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# Brazil's urban ecosystems threatened by law

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# Brazil's urban ecosystems threatened by law

## Abstract

Brazil's federal Law 12,651/2012 (popularly known as the "Forest Code") requires "Permanent Preservation Areas", known as "APPs," which are strips of protected vegetation along the edges of watercourses. The widths of the strips vary, depending on the width of the watercourse, and the law applies to both rural and urban aquatic ecosystems. However, a recently approved law (14,285/2021) undermines the Forest Code by giving municipalities (counties) the attribution of defining the widths of the APPs. This even opens the possibility of eliminating urban APPs altogether if doing so is in the interest of the local administration. Reduction or elimination of APPs would result in numerous negative effects in aquatic ecosystems, which is problematic because ecosystems in cities harbor biodiversity. Therefore, a main needed step is revocation of Law 14,285/2021. Greater attention should be given to the conservation of both terrestrial and aquatic ecosystems in urban areas.

**Keywords:** Biodiversity. Deforestation. Forest Code. Permanent Preservation Areas. Silting. Urbanization

## 1. Introduction

Some of the largest hydrographic systems in the world are located in Brazil (OECD 2015). These freshwater areas harbor high biodiversity (Agostinho et al., 2005) and provide fisheries resources, water and other services to the human populations (e.g., Batista and Petrere Jr., 2004; Mateus et al., 2004; Fearnside et al., 2021; Pelicice et al., 2022). This makes Brazil a key player in discussions of freshwater biodiversity conservation (Azevedo-Santos et al., 2021a).

Virtually all of the principal Brazilian rivers receive tributaries that have passed through urban areas (e.g., Martins et al., 2008; Souto et al., 2011; Pereira et al., 2021). Large rivers also pass in or near cities, as in the case of the Tietê River that crosses, the city of São Paulo. Brazilian drainage areas also contain numerous urban lacustrine ecosystems (e.g., Lopes et al., 2002; Pinese et al., 2008; Silva et al., 2019), whether connected or not to the lotic waterbodies. In addition to these freshwater environments, marine and estuarine ecosystems (e.g., mangroves and salt marshes) are often associated with urban areas (e.g., Albuquerque and Oliveira, 2020).

Urban waterbodies, both lotic and lentic, are important ecosystems (Francis, 2014) — although they are frequently degraded due to human impacts (Walsh et al., 2005). In Brazil these areas often contain considerable diversity of animals (e.g., macroinvertebrates and fishes) and plants (e.g., macrophytes) (Albertoni and Palma-Silva, 2006; Moreno and Callisto, 2006; Zawadzki et al., 2019). This implies that these areas need to be better protected by the country's authorities.

Law 12,651/2012 (popularly known as the "Forest Code") protects Brazil's watercourses and strips of land along their edges, which are designated as "Permanent Preservation Areas" or "APPs" (Brazil, 2012). This law includes both urban and rural aquatic ecosystems (Brazil, 2012). A recently enacted Law (14,285/2021) severely undermines the Forest Code by giving local politicians in municipal (county) governments the attribution of defining the widths of the APPs (Brazil, 2021) and providing an opportunity to remove the protection of urban ecosystems. This law is controversial, from both legal and environmental perspectives (Thomaz et al., 2021; Antunes, 2022; Wacheleski and da Silva, 2022). Here we show potential problems of this recent law and argue the need to preserve urban ecosystems, both terrestrial and aquatic.

## 2. An assault on Law 12,651/2012

Law 12,651/2012 defines the "Permanent Preservation Area" (known as the "APP": *Área de Preservação Permanente*) as a "(…) protected area, whether covered or not by native vegetation, with the environmental function of preserving water resources, the landscape, geological stability and biodiversity, facilitating the gene flow of fauna and flora (…)" (Brazil, 2012: Chapter 1). APPs are "the marginal strips of [land along] any perennial and intermittent natural watercourse, excluding the ephemeral ones, from the edge of the regular streambed (…)" (Brazil, 2012: Chapter 2). Law 12,651/2012 establishes that the vegetation along watercourses must be protected in a strip at least 30 m wide and can require widths greater than this depending on the width of the watercourse (Brazil, 2012). This law has various problems (see Grasel et al., 2018; Terra et al., 2021) but protects urban ecosystems at some level. An illustration of this is the plan for infrastructure to be built near the "Praça das Nascentes" (in Portuguese) square in the city of São Paulo that was stopped based on the argument that the project was within the limits of an APP (Supplementary Material 1). Other similar cases have occurred in Brazil (e.g., Supplementary Material 2). This means that, combined with good enforcement, Law 12,651/2012, if not modified by the new law, reduced impacts on urban ecosystems.

