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Fishes of the Atlantic Rain Forest Streams: Ecological Patterns and Conservation

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1. Introduction

Fishes constitute more than one half of the species of vertebrates, with around 32,000 living species (Froese & Pauly, 2011). Approximately 40% of this global fish diversity lives in freshwater environments, which represents less than 1% of the surface of the Earth (Dudgeon et al., 2006). In the Neotropical Region, freshwater fishes constitute a taxonomically distinct fauna that extends throughout the continental waters from Central Mexico to the southernmost tip of South America. This zoogeographical region is known to harbor the richest and most diverse freshwater fish fauna of the whole planet (Géry, 1969; Vari & Malabarba, 1998; Lundberg et al., 2000; Albert et al., 2011).

The Atlantic Rain Forest is one of the richest biomes in the Neotropics mainly due to the variety of habitats throughout the range of the forest types and subtypes, which originally covered a wide stripe of the Brazilian coastline (Morellato & Haddad, 2000). Considering the fact that the definition of the limits and forest types of the Brazilian Atlantic Rain Forest is controversial and beyond the scope of this study, this vegetation domain was considered here in a narrower sense, comprising the coastal forest formations between 6–30^0 S, with elevations from sea level to approximately 1,000 meters. In this sense, this forest is dispersed along degraded landscapes, embracing some of the largest and oldest Brazilian urban areas, where more than 150 million people live.

The Atlantic Rain Forest constitutes one of Brazil´s most important vegetation domains, because of its historical relationship with the colonization of the country, and also in view of the role that it plays in the conservationist scenario (Silva, 2003). In the broadest and most generic sense of the forest formations, this biome is one of the most biodiverse and endangered ecosystems in the world (Myers et al., 2000).

The region bounded by this forest has a high percentage of fish species with restricted distribution, as a result of the great number of independent coastal drainages (or groups of basins), and the isolating effect of mountain ranges and seawater among coastal rivers (Bizerril, 1994; Menezes et al., 2007). In fact, according to our survey a great amount (70%) of the freshwater fishes can be considered exclusive to the coastal drainages of this vegetation domain The high rate of speciation and high degree of geographic endemism is an important factor that needs to be considered in the conservation policies of the Atlantic Rain Forest remains, as this biome is located in the most populated regions of the country,

making these aquatic environments especially vulnerable to anthropogenic impacts (Menezes et al., 2007).
In this chapter, despite the fact that a standard definition for the term stream is difficult and sometimes controversial, streams were defined as naturally flowing surface waters that are contained in a channel with definite boundaries and hydrodynamics, with channel widths up to approximately 40 m. This definition allowed the inclusion of Atlantic Rain Forest streams of many different characteristics (Fig. 1), all characterized by mosaics of different habitats and microhabitats determined by the system's response to spatial and temporal variation in the input of water, flow regime, depth, sediment, debris, and biotic structure.

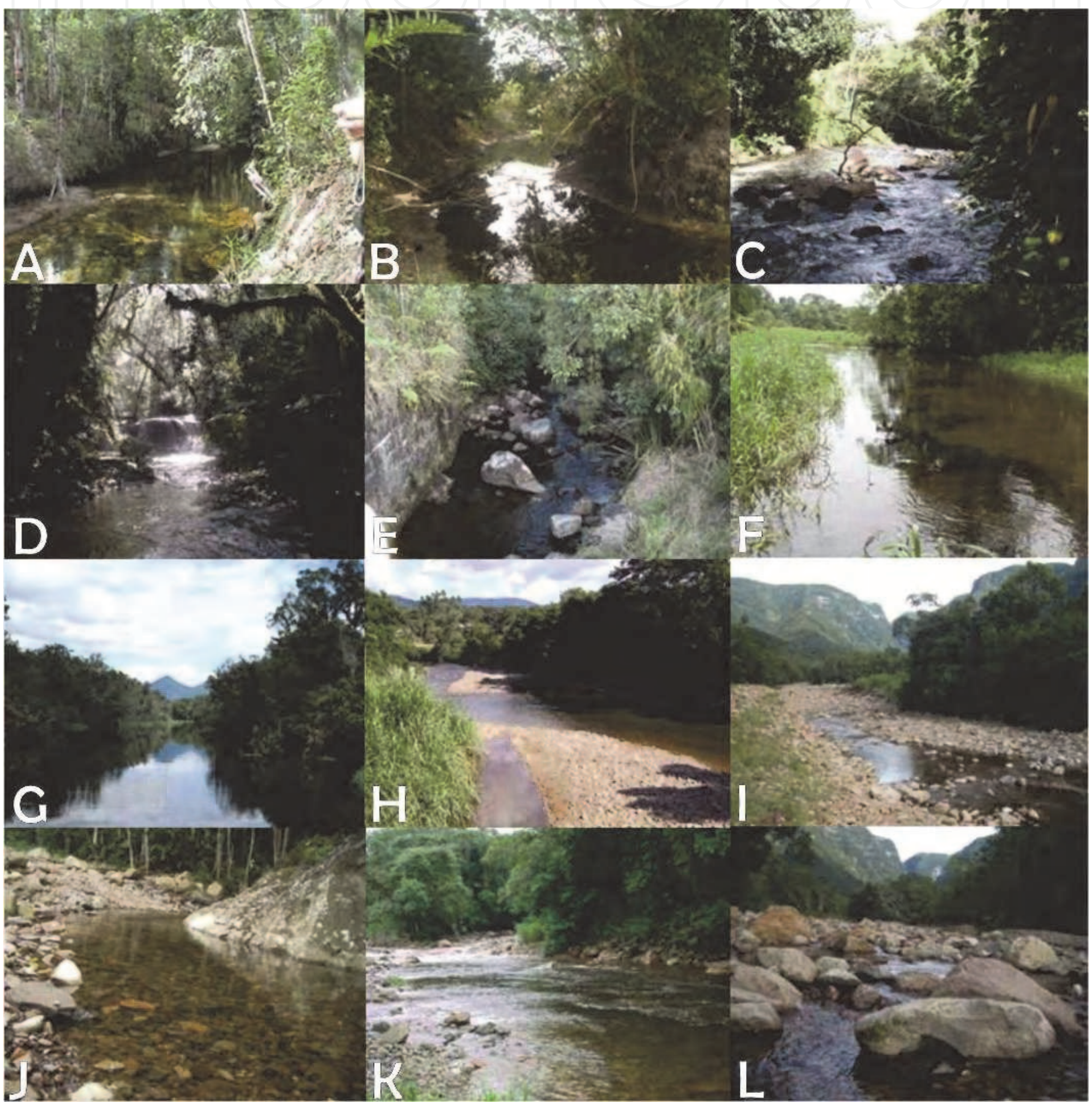


Fig. 1. Atlantic Rain Forest streams habitats along the Brazilian coastline. A. Mocuba River (Bahia); B. Guaibimzinho River (Bahia). C. São João River (Espírito Santo); D. Ubatiba River (Rio de Janeiro). E. São João River (São Paulo). F. Das Pombas River (Paraná); G. Guaraguaçu River (Paraná); H. Nhumdiaquara River (Paraná); I. Ararangua River (Santa Catarina); J. Itapocu River (Santa Catarina); K. Mampituba River (Rio Grande do Sul); L. Do Boi River (Rio Grande do Sul).

This chapter investigates ecological patterns of stream fish community in the Atlantic Rain Forest of Brazil. Several streams that flow through this ecosystem are inhabited basically by small-sized fish species, which dwell in streams or shallow water of rivers, showing sometimes a high rate of speciation and a high degree of geographic endemism. The aim of this chapter is to demonstrate the great biodiversity and high endemism of fish species in the Atlantic Rain Forest streams, and also assess general patterns in assemblage structure and composition, feeding habits and reproductive strategies. Conservation issues and impacts concerning the anthropic pressure were also explored.

2. Stream fish composition and structure

Species richness registered in the Atlantic Rain Forest streams is high. The taxonomic biodiversity is represented by 269 species belonging to 89 genera and 21 families (based on, Menezes & Weitzman, 1990; Lucena & Lucena, 1992; Bizerril, 1994; Schaefer et al., 1997; Pereira & Reis, 2002; Reis & Schaefer, 1998; Weitzman & Malabarba, 1999; Costa, 2002; Bertaco, 2003; Bertaco & Lucena, 2006; Oyakawa et al., 2006; Menezes et al., 2007; Buckup et al., 2007; Lucinda, 2008). Regardless of been relatively poor at higher taxonomic levels (one class), the ichthyofauna is dominated by ostariophysian fishes (205 species), and the most represented orders are Siluriformes (114 species) and Characiformes (83 species) (Fig. 2). These groups also constitute the main fish component of other Neotropical freshwater environments.

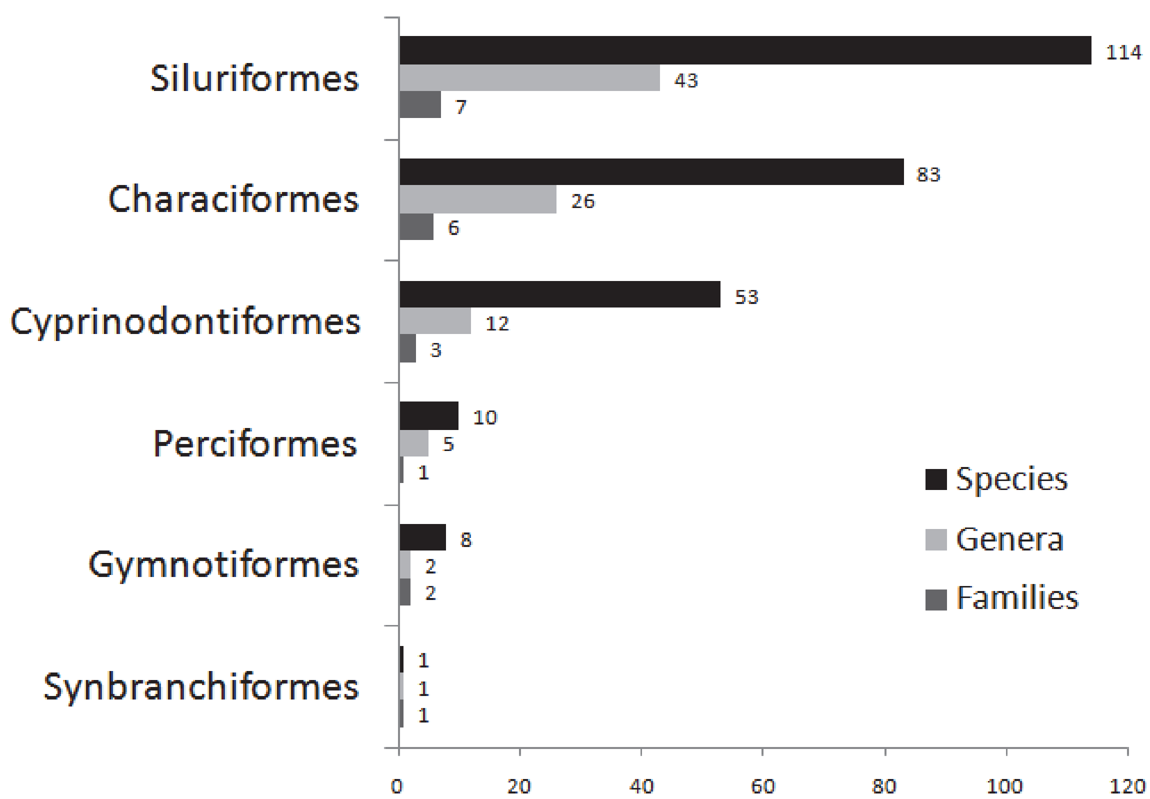


Fig. 2. Number of species, genera and families of freshwater fishes of the Atlantic Rain Forest streams.

