rivers of the world, extensive marshes, high-altitude lakes and rivers, among other settings. Approximately 25–28% of all free, surface fresh water of the world is in South America (Allan, 1995; Vari & Malabarba, 1998). Water chemistry of South American rivers is influenced by landscape features, especially headwater source, dominant vegetation cover and soil types. Rivers that drain the Andes are

sediment-rich, white-water rivers (e.g. Meta, Marañon, Napo, Madeira). Black-water rivers, tannin-rich dark-tea-coloured systems that originate in the thickly forested lowlands (e.g. Atabapo, Japurá, Tefé, Negro), have very low sediment loads. Finally, rivers that drain the ancient and well-weathered crystalline rocks of the Guiana and Brazilian Shields are the clear-water rivers, with low sediment and high transparency (e.g. Xingu, Tapajós, Tocantins, Ventuari) (Albert & Reis, 2011b). When total length or drainage basin area is considered, only two South American rivers (Amazon and Parana) are among the largest ten rivers in the world. However, if average discharge is accounted for, five South American rivers stand among the top ten – Amazon, Orinoco, Madeira, Negro and Parana; together discharging 393 000 m^3 second^{-1} into the Atlantic Ocean. The Amazon River alone is by far the largest in the world, with 219 000 m^3 second^{-1}, the second being Orinoco with 98 000 m^3 second^{-1} and Congo the third with 41 800 m^3 second^{-1}. As impressive as the Amazon discharge are its 250 000 km^2 of periodically flooded lowlands that harbour an enormous diversity of specialized fishes.

South America also has extensive marshes and permanently flooded wetlands, the most remarkable being the Llanos of the Orinoco River with about 300 000 km^2, and the Pantanal of the Paraguay River with around 160 000 km^2 that stretches between Brazil, Bolivia and Paraguay. The drainage density in most of South America is very high, and many low-order creeks and small rivers harbour an immense diversity of small fishes that are frequently isolated from others in adjoining headwaters by mountain ridges or even by the low stretches of the river basins, avoiding gene flow among populations and thus creating a high degree of endemism. Other notable aquatic habitats are the Andean altitudinal rivers and lakes, which have a fish fauna highly specialized for life in fast-flowing, well-oxygenated, cold waters, and the endorheic river basins of the southern cone of the continent, which harbour a very depauperate fish fauna.

THREATS

Several of these habitats are threatened, sometimes significantly, by extensive deforestation, water divergence for irrigation, hydroelectric damming and alluvial gold mining, which completely disrupts river beds and causes mercury contamination and pollution in some restricted areas. Fish species are also threatened by invasive species and overexploitation.

Deforestation

Deforestation and the consequent habitat degradation, especially the severe siltation of river beds, is one of the main threats to thousands of small- to medium-sized rivers. Deforestation in South America involves both legal and illegal logging, clearing for cattle ranching and, especially, for expanding the agricultural frontier, which is now extending towards the Amazon and the Atlantic forest. As an example, Brazil alone deforested between 11 000 and 25 000 km^2 per year in the last 12 years, and Colombia between 2000 and 3000 km^2 of Amazonian forest in the same period.

Hydroelectric damming

Hydroelectric damming affects fish populations in a threefold manner. The transformation of a lotic environment into a lake either eradicates or extremely reduces populations of rheophilic species and at the same time provides conditions for lentic species to proliferate, thus significantly changing the local-community composition. On a wider scale, dams regulate downstream river flow, thus disturbing the annual cycles of feeding and reproduction, and disrupting the migratory routes of many large fishes. This is particularly important in South America because the reproductive biology of large, migratory fish is distinct from that of migratory North American or European fish species, for which fish passages were originally conceived. Contrary to those fishes, South American migratory species move up rivers during

the high-water season, bypassing the dam through fish passages, and spawn in flowing waters above the impoundment. Eggs and then larvae are immediately carried down river by the turbid, well-oxygenated torrent and, under natural conditions, reach floodplains in the low portion of the river courses, where they will complete development. When a dam is present between spawning areas and the floodplains, the eggs either sink as they reach the reservoir or are rapidly eaten, before they reach the fish passages and floodplains, by the many tetras that usually dwell in lakes. In addition to affecting fishes and other aquatic organisms, dams in tropical-forest areas have a significant impact on carbon-dioxide emissions. The Balbina hydrolecteric dam near Manaus, Brazil, drowned 2400 km^2 of rainforest, causing the emission of 23 million tones of carbon dioxide in the first 3 years. Additional damage is likely, as two large dams (Jirau and Santo Antônio) are now under construction in the Madeira River. These will certainly adversely impact the migratory routes of large catfishes (*Brachyplatystoma* spp) in both Brazil and Bolivia. Simultaneously, the Xingu River is threatened with the impending construction of the Belo Monte hydroelectric dam, which will affect several species of reophilic and very specialized armoured catfishes, including the prized Zebra pleco *Hypancistrus zebra*.