In the recently approved Law (14,285/2021) Article 4 opens the possibility of local administrations reduce or eliminating urban APPs altogether after "(…) hearing the state, municipal or district environmental councils (…)" (Brazil, 2021). The justification for this provision as given in the proposal for the law (Proposed Law 2510/2019) is that Law 12,651/2012 is wrong because it "(…) sets equal APP limits for rural and urban areas and allows intervention or suppression of native vegetation in APPs only in cases of public utility, social interest or low environmental impact" (Brazil, 2019) and because "it happens that in such hypotheses [the law] does not fit with various situations that are very common in urban areas, such as private and public buildings close to slopes and watercourses or waterbodies" (Brazil, 2019). We believe that Law 14,285/2021 was proposed to reduce or eliminate the APPs in urban areas.

Leaving it to the municipal authorities to decide the size of the APP in urban areas is likely to result in setbacks for ecosystems. Three features that guarantee this are: (i) lack of knowledge of local decision makers about the scientific evidence (e.g., Casatti, 2010; Valera et al., 2018; Pissarra et al., 2019) showing the importance of these areas, (ii) lobbies from interest groups that can profit from building in areas dismembered from APPs, and (iii) the effect of charismatic measures in attracting votes. Urban APPs are often occupied, and removing the population from these places would be unpopular and would conflict with the electoral interests of local politicians. This means that occupations close to watercourses are almost certain to be legalized by municipal decree.

## 3. Urban ecosystems at stake

The reduction or elimination of APPs under Law 14,285/2021 would generate even more social and ecological impacts. For example, the permission to build houses close to watercourses will result in material losses after floods (Thomaz et al., 2021). This would generate costs both for the people and for the municipal governments. The flooding in São Paulo State caused by torrential rains in 2023 illustrates the situation well (Supplementary Material 3). Negative impacts on urban aquatic ecosystems may be numerous and include introduction of non-native species, pollution of waterbodies (Thomaz et al., 2021), and intentional destruction of wetlands and waterbodies by landfills to allow construction. In addition, interventions in APPs have high potential to generate both direct and indirect siltation (Araújo, 2002; Thomaz et al., 2021; Ottoni et al., 2023) (Figure 1).


**Figure 1.** A silted stream: (a) during; and (b) after intervention in its APPs.

Occupation or other activities in APPs affects biodiversity because native species inhabit urban environments (Figure 2a-c), including waterbodies that are already impacted (e.g., Moreno and Callisto, 2006; Cunico et al., 2011). For example, in a search (Methods in Supplementary Material 4) we found that that numerous studies have documented native fish assemblages in Brazil's urban aquatic ecosystems (Figure 3a-b). Urban aquatic ecosystems contain species that have only been described in the last decade (e.g., Reis et al., 2012; Costa et al., 2021), and also contain species that are threatened (Figure 2b) or considered to be endemic (Table 1). For instance, siltation caused by interventions in APPs may have highly negative impacts on fish diversity in these ecosystems (Azevedo-Santos et al., 2021b). Urban APPs also contain terrestrial fauna (e.g., Figure 2d-f), and the vegetation itself is important for conservation of these biological components.