Characins (tetras and relatives), loricariids (armored catfishes and relatives), trichomycterids (candirus), rivulids (killifishes), and poeciliids (guppies) are strongly dominant. Some species can be found in streams with rapids and rocky bottom, while others live in temporary aquatic environments during rainy seasons. The most speciose genera are *Trichomycterus*, with 19 species, *Phalloceros*, with 18 species, and *Astyanax*, comprising 15 species (Fig. 3).

The Neotropical catfish family Trichomycteridae comprises more than 200 species of small-sized fishes (de Pinna & Wosiacki, 2003) which in general inhabit fast-flowing rocky streams (Arratia, 1983; de Pinna, 1998). Despite the remarkable range of habitats and feeding habits, there is little information on trichomycterids natural history in the Atlantic Rain Forest. Available evidences for the genus *Trichomycterus* suggest that the group is represented by generalist predators of aquatic invertebrates (Trajano, 1997; Rolla et al., 2009), and individuals can be found in streams with rapids and rocky bottom, living usually beneath rocks (Menezes et al., 2007) and buried under sand or leaves.

The livebearing fishes of the family Poeciliidae are characterized by internal fertilization, viviparity, and marked sexual dimorphism. The neotropical genus *Phalloceros* comprises twenty-two species distributed throughout southern and southeastern river basins of South America (Lucinda, 2008). *Phalloceros* species live primilarly near shore in open sunny areas of quiet backwaters of streams, where aquatic vegetation provides cover (Menezes et al., 2007).

The genus *Astyanax* is diverse and widespread in freshwaters of South America, including at least 136 described species (Froese & Pauly, 2011). *Astyanax* is likely a non-monophyletic genus, and the taxonomic status of some species from the Atlantic Rain Forest and adjacent areas is not completely clear (Menezes et al., 2007). *Astyanax* species can be observed in clear and turbid waters, in segments with pools and riffles, within a great variety of substrates such as stones, rocks, sand or mud.

Besides characins, catfishes, killifishes, and guppies, marine species such as sleepers (Eleotridae), mullets (Mugilidae), snooks (Centropomidae), pipefishes (Syngnathidae), and gobies (Gobiidae) make up the list of species that so far have been registered in the Atlantic Rain Forest biome drainages. Some species can be found in streams and in aquatic systems considered as a transitional environment between the estuarine-riverine and the estuarine mixing zones, such as *Dormitator maculatus*, *Poelicia vivipara*, *Gobionellus oceanicus*, *Ctenogobius shufeldti*, *Awaous tajasica*, and *Microphis brachyurus*. The ability to tolerate salinity fluctuations is common to some of this marine/estuarine species, but their adaptability and distribution vary according to the physiologic tolerance of each species.

Coastal Atlantic Rain Forest streams can be recognized as a very distinct area in terms of its ichthyofauna. The predominance of small-sized fish species of tetras, armored catfishes, candirus, killifishes, and guppies, which dwell in streams or shallow water of rivers, and the high rate of speciation and degree of geographic endemism, may indicate a certain degree of uniformity in the characterization of local and regional stream fish assemblages. Main differences in regional diversity of fish community among streams are related to large-scale factors such as biogeographical history, elevation and stream hierarchical organization in the watershed, while local diversity variations seem to be mostly due to site-specific factors (environmental conditions). Differences in fish community are caused by the natural variability of ecosystems, but also by human disturbances like habitat alteration, non native species introduction and pollution.

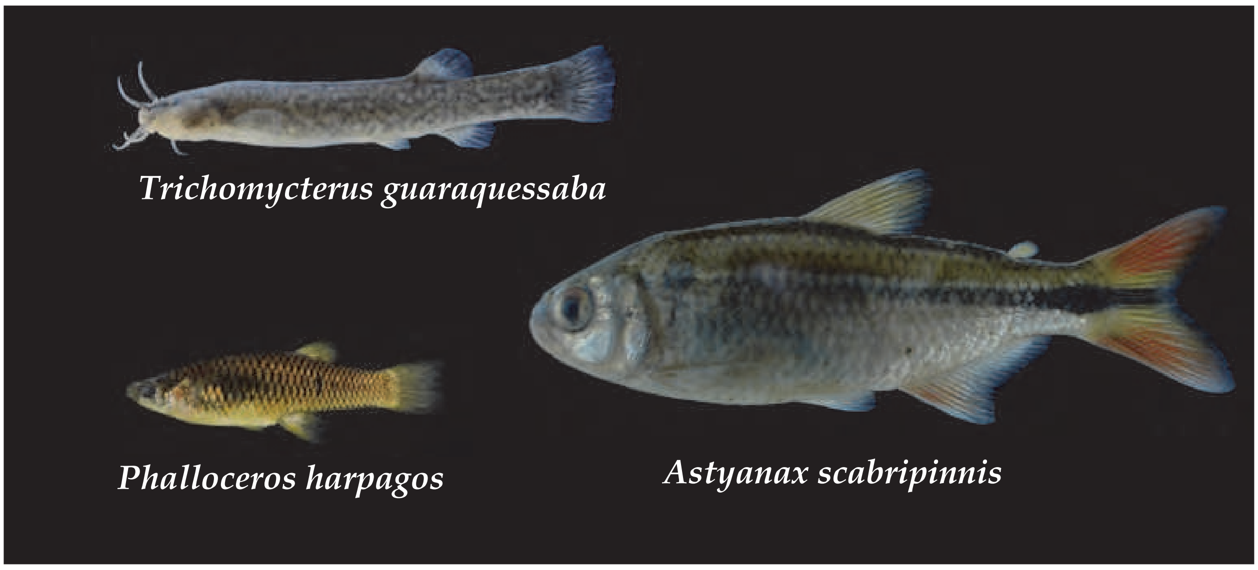


Fig. 3. Atlantic Rain Forest stream species of *Trichomycterus* (72 mm SL), *Phalloceros* (43 mm SL), and *Astyanax* (100 mm SL).

3. Reproduction

Reproduction biology of Atlantic Rain Forest stream fishes have been studied by several authors (Mazzoni & Caramaschi, 1997; Menezes et al., 1998; Amaral et al., 1998; Aranha & Caramaschi, 1999; Mazzoni & Petito, 1999; Sabaj et al., 1999; Mazzoni et al., 2002, 2005; Mazzoni & Iglesias-Rios, 2002a, 2007; Braga et al., 2006; 2008; Mazzoni & Silva, 2006; Becker et al., 2008; Vitule et al., 2007, 2008a). However there still is a large gap on this subject.

Reproductive aspects of fishes are characterized by a wide plasticity that is unique among vertebrates, with several evolutionary transitions between external fertilization and copulation. In general, fishes have a fixed sex (gonochoristic) but there are hermaphroditic ones such as *Synbranchus marmoratus*, a diandric (both primary and secondary male development) protogynous species (females turn into males) (Lo Nostro & Guerrero, 1996). Most teleost species are ovuliparous (external fertilization and development) (e.g. *Rhamdia quelen*, *Hyphessobrycon griemi*, *Gymnotus carapo*, *Crenicichla* spp.), and in some species the common reproductive mode is oviparity, where fertilization is internal but the development is external. This seems to be the case of the characin subfamily Glandulocaudinae, but there is no evidence of actual internal fertilization, only internal insemination (Burns et al., 1995).

Viviparity (internal fertilization and development with birth of live young) is also rare but common to the family Poeciliidae (e.g. *Phalloceros* spp., *Poecilia vivipara*, *Phalloptychus januarius*). This type of reproduction allows the reproduction to be relatively independent from environmental variables, turning this onto an interesting adaptation on such an instable environment as neotropical streams.

Among external fertilizing stream fishes some characins such as *Astyanax* species spawn their eggs into the water column where males release sperm. Other common breeding behaviours are deposition of egg under rocks, into cavities and scattering on the substratum. A few external fertilizing species present parental care. It is common among Loricariinae (armoured catfishes) where males search for shelter to protect their eggs, and in some cases eggs are attached to the body of females. Cichlids are also well kwon for building nests where they protect their eggs and young.

Another important life history pattern of reproduction regards to semelparity (single reproductive event in their life) or iteroparity (species reproduce several times during a lifetime). To date there are no records of a semelparous species at Atlantic Rain Forest streams. Some rivulids such as *Leptolebias aureoguttatus* that live on stream´s adjacent temporary ponds are annual, which means that individuals spawn several times before dying in these temporary aquatic environments during rainy seasons, and eggs survive dry periods buried in the substrate, not characterizing semelparity.

To avoid predation and to enhance fertilization and dispersal fishes have a wide variety of temporal and spatial patterns of spawning. They either release their eggs all at once in the same location (total spawners, e.g. *Characidium* spp., *Geophagus brasiliensis*, *Deuterodon langei*) or scatter them along the year and/or throughout the stream (partial spawner, e.g. *Rhamdia quelen*, *Hypostomus luetkeni*, *Pseudotothyris obtusa*). In the tropics, day length and temperature are slightly uniform and most species opt to breed throughout the whole year, but in the Brazilian coastal rivers rain regime is recognized to be the most important factor influencing species that spawn their eggs at once (Menezes & Caramaschi, 1994; Amaral et al., 1998; Vitule et al., 2008a).

3.1 Reproductive period

Neotropical stream fishes usually present a relatively long reproductive period (e.g. *Harttia* sp., *Phalloceros* spp., *Poecilia vivipara*, *Phalloptychus januarius*, *Jenynsia lineata*, *Characidium pterostictum*, *Hypostomus luetkeni*, *Geophagus brasiliensis*, *Astyanax hastatus*) (Mazzoni & Caramaschi, 1997; Menezes et al., 1998; Aranha & Caramaschi, 1999; Mazzoni & Iglesias-Rios, 2002a; Becker et al., 2008), with some species breeding throughout the whole year (e.g. *Rhamdia quelen*, *Astyanax janeiroensis*) (Gomiero et al., 2007). This pattern is attributed to an adaptive response to unstable environments such as these neotropical stream that are subject to flash floods, a frequent natural hydrological disturbance. This way the continuous input of newborn would assure a higher rate of survival and therefore the maintenance of a viable population in a stochastic environment.

Conversely, there are some species that exhibit a very seasonal and restricted breeding period, usually reproducing during spring and summer (e.g. *Pimelodella pappenheimi*, *Bryconamericus microcephalus*, *Mimagoniates microlepis*, *Deuterodon langei*) (Amaral et al., 1998; Mazzoni & Silva, 2006; Braga et al., 2006, 2008; Vitule et al., 2008a). Flash floods occur mainly on early months of the year, so it seems that these species are adapted to these events and they spawn just before summer rains. Those studied populations present an important difference regarding a latitudinal gradient. With the exception of *Bryconamericus microcephalus* population studied by Mazzoni & Silva (2006) the other populations that presented a seasonal reproduction period are situated at a subtropical region. These habitats with more defined seasons and therefore more variation on photoperiod and temperature may be shaping this reproductive characteristic in different ways. Therefore a macroecological study is needed to unveil a potential pattern in these populations.