Mining

Gold mining in South American rivers is also an enormous environmental problem that adversely affects aquatic organisms. Rivers are heavily dredged, a process completely destroying the river bed and banks. In addition to degradation of the physical habitat, the typical use of mercury to separate the gold from the substrate, followed by vaporization of the mercury to yield pure gold, causes severe poisoning to miners and the environment.

Alien species

Another important threat for South American fishes is posed by the numerous invasive species. This is less of a problem in the Amazon than in many of the river drainages in Argentina, central and eastern Brazil, Chile and other countries that have one to many introduced alien fish species. Aquaculture is the main factor in the introduction of alien species, with salmon introduced in south and central Chile while Brazilian rivers harbour around 13 introduced species from other continents, especially tilapia, carp, trout, ictalurid catfish, clariid catfish and others. In addition, the transposition of South American fishes between distinct river basins is also common, and commercially important fishes, such as the tucunaré (*Cichla*) and the tambaqui (*Colossoma*) from the Amazon basin, have been introduced into the Pantanal and other places. The main problem caused by introduced fish species is the competition for niches and resources and, sometimes, predation. Predatory trout and salmon introduced in Chile and some parts of southern Brazil, respectively, have almost extirpated the local fish fauna in several regions.

CONSERVATION AND FUTURE PLANNING

Despite the complex array of factors threatening South American freshwater fishes, there are few on-the-ground conservation initiatives on the continent. Perhaps the most important and successful conservation project is the Piaba Project, created in 1989 in the Negro River north of Manaus, Brazil, by Labbish Chao. This is a community-based, sustainable ornamental-fisheries project founded on the perception that people living from harvesting ornamental fishes need to preserve the forest. The project's slogan 'Buy a fish and save a tree' describes this intent very well.

Other initiatives toward conserving fishes are the preparation of Red Lists for different countries or regions in South America. Probably the most ambitious of these is the recent partnership between the Brazilian Ministry of Environment and International Union for Conservation of Nature (IUCN), with the aim

of assessing the conservation status of all Brazilian fish species. As this is a gigantic task, species will be assessed by regions within Brazil, based on the freshwater ecoregions of the world as described by Abell *et al*. (2008). The process has begun on the severely fragmented and badly threatened Atlantic Forest. Another important project of the fish Red List includes the lower La Plata River basin in Argentina, Paraguay and Brazil (Cappato & Yanosky, 2009). Results from this project are already available online (http://www.proteger.org.ar/peces-cuenca-plata/). So far, the project has uncovered three Endangered (EN) species, eight Vulnerable (VU) and three Near Threatened among the 184 assessed species (Baigún *et al*., 2012). At a more regional scale, the state of Santa Catarina in southern Brazil recently finished assessing its freshwater fishes revealing a much worse situation: 11 Critically Endangered, three EN, 20 VU, eight Least Concern and 47 Data Deficient, from a total of 89 assessed species. Finally, Peru is beginning the process of assessing the conservation status of their freshwater fishes through a partnership between the Peruvian Ministry of Environment and IUCN South America.

Priorities for future action include completing the conservation status assessments regionally and at a continental (global) level. Only after the Red List assessments are completed for a region or basin, can conservationists proceed to the next step of developing action plans. A very good example of success in developing a conservation action plan for a river basin is that of the Paraíba do Sul River in south-eastern Brazil, recently launched by the Chico Mendes Institute for Conservation of Biodiversity (https://sites.google.com/site/planodeacaoparaibadosul/). Also instrumental for the future of fish conservation in South America will be increasing the PhD level expertise in fish taxonomy and systematics, especially in non-Brazilian countries, improving museum facilities and inventory initiatives to uncover the undescribed fish diversity, and fostering new initiatives of on-the-ground freshwater conservation.

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