**Figure 2.** Photographs exemplifying animal groups that occur in Brazilian urban areas: (a) *Ucides cordatus* (Linnaeus, 1763) in a urban estuary in Belém, Pará; (b) *Leptopanchax splendens* (Myers, 1942), a fish species considered highly threatened with extinct (*sensu* Pavanelli et al. 2018) occurring in Duque de Caxias municipality, Rio de Janeiro (Costa et al. 2019); (c) Freshwater turtle (Chelidae) in a small urban watercourse in Frutal municipality, Minas Gerais; (d) *Iguana iguana* (Linnaeus, 1758) in an APP of Belém, Pará; (e) *Sicalis flaveola* (Linnaeus, 1766), in a remaining APP in Frutal municipality, Minas Gerais; (f) *Bradypus variegatus* (Schinz, 1825) in an APP of Belém, Pará.

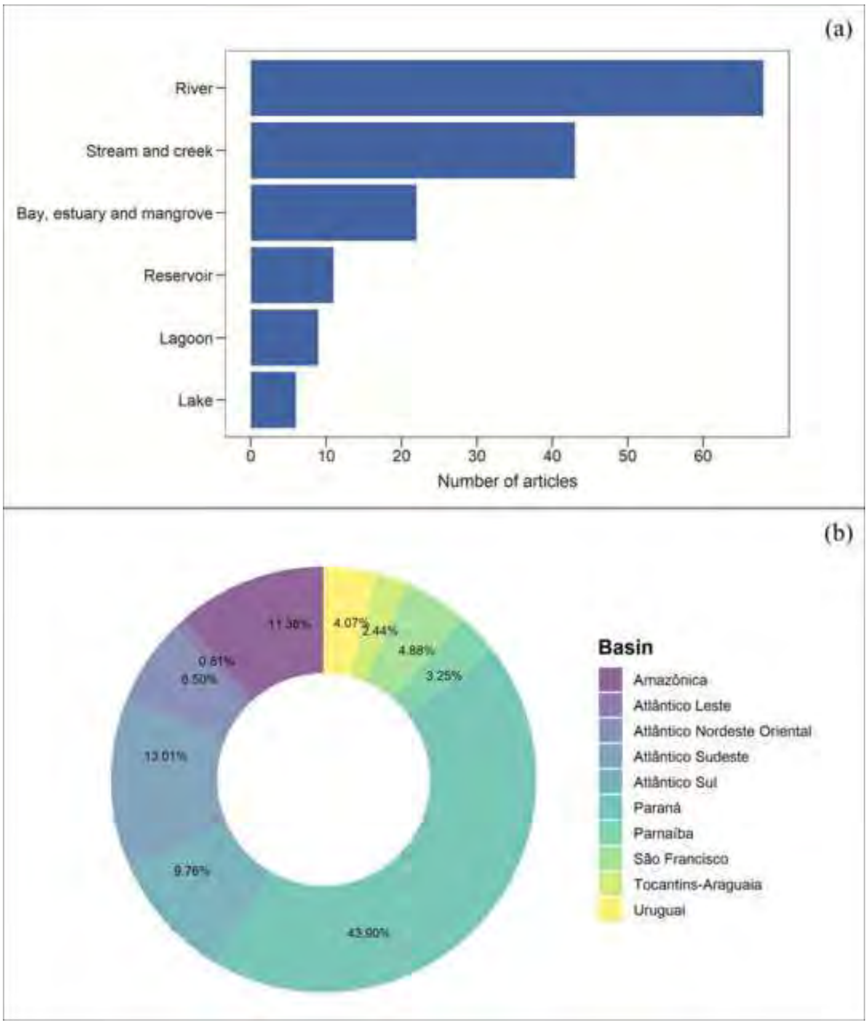


**Figure 3.** Number of studies on urban watercourses by (a) type of environment (b) hydrographic basin (based on Supplementary Material 4).