3.2 Sexual dimorphism

The most common form of sexual dimorphism among fish are body size and length-weight relationship. An increase in fecundity is an advantage provided by large females whereas larger males are more successful in territorial confrontations and thus increase reproductive fitness (e.g. *Mimagoniates* spp.). Among nest guarding species larger males (e.g. *Harttia* sp.) is also an advantage as they would be more successful at protecting its offspring. As previously mentioned, high fecundity is an important feature among Atlantic Rain Forest stream fishes and so larger females seem to be the general pattern found on these habitats. Examples of some species that present this characteristic are *Rhamdia quelen*, *Characidium* spp. *Astyanax janeiroensis*, *Deuterodon langei* and *Bryconamericus microcephalus*. Secondary sexual characters are also found in Glandulocaudinae and Poeciliidae. Males of Glandulacoudinae (e.g. *Mimagoniates* spp., *Glandulocauda* spp.) display in their caudal fin, glandular tissues associated to modified scales which presumably pumps pheromone to attract females. Poeciliidae males are easily distinguished for their modified anal fin that is called gonopodium which is used to inseminate females of the species.

4. Ontogenetic migration

Another pattern found in Atlantic Rain Forest stream fishes is a longitudinal segregation. In some populations a greater amount of small individuals (in proportional terms) are found at lower portions of the stream while larger individuals (in proportional terms) concentrate at the higher portions (Fig. 4). It is hypothesized that during flash floods, eggs, larvae and small individuals along with rocks, branches and other aquatic fauna, get carried out to the lower portions of the stream. As they grow, they increase their swimming capability and become able to explore upstream habitats, where they reproduce and complete the cycle. This dynamic ensure the long term permanence of the population along the whole hydrographic basin. Opposed to a spawning migration as observed in larger characin species inhabiting large neotropical rivers, this ontogenetic migration is not restricted to the reproduction period at wet seasons and can be observed along the whole year. This pattern was observed for *Hypostomus punctatus*, *Astyanax janeiroensis*, *Deuterodon langei, Geophagus brasiliensis,* and *Mimagoniates microlepis* (Menezes & Caramaschi, 2000; Mazzoni & Lobón-Cerviá, 2000; Mazzoni et al., 2004; Braga et al., 2007; Vitule et al., 2008a). This is probably a pattern derived mainly by ecological factors with low phylogenetic interference.

Several hypotheses of patterns and main drivers of this segregation must be tested in different streams and with more species and direct field experiments (Fig. 5). For example, the prediction that due to the stream bed inclination, the average size of individuals within a population increases towards higher altitudes and is more accentuated as altitude variation increases. The average length is also expected to decrease as distance from stream spring increases due to water carrying of small individuals. Also flash flood intensity and/or frequency may be responsible for a decrease of the average length at upstream sites. As pointed out by Vitule et al. (2008a) for *Deuterodon langei*, reproductive intensity should decrease along the longitudinal gradient as an indirect effect of size segregation, but the young proportion increases at lower habitats as small individuals are carried out and larger ones (adults) persist or swim back to higher habitats. As this is a flash flood dependent dynamic as the water velocity increases, the size segregation becomes more evident. In a climate change scenario it is clear that as temperature rises, flash floods become more often and/or intense, possibly increasing the average speed of the water and compromising several species ability to settle at upstream sites. Apparently this is not far from happening as shown by recent events in the Atlantic Rain Forest (Fig. 6). These hypotheses reinforce the importance of preserving the entire portion of the stream as each part represents an important habitat for each stage of the life of stream fish.

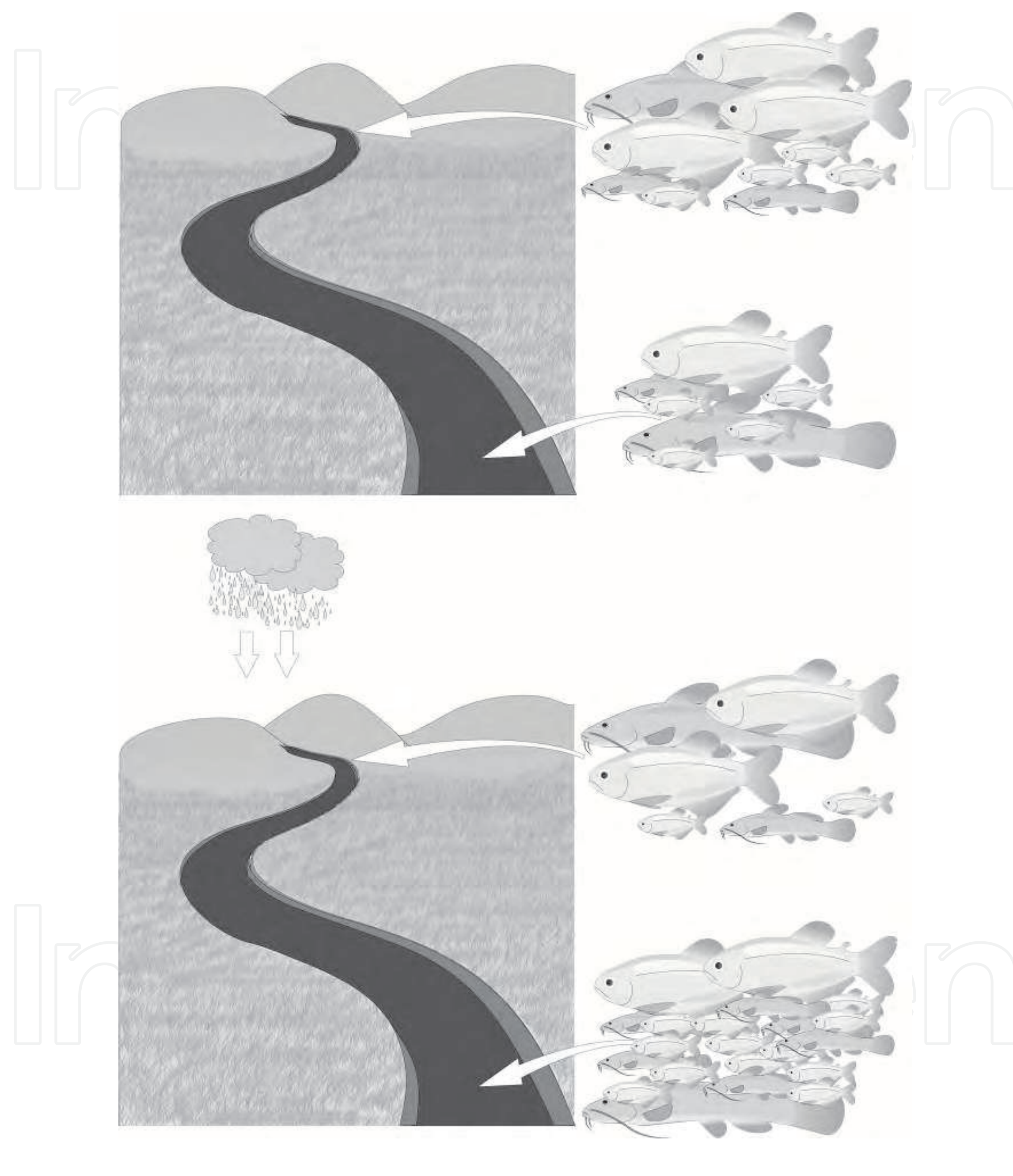


Fig. 4. A hypothetical scenario of ontogenetic migration. After a disturbance (flash flood), a greater amount of small individuals (in proportional terms) are found at lower portions of the stream while larger individuals (in proportional terms) concentrate at the higher portions (Illustration by Igor Kintopp).

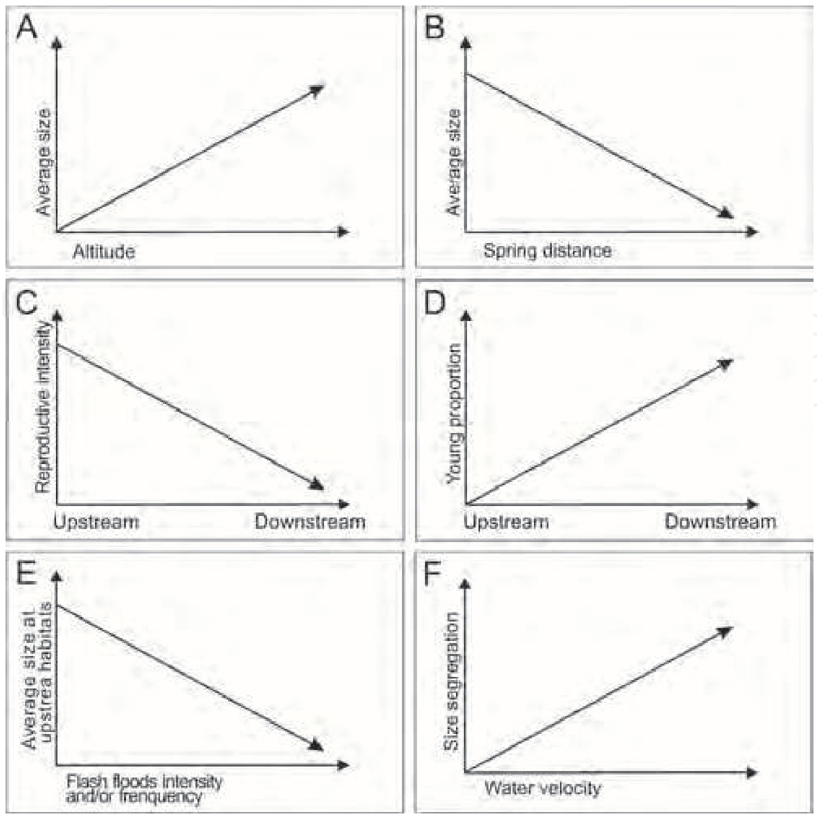


Fig. 5. Hypotheses of patterns and main drivers of the ontogenetic migration. A. Average size of individuals within a population increases towards higher altitude; B. Average size of individuals within a population decreases with spring distance; C. Population's reproductive intensity decreases along the longitudinal gradient from upstream to downstream; D. Proportion of young individuals increases along the longitudinal gradient from upstream to downstream; E. Average size of the individuals within a population decreases with higher flash flood intensity and/or frequency; F. Size segregation becomes more evident as water velocity increases (Illustration by Igor Kintopp).

Fig. 6. On March 11, 2011 the Paraná coast (Brazil) was affected by heavy rains, causing floods in the cities of Morretes, Antonina and rural region, blocking highways to Paranaguá city. This rain caused one of the most catastrophic destructions at the Jacarezinho and Sambaqui River on the last decades.

