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Environmental disturbances and fishes in the Amazon

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The Amazon is a multi-faceted biome extending across all of the countries in northern South America. Aquatic habitats include watercourses of all sizes, beaches, lakes, flooded forests and floodplain areas. White, black and clear water types differ in the amount and nature of their sediments and in their levels of dissolved organic carbon, ion content, pH, water density and temperature. This environmental diversity is added to the regular cycle of changes driven by region's annual flood pulses. Over millions of years, the region has experienced challenges requiring continuous biological adjustments of all organisms. These natural constraints are claimed to be the cause of the unparalleled diversity of fish species in the region.

The fishes have developed myriad adjustments at all biological levels to face the never-ending environmental challenges that naturally occur in their habitats (Almeida-Val *et al.*, 1999). These challenges are now joined by recent human disturbances that are pushing fishes to their biological limits. The scientific community must therefore focus efforts on developing reliable strategies for biological conservation, and local, regional, national and transnational authorities must promptly adopt these strategies.

River damming is one of the most controversial environmental challenges. Hydroelectric dams have both costs and benefits, but the costs (both monetary and non-monetary) are consistently understated and the benefits exaggerated (Fearnside, 2014). Blocking fish migration is a critical effect of dams. Many Amazonian fishes have an annual piracema, or mass stock migration ascending Amazon tributaries to breed in the headwaters. The most dramatic case is the blockage of migration of the 'giant catfish' of the Madeira River [including *Brachyplatystoma rousseauxii* (Castlenau 1855) and *Brachyplatystoma vaillantii* (Valenciennes 1840)]. These magnificent fishes were a major economic and nutritional resource for riverside populations in Brazil, Peru and Bolivia. The large catfishes did not succeed in locating and entering the fish passages installed at the two dams (Fearnside, 2014). Blocking fish migration also causes fragmentation of populations and loss of gene flow, which also affects fish yields.

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Reduced fish yield is also observed downstream of hydroelectric dams due to release of water with little or no oxygen. In the case of the Tucuruí Dam, commercial fisheries were decimated in the lower Tocantins River. Fish landings at Cametá declined by 82% from 4726 t in 1985 to 831 t in 1987, and the freshwater shrimp *Macrobrachium amazonicum* harvest declined by 65% from 179 t in 1981 to 62 t in 1988 (Fearnside, 2001). From the closing of the Tucuruí Dam during 1984–2006, the fishes caught in the reservoir never came close to replacing the loss of fishes in the natural river.

Dams also affect fish species that depend on habitats such as rapids, not only in the areas flooded by the reservoirs, but also in other parts of the river's course. In the case of the Belo Monte Dam currently under construction on the Xingu River, a 100 km reduced flow stretch below the main dam will have very little water, as 80% of the river's flow will be diverted to the side through a series of canals to generate power at a point below the reduced flow stretch. The zebra pleco *Hypancistrus zebra* Insbrücker & Nijssen 1991 is a charismatic ornamental fish whose range is restricted to rapids in this stretch and in the stretch to be flooded by Belo Monte.

Other interventions have effects of similar dimensions. Deforestation reduces habitat complexity and so affects fish behaviour. Oil spills and global warming can also reduce fish population and growth rates (Val *et al.*, 2006). Unfortunately, most decision-makers are not aware of the direct and indirect implications of interventions in the heterogeneous Amazon.

Considering the above-mentioned constraints, fish conservation in the Amazon must rely on public policies to avoid habitat losses. Genetic characteristics of different groups of species must be considered along with their distributions and biological traits. Management and conservation actions will therefore require substantial efforts to collect information on the environments surrounding each intervention point, as well as on more general environmental effects. Local efforts and specific rules will succeed better than general rules designed for the whole basin. Fishing regulations will need species-specific knowledge and must be based on the characteristics of commercially exploited species rather than on general statements. Finally, laws must protect critically important freshwater environments such as the floodplain (várzea) lakes that serve as nurseries for many fish species and the small streams (igarapés) that contain unique and complex fish assemblages. The success of any of these actions depends on a massive educational process. Such efforts will not be effective if education is neglected.

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