5. Feeding

Feeding ecology of Atlantic Rain Forest stream fishes has been studied by several authors (e.g. Buck & Sazima, 1995; Aranha et al., 1998, 2000; Esteves & Lobon-Cerviá, 2001; Vilella et al., 2002; Vitule & Aranha, 2002; Deus & Petrere, 2003; Fogaça et al., 2003; Mazzoni & Rezende, 2003; Rezende & Mazzoni, 2003, 2006; Barreto & Aranha, 2006; Abilhoa et al., 2007, 2010a,b; Botelho et al., 2007; Mazzoni & Costa, 2007; Gomiero & Braga, 2008; Vitule et al., 2008; Rolla et al., 2009; Mazzoni et al., 2010). Based on the analysis of 55 species' gut contents in the above studies, stream-dwelling fishes in Atlantic Rain Forest exhibit diverse feeding habits, and "omnivory" (i.e. predation in >1 trophic level, with an opportunistic use of resources) seems to be the predominant feeding strategy. Diet analysis also revealed a wide range of food items and allowed the recognition of five major trophic groups: omnivorous (47.2%), insectivorous (21.8%), herbivorous (20%), carnivorous non-insectivorous (5.4%), and detritivorous (5.4%). These general groups have been divided into more restricted trophic guilds (sometimes artificial groups) which makes data compelling and metanalysis more difficult and less accurate.

Trophic plasticity of fishes seems to favour the utilization of a large array of food resources. The carnivorous guild, for example, shows different capture tactics according to the microhabitat and prey behaviour. While some benthic invertebrate predators are non-selective (generalists), others are specialized and use sit-and-wait predation (*Characidium* spp.) (Casatti & Castro, 1998) and substrate speculation (heptapterids catfishes) as feeding strategies. Piscivorous fishes have their diets based on the pursuit (e.g. *Oligosarcus* spp.) or ambush (e.g. *Hoplias malabaricus*) of preys, although they may complement their diets with allochthonous items (mainly terrestrial insects). In spite of the fact that insectivorous fishes are a type of carnivores, they are commonly placed in their own category. In this case, most small-sized Atlantic Rain Forest characins are mainly insectivorous (Costa, 1987; Sabino & Castro, 1990; Aranha et al., 1998; Vitule et al., 2008b), feeding on autochthonous (aquatic immature and aquatic adult insects) and allochthonous food material. Several fish species feed primarily on terrestrial insects (Costa, 1987; Allan, 1995; Casatti & Castro, 1998; Aranha et al., 1998; Sabino & Zuanon, 1998; Abilhoa et al., 2009), collecting insects that fall into the stream from the riparian vegetation. The fusiform body shape, eyes dorsolaterally placed on the head, and sometimes the upward turned mouth (e.g. *Mimagoniates* spp., *Rachoviscus* spp., *Rivulus* spp.), indicate surface picking behaviour as a feeding strategy for small-jawed characins, by which the fish swims upstream and catches terrestrial items on the water surface (Sazima, 1986).

Besides insects, the input of terrestrially derived organic material (e.g. plants, seeds, fruits, and other invertebrates) is also considered important for fish feeding in Atlantic Rain Forest streams, where riparian forest blocks part of sunlight and the primary productivity is relatively low. As the importance of autochthonous production of organic matter in rivers is generally expected to increase downstream from the headwaters because of the widening of the stream channel, which allows more light to reach the water, small forested streams depend on the allochthonous resources coming from the riparian forest to maintain the predominantly heterotrophic biota (Vannote et al., 1980). Riparian input may be the primary energy source to consumers in low-order streams worldwide (Minshall et al., 1985).

The guild of herbivorous comprises usually armored catfishs. Loricariids have a dorsoventrally flattened body, a sucker-like mouth, and comb-like tooth plates, morphological specializations that enable them to scrape attached algae and diatoms from the substrate.

These bottom feeders can also suck up organic matter (detritus), a poor nutritionally source of food compound by large amounts of associated microorganisms (Gerking, 1994).
On the other hand, detritus can turn into an important resource during dry seasons once the availability of other food items decrease. For *Deuterodon langei* it was detected an association between abundance and occurrence of detritus and microscopic algae, thus suggesting that the greater the proportion of detritus the greater will be the proportion of microalgae (Vitule et al., 2008b). In this sense, the abundance of microscopic algae can be related to the presence of detritus in benthic food resource such as periphyton, which increase with gradual drying (Vitule et al., 2008b). The only detritivorous specialized fish in the Atlantic Rain Forest seems to be the curimatid *Cyphocharax santacatarinae*. All these species above mentioned possess a long, narrow and twisted (coiled in Loricariids) digestive tract, morphological adaptations of the digestive system reported for several herbivorous/detritivorous neotropical fishes (Delariva & Agostinho, 2001, Vitule et al., 2008b).
Additionally, most studies on the feeding ecology of fish have shown that the increase of feeding activity can be related with the rainy period, when prey availability is higher, and several species shift their diets according to the ontogenetic development (Vitule & Aranha, 2002; Abilhoa et al., 2007; Vitule et al., 2008b; Abilhoa et al., 2009), what seems to be related with morphological (e.g. buccal opening) an behavioral (e.g., locomotion capability) changes during development (Wooton, 1999).
In recent years, it has become apparent that some omnivorous stream fishes (e.g. *Bryconamericus* sp., *Phalloceros* sp.) that ingested great amount of allochthonous material, predominantly assimilated carbon derived from algae (Brito et al., 2006). The utilization of stable isotope analysis indicates that stomach content studies provide only instantaneous information on these species' diet, but does not account for long-term patterns of mass transfer (Woodward & Hildrew, 2002). Thus traditional dietary inference probably failed in giving a clear indication of the origin of sources of carbon and their flow through food webs (Peterson & Fry, 1987). Despite the strong tendency towards omnivory among fishes indicated by gut contents analysis, we think that many fundamental questions associated with the trophic ecology and the investigations of energy transfer in neotropical streams are necessary to be accessed in order to clarify this paradigm.
Stomach content analysis is often considered to provide a short-term information about ingested prey, and may be influenced by differences in digestion rates of prey resulting in under-representation or bias (Hyslop, 1980). Stable isotope analysis, on the other hand, is considered to provide long-term information about resource intakes (Phillips & Gregg, 2003). We therefore suggest that mixing models using stomach contents and stable isotopes can provide a robust and synthetic approach to understand the trophic ecology in Atlantic Rain Forest ecosystems in the near future. Several other methodologies such as non-lethal methods (regurgitation and direct observations) and fatty acid analysis exist but are rarely used. Alternative methodologies can be of great interest and use for these Neotropical stream fishes once non-lethal techniques can constitute a unique opportunity to study the feeding ecology of endangered species.

6. Threats, impacts and conservation

6.1 Threats and impacts

The Atlantic Forest (*lato sensu*) embraces a large number of species (~1–8% of the world's species) and a high number of endemic species (Myers et al., 2000). An up to date assessment revealed a massive number of endemic species, such as 8000 tree species (40% of the total), 200 birds (16%), 71 mammals (27%), 94 reptiles (31%), and 286 amphibians (60%), not to mention least-known taxonomic groups (Metzger, 2009). The Atlantic Rain Forest has lost nearly 93% of its primary vegetation and is considered a hotspot for conservation. Habitat loss due to illegal deforestation and urbanization along with the introduction of non-native species and pollution are major threats to these areas.

Freshwater habitats represent round 0.8% of the Earth's surface and supports more than 6% of all described species. Its biodiversity comprise a precious natural resource in terms of economic, cultural, aesthetic, scientific and educational value (Dudgeon et al., 2006) both in global and regional scales. Unfortunately, freshwaters ecosystems are the most threatened ones (Abell, 2002) mostly due to the water demands and human negative impacts on ecological integrity.

Therefore, to understand the ecosystem dynamics and improve conservation in this important hotspot, basic ecological studies are fundamental, especially with the increasing advance of human activities and its negative impacts to the water, its fauna and humans themselves. In addition, many local anthropogenic problems have synergetic effects with global changes, but these associations are difficult to predict (Fig. 7). Proper management (e.g. forestry code enforcement, reducing non-native species introduction, landscape planning) will be decisive for conservation of the Atlantic Rain Forest basins and its fish fauna. We believe that we still have a huge gap in understanding stream fish biodiversity. Some important specific objectives for the near future are: (i) to exchange and disseminate scientific, technical, and practical information about endangered species and their conservation priorities; (ii) to recognize current and future practices in the conservation of the Atlantic Rain Forest fish fauna.

6.1.1 Information gaps and conservation efforts

Information gaps on biodiversity jeopardize stream fish conservation efforts, as there is little understanding about species distribution, abundance, dispersal processes, metapopulation structures, population viability, and many other basic biological data. We need also to comprehend specific adaptations and how populations, communities, and ecosystems are affected by anthropogenic alterations. We predict that survey intensification into least studied areas can reveal a wealth of diversity. This intensification is highly important as Abell (2002) argues that: "there is insufficient empirical evidence to convince some policymakers".

In general, there is an imperative apprehension on the possibility that the functioning of ecosystems might be threatened by biodiversity loss. Many eminent ecologists argue that, diversity tends to stabilize community dynamics and/or increase productivity (Odum, 1953; MacArthur, 1955; Elton, 1958). Obviously ecosystem functioning links are complex (Cameron, 2002). Therefore fish biodiversity and net productivity in streams of the Atlantic Rain Forest can have intricate links due to its richness and complexity and a change in only one of these variables can have an impact on one another. In spite of that there are no comprehensive studies about relationships between stream fish biodiversity and ecosystem services, we believe that it's highly important to improve studies using stream fish richness or other kinds or measures of diversity (e.g. species, genetic, community, functional, evenness, Shannon–Weaver, etc.) as a proxy of biodiversity and its importance or relationship for ecosystem services. In sum, if fish biodiversity has an influence on Atlantic Rain Forest ecosystem functioning, it could affect ecosystem services, goods and human welfare in a near future. As a result, improving basic and applied research about connection between biodiversity and ecosystem functioning is of direct relevance to public policy and to the "real world".

Knowledge on endemic areas and species distribution or extinction rates and conservation is still scarce and inaccurate. The application of biogeographical tools, principles, theories and analyses is fundamental for an effective conservation of fishes inhabiting these ecosystems. Recently, some core challenges to conservation of freshwater fish were recognized (Olden et al., 2010), such as: (1) Testing new ecological theories for this specific fauna; (2) Quantifying with accuracy the extinction risk and loss of genetic, taxonomic (e.g. species) and functional biodiversity; (3) Evaluating the magnitude of extinction debt for freshwater fishes; (4) Elucidating the patterns and drivers of freshwater fish invasions; (5) Forecasting the future biogeography of the Atlantic Rain Forest fishes; (6) Understanding the interactive or synergetic effects of multiple environmental and ecological stressors; (7) Identifying and quantifying new features of the small scale biodiversity (8) Identifying and quantifying fish faunal homogenization and the emergence of novel assemblages; (9) Promoting and improving scientific rigour in conservation strategies and conservation planning strategies for freshwater fish species and (10) explain all this and spread to society in general.

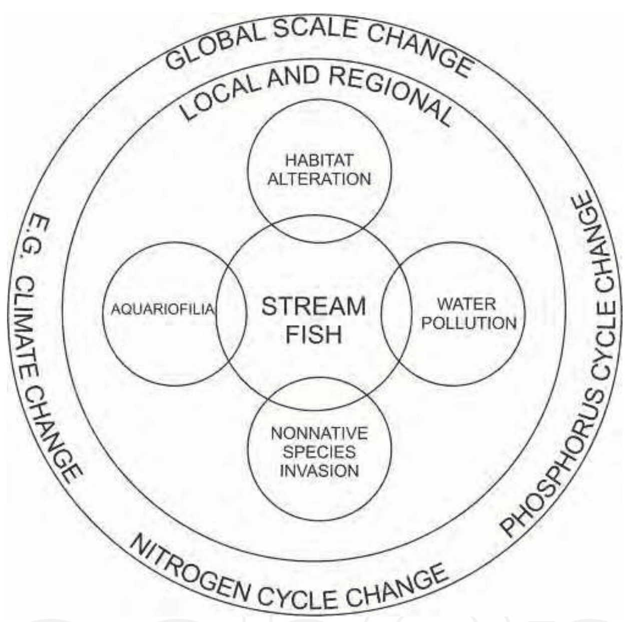


Fig. 7. Local and regional anthropogenic negative impacts and their potential interactive impacts to the Atlantic Rain Forest fish biodiversity. Environmental global changes such as climate change, nitrogen and phosphorous cycle changes can affect and amplify all these threats (Illustration by Igor Kintopp).

Despite the fact that biodiversity assessments provide data on global priority regions for freshwater conservation (e.g. Abell et al., 2008), accurate local scale priorities remain unknown around the World (Nogueira et al., 2010). Scale refining of biodiversity assessments and the translation of these into conservation priorities remains a major challenge to biodiversity science. In Atlantic Rain Forest streams biodiversity science depends directly on improvement of accurate basic data like species occurrence with high taxonomic and geographic resolution. Implementation of local scale conservation actions is also in a weak position by the reality that most conservation assessments tend to treat freshwater ecosystems as formerly separate hydrographic basins and/or smallest biogeographical units even within the same basin or subbasin. In sum, it's highly important to divide areas into units with similar environmental/geophysical conditions as well as similar fish assemblages, natural communities and ecosystem dynamics.

6.1.2 Climate change

There are many potential direct (more obvious) and indirect impacts of climate change or "global warming" on freshwater fish, especially into hotspots like the Atlantic Rain Forest coastal freshwater habitats. First of all the melting of polar ice caps and thermal expansion of seawater will result in a sea level rise that would inundate foremost important habitats in the Atlantic Forest, and/or cause modifications on disturbance regimes. Second, temperature is a major variable in all freshwater systems because of its widespread effects on the life history, physiology, behavior and ecology of most freshwater organisms. Moreover, fish have evolved with their current local micro climate and hydrological conditions like disturbance regime (e.g. frequency and intensity of flash floods). The homeostasis or optimal physical and biological range of each individual, species or population is determined by temperature as they are all hexothermic or "cold-blooded (Schmidt-Nielsen, 1990). In other words, all fish have their ideal temperatures that are necessary for optimal or efficient metabolism, reproductive success, and disease or parasites resistance (Schmidt-Nielsen, 1990).

Temperature increase is a major concern since environmental thermal conditions may encroach on suboptimal conditions for many local adapted stream fishes, or bring them closer to their incipient lethal temperatures. Moreover, climate change can affect fish populations through its influence on rain regimes, disturbance intensity and physical factors such as limnology and water chemistry (e.g. pH, oxygen solubility, hydrological regimes, and primary net productivity). Even small increases in temperature (~ 1 - 2^{o}C) can be sufficient to have major effects on tropical fish physiology; reproduction in particular, especially when combined with an altered hydrologic regime and other anthropogenic stressors (e.g. invasive species). Facing climate changes, tropical fish populations can achieve new equilibrium dictated largely by the new energetic cost, so some species may increase or decrease in abundance, others may experience new interactions, range expansions or contractions, and many species may face extinction. In this sense, climate changes are new challenges to survival and reproductive success by influence of many ecological parameters and human stressors. We argue that conservation biologists have not yet developed a sufficient understanding of the precise impacts of the climate changes for all tropical fish species, especially for the Atlantic Rain Forest streams, but certainly they exist and are imperative.

Unfortunately, accurate risk assessment is impeded by contingency: the impacts of climate changes on tropical fish species vary over time and space under the influence of local environmental variables, interspecific interactions and evolutionary changes. But certainly, some potential impacts of climate change, such as species extinctions, are large and irrevocable. Finally, removing other stressors from natural systems is a necessary and important proactive management strategy for tropical fish conservation.

6.1.3 Habitat destruction and alteration

The increase of human activities, if poorly managed, can generate significant negative impacts on water bodies and wildlife. The destruction of habitat as a result of expansion of urban areas near water bodies may cause changes in species composition, favoring species better adapted to degraded environments, or even completely extinguish some species, most notably the rare and endangered ones. This occurs due to direct and/or indirect effects, such as channel rectification, substrate dredging, illegal occupation of riparian forest and adjacent areas, and construction of landfills and illegal dumps. All these processes can cause dramatic ecological changes, for instance, a significant decrease on energy exchange between riparian and aquatic environments. Changes in water flow dynamics can lead to profound alteration on aquatic fauna, reducing productivity, variability and environmental heterogeneity. For example, the high input of organic matter may lead to eutrophication or to its demise and reduced physical complexity (Allan, 1995).

In many rivers, certainly in small ones, much of the energy present in the food chain comes from terrestrial habitats. Therefore changes in terrestrial habitats may act as an important source of impacts to the aquatic environment (Allan, 1995), and to the land itself, due to their interdependence. On the other hand, the process of dredging, construction and formation of artificial channels produce different changes in the environment, not only in water but also in the adjacent terrestrial environment. There are countless negative effects to the natural ecosystem, for example, flooding of forested areas, changes on physical and chemical properties adjacent to the aquatic environment and changes in structure and composition of communities in small streams. Furthermore, the modification of natural hydrologic regimes and biological invasions are two synergistic and major threats to freshwater biota (Johnson et al., 2008).

In streams, as in large rivers, impoundments negatively affect flooding patterns, flow regime, sediment transport, trophic structure and species composition. Dams and associated impoundments also have major influence on the β and γ diversity along small basin network. Dam effects can reduce hydrologic connectivity between neighboring aquatic habitats by preventing fish migration up or downstream and affecting recruitment. On the other hand, impoundments can allow dispersal of undesirable fish into systems outside of their natural range, facilitating invasion and contributing to biotic homogenization process through habitat homogenization, where local riverine biota is replaced by cosmopolitan lentic species (Rahel, 2002). In the Neotropical Region, the increase on dam numbers has altered hydrology and is affecting the freshwater fish fauna, which was previously subject to geographic constraints by a multiplicity of physiographic barriers. Besides the fact that predicting long-term cumulative environmental impacts on aquatic ecosystems is a challenging mission, the potential problem of eliminating natural obstacles in streams and its consequence has not received attention during environmental impact studies of hydropower facilities.

6.1.4 Water pollution

The most common source of pollution includes agriculture, industries and discharge of untreated sewage. The direct or indirect consequences of domestic dump and industrial effluents, often highly toxic can cause profound changes in the diversity of fish, favoring species with greater adaptability, or completely extinguishing all species of fish. The enrichment of water with nutrients (especially phosphorus and potassium) can cause eutrophication. In this process, the richness and diversity are profoundly diminished, leaving only species highly resistant to low oxygen concentration (Allan, 1995).

6.1.5 Introduction of non-native species and invasions

Introduced fishes have a long history of globally catastrophic cases, including examples in the Atlantic Rain Forest (Vitule, 2009), being a precursor of a prominent global biotic homogenization. A species of fish can be considered non-native, even at the level of basins or sub-basins. This makes the perception and/or detection of introduced fish even more complex in nations like Brazil, due to its continental dimensions and rich continental aquatic environments. In this sense, fish introductions become serious threats as these organisms are very widespread, mobile and of difficult perception and/or detection. It is a common fact that introductions of this group of organisms are perceived only when they are already in advanced stages of the invasion process and the damage is irreversible. Some non-native fish to the Atlantic Rain Forest streams may be considered "invisible" (e.g. less exposed than the majority of the introduced terrestrial organisms). Often, cultural aspects and time of release contribute to the "invisibility" of the problem. Some fish species that were translocated from other continents (e.g. carp, tilapia, and trout) a long time ago are considered "native" and/or even important for some small human groups that don't understand its potential or real impacts (Vitule, 2009; Vitule et al., 2009).

Despite the recent increase in publicity about the subject and its problems worldwide, the numbers of non-native species introductions may have a tendency to exponential increases in aquatic environments of the Neotropical Region. In the case of introduction of non-native species with huge invasive potential, lack of action can result in serious and irreversible problems. Introduced species may be restricted and avoided, and if they invade a new environment where they are unwanted and/or may cause harm, it should be eradicated. If not possible, they should be studied in long term, monitored and maintained at acceptable low population's levels. In other developed countries, committed a long time ago to this issue, there are examples of success in all types of actions mentioned above, although, even in developed and rich countries, there are few investments, studies and efforts. If there is a lack of serious interest and investment worldwide, the scenario is much worst in developing countries such as Brazil. For example, even in the scientific field the theme of aquatic invasions into the Atlantic Rain Forest streams is very under-explored in Brazil. However, information about troubles that may arise from biological invasions is building up (Vitule, 2009). Given the magnitude of the problem, and disproportion in the search for answers and impacts, a review of the theme with suggestions for actions is presented in Vitule (2009).

A clear and highly problematic example of introduction is the release of the trout *Oncorhynchus mykiss* in southern Brazil. Inexplicably, this is a project of the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), with support from United Nations Program for Development in Brazil (Vitule, 2009). It therefore seems rather serious, rather serious, since *O. mykiss is officialy* listed in the Global Invasive Species Database as one of the 100 worst "alien species" and it is considered a potential pest (Froese & Pauly, 2011). In previous example, we see again a complete distortion in the costs/benefits relationship and a total disregard by the authorities with respect to natural biodiversity. There are analogue cases that have been occurring in several streams and states of Brazil. Deliberated and illegal releases are very easy to identify. With a simple internet search, the release of great amounts of fish can be documented with photos of ecovandalism events. Easily any one can find sites that sell non native fish species (fingerlings or adults). Such virtual mechanisms can be easily tracked, hunted and restricted the same way as done with child pornography or other illegal sites.

6.1.6 Aquarium trade and illegal commerce

Although not officially recorded, it is a fact that all small beautiful species treated here appear in books and/or international aquarium sites. It is strange that these species sometimes listed in the local Red List are used as aquarium animals at other countries and/or continents. In this sense, its use is inappropriate, because these species may have been caught through illegal collecting, characterizing animal trafficking and/or biopiracy. These are impacts that must be considered and investigated thoroughly.

6.2 Conservation

Recently, foremost multi-taxa projects have amplified the ecological understanding of major causes and consequences of Atlantic forest alterations (Metzger, 2009). Unfortunately, this is not a homogenous reality for all sub-areas or regions and/or kind of habitats and organism. In our view there are discrepant disproportions in the ecological and conservation research between terrestrial and aquatic ecosystems. Much of the knowledge on Atlantic Rain Forest stream fish conservation is dispersed and fragmented and the need to assemble the information is crucial. We believe that enhancement about specific studies on stream fish ecology and conservation biogeography can provide clear recommendations for biological conservation in a near future. Another top high priority should be perhaps to take on its stream physical and biological restoration, but a successful stream restoration, will depend on our knowledge about many of the basic ecological processes embracing fish fauna remains unknown. We hope that in the future the general knowledge obtained in Atlantic Rain Forest can help conservation efforts in other tropical areas.

6.2.1 Case study

A case study of some threatened species of the coastal plain in the state of Paraná, southern Brazil: an example of what happens to Atlantic Rain Forest stream fish.

Despite the scarcity of information, the national (Machado et al., 2008) and Paraná (Abilhoa & Duboc, 2004) lists of threatened fishes present endemic species of Atlantic Rain Forest coastal plain streams of Paraná: *Mimagoniates lateralis, Spintherobolus ankoseion, Rachoviscus crassiceps,* and *Scleromystax macropterus.* Due to the observation of populations decline, reduced distribution areas and/or strong anthropogenic pressures, these species were grouped into categories of threat according to IUCN, but unfortunately none of which actually appears on the official list of the IUCN. These species are all exclusive of low altitude water bodies extending from Paraná to north of Santa Catarina. Available information, although sparse, show that these populations occur in areas near large urban centers, and are therefore under strong pressure. Despite its importance and high degree of endemism, there are no official records of individuals of these species in captivity for conservational finalities. However, as stated earlier, all species mentioned have appeared in books and worldwide aquarium web sites. For those reasons if we wish to improve the success of conservation projects, it is extremely important to gather basic information concerning species ecology, including habitat preferences and environmental tolerances. In the near future, we hope that modern molecular techniques will discriminate evolutionary diversity within species, aiding conservation efforts.

7. Conclusions and perspectives

In the Atlantic Rain Forest, natural physical isolation and dispersal limitation that contributed to the high freshwater diversity can also enhance extinction rates along with anthropogenic changes. At last, this chapter does not want to exhaust this subject; we expect that our compilation and ideas will offer a useful guideline for identifying challenges, key research questions and new paths of investigation into the Atlantic Rain Forest fish domain. The balance between the practice of backward reflection and forward-looking is critical to advance the knowledge about freshwater fishes in this important region to global biodiversity.

8. References

Abell, R. (2002). Conservation Biology for the Biodiversity Crisis: a Freshwater Follow-up. *Conservation Biology*, Vol.16, pp. 1435–1437, ISSN 0888-8892

Abell, R.; Thieme, M.L.; Revenga, C.; Bryer, M.; Kottelat, M.; Bogutskaya, N.; Coad, B.; Mandrak, N.; Balderas, S.C.; Bussing, W.; Stiassny, M.L.J.; Skelton, P.; Allen, G.R.; Unmack, P.; Naseka, A.N.G.; Sindorf, N.; Robertson, J.; Armijo, E.; Higgins, J.V.; Heibel, T.J.; Wikramanayake, E.; Olson, D.; López, H. L.; Reis, R. E.; Lundberg, J. G.; Sabaj-Pérez, M.H. & Petry, P. (2008) Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation. *BioScience*, Vol. 58, No. 5, pp. 403-414, ISSN 0006-3568

Abilhoa, V. & Duboc, L.F. (2004). Peixes, In: *Livro vermelho da fauna ameaçada no Estado do Paraná.* S.B. Mikich & R.S. Bérnils (Eds.), 581-682, Instituto Ambiental do Paraná, ISBN 85-98415-01-4, Curitiba, Brasil

Abilhoa, V., Vitule, J.R.S. & Bornatowski, H. (2010b). Feeding ecology of *Rivulus luelingi* (Aplocheiloidei: Rivulidae) in a coastal Atlantic rainforest stream, southern Brazil. *Neotropical Ichthyology*, Vol.8, No.4, pp. 813-818, ISSN 1679-6225

Abilhoa, V., Vitule, J.R.S.; Bornatowski, H.; Lara, F.B.; Kohler, G.U.; Festti, L.; Carmo, W.P.D. & Ribeiro, I.K. (2010a). Effects of body size on the diet of *Rivulus haraldsiolii* (Aplocheiloidei: Rivulidae) in a coastal Atlantic Rainforest island stream, southern Brazil. *Biotemas.* Vol.23, No.4, pp. 59-64, ISSN 0103-1643

Abilhoa, V.; Bastos, L.P. & Wegbecher, F. (2007). Feeding habits of *Rachoviscus crassiceps* (Teleostei: Characidae) in a coastal Atlantic rainforest stream, southern Brazil. *Ichthyological Exploration of Freshwaters*, Vol.18, No.3, pp. 227-232, ISSN 0936-9902

Abilhoa, V.; Bornatowski, H. & Otto, G. (2009). Temporal and ontogenetic variations on feeding habits of *Hollandichthys multifasciatus* (Teleostei: Characidae) in coastal Atlantic rainforest streams, southern Brazil. *Neotropical Ichthyology*, Vol.7, No.3, pp. 415-420, ISSN 1679-6225

Albert, J.S.; Petry, P.; Reis, R.E. (2011). Major biogeographic and phylogenetic patterns, In: *Historical Biogeography of Neotropical Freshwater Fishes*. J.S. Albert & R.E. Reis (Eds.), 21-57, Berkeley University of California Press, ISBN 978-0-520-26868-5, Berkeley, USA

Allan, J.D. (1995). *Stream ecology: structure and function of running waters,* Chapman and Hall, ISBN 140205582X, London, UK

Amaral, M.F.; Aranha, J.M.R. & Menezes, M.S. (1998) Reproduction of the freshwater catfish *Pimelodella pappenheimi* in southern Brazil. *Studies on Neotropical Fauna and Environmental*, Vol.33, pp. 106–110, ISSN 0165-0521

Aranha, J.M.R. & Caramaschi, E.P. (1999). Estrutura populacional, aspectos da reprodução e alimentação dos Cyprinodontiformes (Osteichthyes) de um riacho do sudeste do Brasil. *Revista Brasileira de Zoologia*, Vol.16, No.1, pp. 637-651, ISSN 0101-8185

Aranha, J.M.R.; Gomes, J.H.C. & Fogaça, F.N.O. (2000). Feeding of two sympatric species of *Characidium*, *C. lanei* and *C. pterostictum* (Characidiinae) in a coastal stream of Atlantic Forest (Southern Brazil). *Brazilian Archives of Biology and Technology*, Vol.43, No.5, pp. 527-531, ISSN 1516-8913

Aranha, J.M.R.; Takeuti, D.F.; Yoshimura, T.M. (1998). Habitat use and food partitioning of the fishes in a coastal stream of Atlantic Forest, Brazil. *Revista de Biología Tropical*, Vol.46, No.4, pp. 951-959, ISSN 0034-7744

Arratia, G. 1983. Preferencias de habitat de peces Siluriformes de aguas continentales de Chile (Fam. Diplomystidae y Trichomycteridae). *Studies on Neotropical Fauna and Environmental*, Vol.18, pp. 217–237, ISSN 0165-0521

Barreto, A.P. & Aranha, J.M.R. (2006). Alimentação de quatro espécies de Characiformes de um riacho da Floresta Atlântica, Guaraqueçaba, Paraná, Brasil. *Revista Brasileira de Zoologia*, Vol.23, No.3, pp. 779-788, ISSN 0101-8185

Becker, F.G.; Carvalho, S. & Hartz, S.M. (2008). Life-history of the South American darter, *Characidium pterostictum* (Crenuchidae): evidence for small scale spatial variation in a piedmont stream. *Neotropical Ichthyology*, Vol.6, No.4, pp. 591-598, ISSN 1679-6225

Bertaco, V.A. & Lucena, C.A.S. (2006). Two new species of *Astyanax* (Ostariophysi: Characiformes: Characidae) from eastern Brazil, with a synopsis of the *Astyanax scabripinnis* species complex. *Neotropical Ichthyology*, Vol.4, No.1, pp. 53-60, ISSN 1679-6225

Bertaco, V.A. (2003). Taxonomia e filogenia do gênero *Hollandichthys* Eigenmann, 1909 (Teleostei: Characidae) do sul e sudeste do Brasil. *Unpublished M.S. Dissertation*, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil

Bizerril, C.R.S.F. (1994). Análise taxonômica e biogeográfica da ictiofauna de água doce do leste brasileiro. *Acta Biológica Leopoldensia*, Vol.16, No.1, pp. 51–80, ISSN 0101-5354

Botelho, M.L.L.A.; Gomiero, L.M. & Braga, F.M.S. (2007). Feeding of *Oligosarcus hepsetus* (Cuvier, 1829) (Characiformes) in the Serra do Mar State Park - Santa Virgínia Unit, São Paulo, Brazil. *Revista Brasileira de Biologia*, Vol.67, No.4, pp. 741-748, ISSN 0034-7108

Braga, M.R.; Menezes, M.S.; Aranha, J.M.R. (2006). Táticas reprodutivas de *Mimagoniates microleptis* (Steindachner, 1876) (Characidae, Glandulocaudinae) no rio Colônia Pereira. *Estudos de Biologia*, Vol.28, No.65, pp. 15-22, ISSN 1980-590X

Braga, M.R.; Vitule, J.R.S. & Aranha, J.M.R. (2007). Estrutura populacional de *Mimagoniates microlepis* (Steindachner, 1876) (Characidae, Glandulocaudinae) em um riacho de Floresta Atlântica, Paraná (Brasil). *Acta Biológica Paranaense*, Vol.36, No.1-2, pp. 67-81, ISSN: 0301-2123

Braga, M.R.; Vitule, J.R.S. & Aranha, J.M.R. (2008). Reproduction period of *Mimagoniates microlepis* (Steindachner, 1876) (Characidae, Glandulocaudinae) from an Atlantic Forest Stream in Southern Brazil. *Brazilian Archives of Biology and Technology*, Vol.51, No.6, pp. 345-351, ISSN 1516-8913

Brito, E.F.; Moulton, T.P.; de Souza, M.L. & Bunn, S.E. (2006). Stable isotope analysis indicates microalgae as the predominant food source of fauna in a coastal forest stream, south-east Brazil. *Austral Ecology*, Vol.31, pp. 623–633, ISSN 1442-9993

Buck, S. & Sazima, I. (1995). An assemblage of mailed catfishes (Loricariidae) in southeastern Brazil: distribution, activity, and feeding. *Ichthyological Exploration of Freshwaters*, Vol.6, No.4, pp. 325-332, ISSN 0936-9902

Buckup, P.A.; Menezes, N.A. & Ghazzi, M.S. (2007). *Catálogo das espécies de peixes de água doce do Brasil,* Museu Nacional, ISBN: 978-85-7427-018-0, Rio de Janeiro, Brazil

Burns, J.R.; Weitzman, S.H.; Grier, H.J. & Menezes, N.A. (1995). Internal fertilization, testis and sperm morphology in Glandulocaudine fishes (Teleostei: Characidae: Glandulocaudinae). *Journal of Morphology*, Vol.224, pp. 131-145, ISSN 0717-9502

Cameron, T. (2002). 2002: the year of the 'diversity-ecosystem function' debate. *Trends in Ecology and Evolution*, Vol.17, No.11, pp. 495–496, ISSN 0169-5347

Casatti, L. & Castro, R.M.C. (1998). A fish community of the São Francisco River headwaters riffles, southeastern Brazil. *Ichthyological Exploration of Freshwaters*, Vol. 9, No. 3, pp. 229-242, ISSN 0936-9902

Costa, W.J.E.M. (1987). Feeding habits of a fish community in a tropical coastal stream, rio Mato Grosso, Brazil. *Studies on Neotropical Fauna and Environmental*, Vol.22, No.3, pp. 145–153, ISSN 0165-0521

Costa, W.J.E.M. (2002). *Peixes anuais brasileiros: diversidade e conservação,* UFPR, ISBN 8573350792, Curitiba, Brazil

de Pinna, M.C.C. & Wosiacki, W.B. (2003). Family Trichomycteridae (Pencil or parasitic catfishes), In: *Check list of the freshwater fishes of South and Central America*, R.E. Reis, S.O. Kullander & C.J. Ferraris, (Eds.), 270–290, Edipucrs, ISBN 8574303615, Porto Alegre, Brazil.

de Pinna, M.C.C. (1998). Phylogenetic relationships of neotropical Siluriformes (Teleostei: Ostariophysi); historical overview and synthesis of hypotheses, In: *Phylogeny and Classification of Neotropical Fishes*, L.R. Malabarba, R.E. Reis, R.P. Vari, Z.M.S. Lucena & C.A.S. Lucena, (Eds.), 279-330, Edipucrs, ISBN 8574300357, Porto Alegre, Brazil.

Delariva, R. L. & Agostinho, A.A. (2001). Relationship between morphology and diets of six neotropical loricariids. *Journal of Fish Biology*, Vol.58, pp. 832-847, ISSN 0022-1112

Deus, C.P. & Petrere-Junior, M. (2003). Seasonal diet shifts on seven fish species in an Atlantic Rainforest stream in southeastern Brazil. *Brazilian Journal of Biology*, Vol.63, No.4, pp. 579-588, ISSN 1678-4375

Dudgeon, D.; Arthington, A.H.; Gessner, M.O.; Kawabata, Z.I.; Knowler, D.J.; Leveque, C.; Naiman, R.J.; Prieur-Richard, A.H.; Soto, D.; Stiassny, M.L.J. & Sullivan, C.A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Review*, Vol.81, pp. 163-182, ISSN 1464-7931

Elton, C.S. (1958). *Ecology of Invasions by Animals and Plants,* Chapman and Hall, ISSN 0309-1333, London, UK

Esteves, K.E. & Lobón-Cerviá, J. (2001). Composition and trophic structure of a fish community of a clear water Atlantic rainforest stream in southeastern Brazil. *Environmental Biology of Fishes*, Vol.64, No.4, pp. 429-440, ISSN 1573-5133

Fogaça, F.N.; Aranha, J.M.R. & Esper, M.L.P. (2003). Ictiofauna do rio do Quebra (Antonina, PR, Brasil): ocupação espacial e hábito alimentar. *Interciencia*, Vol.28, No.3, pp. 168-173, ISSN 0378-1844

Froese, R. & Pauly, D. (February 2011). FishBase. In: *World Wide Web electronic publication*, May, 23 2001, Available from: <www.fishbase.org>

Gerking, S.D. (1994). *Feeding Ecology of Fish*, Academic Press, ISSN 0122807804, San Diego, USA

Gery, J. (1969). The Freshwater Fishes of South America, In: *Biogeography and Ecology in South America*, E.J. Fittkau; J. Illies; H. Klinge; G.H., Schwabe, H. Sioli, (Eds.), 828-848,. The Hague, ISBN 978-90-6193-071-6, Netherlands

Gomiero, L.M. & Braga, F.M.S. (2008). Feeding habits of the ichthyofauna in a protected area in the state of São Paulo, southeastern Brazil. *Biota Neotropica*, Vol.8, No.1, pp. 1-8, ISSN 1676-0603

Gomiero, L.M.; Souza, U.P. & Braga, F. (2007). Reprodução e alimentação de *Rhamdia quelen* (Quoy & Gaimard, 1824) em rios do Núcleo Santa Virginia, Parque Estadual da Serra do Mar, São Paulo, SP. *Biota Neotropica*, Vol.7, No.3, pp. 1-7, ISSN 1676-0603

Hyslop, E.J. (1980). Stomach contents analysis, a review of methods and their application. *Journal of Fish Biology*, Vol.17, pp. 411-430, ISSN 0022-1112

Johnson, P.T.J., Olden, J.D. & Zanden, M.J.V. (2008). Dam invaders: impoundments facilitate biological invasions into freshwaters. *Frontiers in Ecology and the Environment*, Vol.6, pp. 357-363, ISSN 1540-9309

Kullander, S.O. & Lucena, C.A.S. (2006). A review of the species of *Crenicichla* (Teleostei: Cichlidae) from the Atlantic coastal rivers of southeastern Brazil from Bahia to Rio Grande do Sul States, with descriptions of three new species. *Neotropical Ichthyology*, Vol.4, No.2, pp. 127-146, ISSN 1679-6225

Lo Nostro, F.L. & Guerrero, G.A. (1996). Presence of primary and secondary males in a population of the protogynous *Synbranchus marmoratus*. *Journal of Fish Biology*, Vol.49, pp. 788-800, ISSN 0022-1112

Lucena, Z.M.S. & Lucena, C.A.S. (1992). Revisão das espécies do gênero *Deuterodon* Eigenmann, 1907 dos sistemas costeiros do sul do Brasil com a descrição de quatro espécies novas (Ostariophysi, Characiformes, Characidae). Comunicações do Museu de Ciêcias da PUCRS, Vol.5, No.1, pp. 123-168, ISSN 0104-6950

Lucinda, P.H.F. (2008). Systematics and biogeography of the genus *Phalloceros* Eigenmann, 1907 (Cyprinodontiformes: Poeciliidae: Poeciliinae), with the description of twenty-one new species. *Neotropical Ichthyology*, Vol.6, No.2, pp. 113-158, ISSN 1679-6225

Lundberg, J.G.; Kottelat, M.; Smith, G.R.; Stiassny, M. & Gill, A.C. (2000). So many fishes, so little time: An overview of recent ichthyological discovery in continental waters. *Annals of the Missouri Botanical Garden*, Vol.87, pp. 26-62, ISSN 0026-6493

MacArthur, R.H. (1955). Fluctuations of animal populations and a measure of community stability. *Ecology,* Vol.36, pp. 533–536, ISSN 0012-9658

Machado, A.B.M.; Drummond, G.M. & Paglia, A.P. (2008). *Livro vermelho da fauna brasileira ameçada de extinção*, Fundação Biodiversitas, ISBN 978-85-7738-102-9, Belo Horizonte, Brasil.

Mazzoni, R. & Caramaschi, E.P. (1997). Observations on the reproductive biology of female *Hypostomus luetkeni* Lacepede 1803. *Ecology of Freshwater Fish*, Vol.6, No.1, pp. 53-56, ISSN 1600-0633

Mazzoni, R. & Costa, L.D.S. (2007). Feeding ecology of stream-dwelling fishes from a coastal stream in the Southeast of Brazil. *Brazilian Archives of Biology and Technology*, Vol.50, No.4, pp. 627-635, ISSN 1516-8913

Mazzoni, R. & Iglesias-Rios, R. (2002a). Environmentally related life history variations in *Geophagus brasiliensis*. *Journal of Fish Biology*, Vol.61, No.6, pp. 1606-1618, ISSN 0022-1112

Mazzoni, R. & Iglesias-Rios, R. (2002b). Distribution pattern of two fish species in a coastal stream in Southeast Brazil. *Brazilian Journal of Biology*, Vol.62, No.1, pp. 171-178, ISSN 1678-4375

Mazzoni, R. & Iglesias-Rios, R. (2007). Patterns of invesment of the reproductive strategy of two stream-dwelling Characidae. *Brazilian Journal of Biology*, Vol.67, No.4, pp. 695-699, ISSN 1678-4375

Mazzoni, R. & Lobón-Cerviá, J. (2000). Longitudinal structure, density and production rates of a neotropical stream fish assemblage: the river Ubatiba in the Serra do Mar, southeast Brazil. *Ecography*, Vol.23, No.5, pp. 588-602, ISSN 0906-7590

Mazzoni, R. & Petito, J. (1999). Reproductive biology of a Tetragonopterinae (Osteichthyes, Characidae) of the Ubatiba fluvial system, Maricá-RJ. *Brazilian Archives of Biology and Technology*, Vol.42, No.4, pp. 455-461, ISSN 1516-8913

Mazzoni, R. & Rezende, C.F. (2003). Seasonal diet shift in a Tetragonopterinae (Osteichthyes, Characidae) from the Ubatiba River, RJ, Brazil. *Brazilian Journal of Biology*, Vol.63, No.1, pp. 69-74, ISSN 1678-4375

Mazzoni, R. & Silva, A.P.F. (2006). Aspectos da história de vida de Bryconamericus microcephalus (Miranda Ribeiro) (Characiformes, Characidae) de um riacho costeiro de Mata Atlântica, Ilha Grande, Rio de Janeiro. *Revista Brasileira de Zoologia*, Vol.23, No.1, pp. 228-233, ISSN 0101-8185

Mazzoni, R.; Araújo, R.R.S.; Santos, G.C.T. & Iglesias-Rios, R. (2010). Feeding ecology of *Phalloceros anisophallos* (Osteichthyes: Cyprinodontiformes) from Andorinha Stream, Ilha Grande, Brazil. Vol.8, No.1, pp. 179-182, ISSN 1679-6225

Mazzoni, R.; Caramaschi, E.P. & Fenerich-Verani, N. (2002). Reproductive biology of a Characidiinae (Osterichthyes, Characidae) from the Ubatiba River, Maricá - RJ. *Brazilian Journal of Biology*, Vol.62, No.3, pp. 487-494, ISSN 1678-4375

Mazzoni, R.; Mendonça, R.S. & Caramaschi, E.P. (2005). Reproductive biology of Astyanax janeiroensis (Osteichthyes, Characidae) from the Ubatiba River, Maricá,, RJ, Brazil. *Brazilian Journal of Biology*, Vol.65, No.4, pp. 643-649, ISSN 1678-4375

Mazzoni, R.; Schubart, A.S.; Iglesias-Rios, R. (2004). Longitudinal segregation of *Astyanax janeiroensis* in Rio Ubatiba: a Neotropical stream of south-east Brazil. *Ecology of Freshwater Fish*, Vol.13, pp. 231-234, ISSN 1600-0633

Mazzoni, R.; Schubart, S.A. & Iglesias-Rios, R. (2004). Longitudinal segregation of *Astyanax janeiroensis* in Rio Ubatiba: a neotropical stream of south-east Brazil. *Ecology of Freshwater Fish*, Vol.13, No.3, ISSN 1600-0633.

Menezes, M.S. & Caramaschi, E.P. (1994). Característica reprodutivas de *Hypostomus* grupo *H. punctatus* no rio Ubatiba, Maricá, (RJ) (Osteichthyes, Siluriformes). *Revista Brasileira de Biologia*, Vol.54, pp. 503-513, ISSN 0034-7108

Menezes, M.S. & Caramaschi, E.P. (2000). Longitudinal distribution of *Hypostomus punctatus* (Osteichthyes, Loricariidae) in a coastal stream from Rio de Janeiro, Southeastern. *Brazilian Archives of Biology and Technology*, Vol.43, No.2, pp. 221-227, ISSN 1516-8913

Menezes, M.S.; Aranha, J.M.R. & Caramaschi, E.P. (1998). Ocorrência e aspectos da biologia reprodutiva de *Harttia loricariformis* (Loricariinae) no trecho inferior do rio Paraíba do Sul (Rio de Janeiro, Brasil). *Acta Biológica Paranaense*, Vol.27, pp. 15-26, ISSN 0301-2123

Menezes, N.A. & Weitzman, S.H. (1990). Two new species of *Mimagoniates* (Teleostei: Characidae: Glandulocaudinae), their phylogeny and biogeography and a key to the glandulocaudin fishes of Brazil and Paraguay. *Proceedings of the Biological Society of Washington*, Vol.103, No.2, pp. 380-426, ISSN 0006-324X

Menezes, N.A.; Weitzman, S.H.; Oyakawa, O.T.; Lima, F.C.T.; Castro, R.M.C. & Weitzman, M.J. (2007). *Peixes de água doce da Mata Atlântica*, Museu de Zoologia da Universidade de São Paulo, ISBN 85-87735-03-4, São Paulo, Brazil

Metzger, J.P. (2009). Conservation issues in the Brazilian Atlantic forest. *Biological Conservation*, Vol. 142, pp. 1138–1140, ISSN 0006-3207

Minshall, G.W.; Cummins, K.W.; Petersen, R.C.; Cushing, C.E.; Bruns, D.A.; Sedell, J.R. & Vannote, R.L. (1985). Developments in stream ecosystem theory. *Canadian Journal of Fisheries and Aquatic Sciences*, Vol.42, ISSN: 0706-652X

Morellato, L.P.C. & Haddad, C.F.B. (2000). Introduction: The Brazilian Atlantic Forest. *Biotropica*, Vol.32, pp. 786-792, ISSN 0006-3606

Myers, N.; Mittermeier, R.A.; Mittermeier, C.G.; Fonseca, G.A. & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, Vol.403, pp. 853-858, ISSN 0028-0836

Nogueira, C.; Buckup, P.A.; Menezes, N.A.; Oyakawa, O.T. & Kasecker, T.P. (2010). Restricted-Range Fishes and the Conservation of Brazilian Freshwaters. *PLoSONE*, Vol.5, No.6, pp. 1-10, ISSN 1932-6203

Odum, E.P. (1953). *Fundamentals of Ecology,* Saunders, ISSN 0006-3568, Philadelphia, USA.

Olden, J.D.; Kennard, M.J; Leprieur, F.; Tedesco, P. A.; Winemiller, K.O. & García-Berthou, E. (2010) Conservation biogeography of freshwater fishes: recent progress and future challenges. *Diversity and Distributions*, 16, 496–513, ISSN 1472-4642

Oyakawa, O.T.; Akama, A.; Mautari, K.C. & Nolasco, J.C. (2006). *Peixes de riachos da Mata Atlântica*, Editora Neotrópica, ISBN 859904902X, São Paulo, Brazil

Pereira, E.H.L. & Reis, R.E. (2002). Revision of the loricariid genera *Hemipsilichthys* and *Isbrueckerichhtys* (Teleostei: Siluriformes), with descriptions of five new species of Hemipsilichthys. *Ichthyological Exploration of Freshwaters*, Vol.13, No.2, pp. 97-146, ISSN 0936-9902

Peterson, B.J. & Fry, B. (1987). Stable isotopes in ecosystem studies. *Annual Review of Ecology and Systematics*, Vol.18, pp. 293-320, ISSN 0066-4162

Phillips, D.L. & Gregg, J.W. (2003). Source partitioning using stable isotopes: coping with too many sources. *Oecologia*, Vol.136, pp. 261-269, ISSN 1432-1939

Rahel, F.J. (2002) Homogenization of freshwater faunas. *Annual Review of Ecology and Systematics*, Vol.33, pp. 291-315, ISSN 0066-4162

Reis, R.E. & Schaefer, S.A. (1998). New Cascudinhos from southern Brazil: Systematics, endemism, and relationships (Siluriformes, Loricariidae, Hypoptopomatinae). *American Museum Novitates*, Vol.3254, pp. 1-25, ISSN 0003-0082.

Rezende, C.F. & Mazzoni, R. (2003). Aspectos da alimentação de *Bryconamericus microcephalus* (Characiformes, Tetragonopterinae) no Córrego Andorinha, Ilha Grande - RJ. *Biota Neotropica*, Vol.3, No.1, pp. 1-6, ISSN 1676-0603

Rezende, C.F. & Mazzoni, R. (2006). Contribuição da matéria autóctone e alóctone para a dieta de *Bryconamericus microcephalus* (Miranda-Ribeiro) (Actinopterygii, Characidae), em dois trechos de um riacho de Mata Atlântica, Rio de Janeiro, Brasil. *Revista Brasileira de Zoologia*, Vol.23, No.1, pp. 58-63, ISSN 0101-8185

Rolla, A.P.P.; Esteves, K.E. & Ávila-da-Silva, A.O. (2009). Feeding ecology of a stream fish assemblage in an Atlantic Forest remnant (Serra do Japi, SP, Brazil). *Neotropical Ichthyology*, Vol.7, No.1, pp. 65-76, ISSN 1679-6225

Sabaj, M.H.; Armbruster, J.W. & Page, L.M. (1999). Spawning in *Ancistrus* (Siluriformes: Loricariidae) with comments on the evolution of snout tentacles as a novel reproductive strategy: larval mimicry. *Ichthyological Exploration of Freshwaters*, Vol.10, No.3, pp. 217-229, ISSN 0936-9902

Sabino, J. & Castro, R.M.C. (1990). Alimentação, período de atividade e distribuição espacial dos peixes de um riacho da floresta Atlântica (sudeste do Brasil). *Revista Brasileira de Biologia*, Vol.50, No.1, pp. 23-26, ISSN 0034-7108

Sazima, I. (1986). Similarities in feeding behaviour between some marine and freshwater fishes in two tropical communities. *Journal of Fish Biology*, Vol.29, No.1, pp. 53-65, ISSN 0022-1112

Schaefer, S.A. (1997). The neotropical cascudinhos: systematics and biogeography of the *Otocinclus* catfishes (Siluriformes, Loricariidae). *Proceedings of the Academy of Natural Sciences of Philadelphia*, Vol.148, pp. 1-120, ISSN 0097-3157

Schmidt-Nielsen, K. (1990). *Animal physiology: adaptation and environment*, University of Cambridge Press, ISSN 0101-8175, Cambridge, UK.

Silva, S.M. (2003). A Floresta Atlântica no Paraná, In: *Floresta Atlântica: Reserva da Biosfera*, C.R. Fernandes, (Ed.), 17-35, ISBN 85-326-2529-0, Curitiba, Brazil

Trajano, E. (1997). Food and reproduction of *Trichomycterus itacarambiensis*, cave catfish from southeastern. *Journal of Fish Biology*, Vol.51, pp. 53-63, ISSN 0022-1112

Vannote, R.L.; Minshall, G.W.; Cummins, K.W.; Sedell, J.R. & Cushing, C.E. (1980). The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences*, Vol.37, No.1, pp. 130-137, ISSN: 0706-652X

Vari, R.P. & Malabarba, L.R. (1998). Neotropical Ichthyology: an overview, In: *Phylogeny and classification of Neotropical fishes*, L.R. Malabarba, R.E. Reis, R.P. Vari, Z.M.S. Lucena & C.A.S. Lucena, (Eds.), 1-11, Edipucrs, ISBN 85-7430-035-7, Porto Alegre, Brazil

Vilella, F.S.; Becker, F.G. & Hartz, S.M. (2002). Diet of *Astyanax* species (Teleostei, Characidae) in an Atlantic Forest River in Southern Brazil. *Brazilian Archives of Biology and Technology*, Vol.45, No.2, pp. 223-232, ISSN 1516-8913

Vitule, J.R.S. & Aranha, J.M.R. (2002). Ecologia alimentar do lambari, *Deuterodon langei* Travassos, 1957 (Characidae, Tetragonopterinae), de diferentes tamanhos em um riacho da Floresta Atlântica, Paraná (Brasil). *Acta Biológica Paranaense*, Vol.31, pp. 137-150, ISSN 0301-2123

Vitule, J.R.S. (2009) Introdução de peixes em ecossistemas continentais brasileiros: revisão, comentários e sugestões de ações contra o inimigo quase invisível. *Neotropical Biology and Conservation*, Vol.4, pp. 111-122, ISSN 1809-9939

Vitule, J.R.S., Freire, C.A. & Simberloff, D. (2009). Introduction of non-native freshwater fish can certainly be bad. *Fish and Fisheries*, Vol.10, pp. 98-108, ISSN 1467-2979

Vitule, J.R.S.; Braga, M.R. & Aranha, J.M.R. (2008a). Population structure and reproduction of *Deuterodon langei* travassos, 1957 (Teleostei, Characidae) in a neotropical stream basin from the Atlantic Forest, Southern Brazil. *Brazilian Archives of Biology and Technology*, Vol.51, No.6, pp. 1187-1198, ISSN 1516-8913

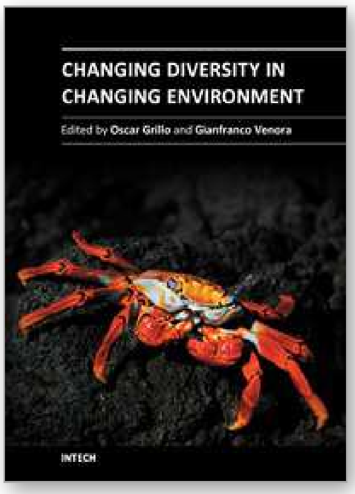
Vitule, J.R.S.; Braga, M.R. & Aranha, J.M.R. (2008b). Ontogenetic, spatial and temporal variations in the feeding ecology of *Deuterodon langei* Travassos, 1957 (Teleostei: Characidae) in a Neotropical stream from the Atlantic rainforest, southern Brazil. *Neotropical Ichthyology*, Vol.6, No.2, pp. 211-222, ISSN 1679-6225

Vitule, J.R.S.; Gazola-Silva, F.F. & Aranha, J.M.R. (2007). Desenvolvimento gonadal de *Deuterodon langei* Travassos (Teleostei, Characidae). *Acta Biológica Paranaense*, Vol.36, No.3-4, pp. 113-119, ISSN 0301-2123

Weitzman, S.H. & Malabarba, L.R. (1999). Systematics of *Spintherobolus* (Teleostei: Characidae: Cheirodontinae) from Eastern Brazil. *Ichthyological Exploration of Freshwaters*, Vol.10, No.1, pp. 1-43, ISSN 0936-9902

Woodward, G. & Hildrew, A.G. (2002). Food web structure in riverine landscapes. *Freshwater Biology*, Vol.47, pp. 777-798, ISSN 1365-2427.

Wooton, J.H. (1999). *Ecology of teleost fish,* Kluwer Academic Publishers, ISBN 978-041-2642-00-5, Dordrecht, Netherlands



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