**Table 1.** Endemic fish species reported in the studies we analyzed (based on Supplementary Material 4). Conservation status according to Akama et al. (2018), Santos et al. (2018), Zanata et al. (2018), Pavanelli et al. (2018), Zawadzki et al. (2019).

| Species | Status | Basin |
|---|---|---|
| **Anostomidae** | | |
| *Leporinus piau* Fowler 1941 | Least-Concern | Atlântico Nordeste Oriental |
| **Trichomycteridae** | | |
| *Cambeva barbosae* Costa, Feltrin & Katz, 2021 | Not evaluated | Uruguai |
| *Cambeva botuvera* Costa, Feltrin & Katz, 2021 | Not evaluated | Uruguai |
| **Characidae** | | |
| *Glandulocauda caerulea* Menezes & Weitzman, 2009 | Least-Concern | Paraná |
| **Crenuchidae** | | |
| *Characidium bimaculatum* Fowler 1941 | Least-Concern | Atlântico Nordeste Oriental |
| **Curimatidae** | | |
| *Psectrogaster rhomboides* Eigenmann & Eigenmann 1889 | Least-Concern | Atlântico Nordeste Oriental |
| *Steindachnerina notonota* (Miranda Ribeiro 1937) | Least-Concern | Atlântico Nordeste Oriental |
| **Hemiodontidae** | | |
| *Hemiodus microlepis* Kner 1858 | Least-Concern | Parnaíba |
| **Parodontidae** | | |
| *Apareiodon davisi* Fowler 1941 | Endangered | Atlântico Nordeste Oriental |
| **Prochilodontidae** | | |
| *Prochilodus brevis* Steindachner 1875 | Least-Concern | Atlântico Nordeste Oriental |
| **Serrasalmidae** | | |
| *Ossubtus xinguense* Jégu 1992 | Vulnerable | Amazônica |
| **Triportheidae** | | |
| *Triportheus signatus* (Garman 1890) | Least-Concern | Atlântico Nordeste Oriental |
| **Cichlidae** | | |
| *Cichlasoma orientale* Kullander 1983 | Least-Concern | Atlântico Nordeste Oriental |
| **Aplocheilidae** | | |
| *Leptopanchax splendens* (Myers 1942) | Critically Endangered | Atlântico Sudeste |
| **Rivulidae** | | |
| *Atlantirivulus santensis* (Köhler 1906) | Least-Concern | Paraná |

| | | |
|---|---|---|
| **Heptapteridae** | | |
| *Pimelodella enochi* Fowler 1941 | Least-Concern | Atlântico Nordeste Oriental |
| **Loricariidae** | | |
| *Eurycheilichthys pantherinus* (Reis & Schaefer 1992) | Least-Concern | Uruguai |
| *Hypostomus pusarum* (Starks 1913) | Least-Concern | Atlântico Nordeste Oriental |
| *Hypostomus subcarinatus* Castelnau, 1855 | Critically Endangered | São Francisco |
| *Pareiorhaphis hystrix* (Pereira & Reis 2002) | Least-Concern | Uruguai |
| *Parotocinclus jumbo* Britski & Garavello 2002 | Least-Concern | Atlântico Nordeste Oriental |
| *Parotocinclus spilosoma* (Fowler 1941) | Least-Concern | Atlântico Nordeste Oriental |
| *Parotocinclus spilurus* (Fowler 1941) | Least-Concern | Atlântico Nordeste Oriental |
| *Plesioptopoma curvidens* Reis, Pereira & Lehmann A, 2012 | Not evaluated | São Francisco |

Regional-level negative impacts may occur in addition to local impacts. For example, pollution events due to higher population density near watercourses will impact downstream areas (see Azevedo-Santos et al., 2019). For instance, over 50% of the length of the Tietê River passes through rural areas after leaving the urban area of São Paulo. This downstream portion of the river has part of its flow diverted for irrigating crops (Tundisi et al., 1991), and the river is used for fishing (e.g., Novaes and Carvalho, 2011) and for other purposes. Loss of APPs in urban areas will therefore compromise environment services in downstream rural areas.

## 4. More care is needed for urban ecosystems

The aquatic urban environment in Brazil needs to be better protected. A first needed step is revocation of Law 14,285/2021. In April 2022 a coalition of four political parties submitted a "Direct Suit of Unconstitutionality" (ADI) to Brazil's Federal Supreme Court (STF) requesting revocation of this law (Maimoni et al., 2022). The suit continues without a decision (STF, 2022). Legal opinions indicate that the law is, indeed, unconstitutional (Antunes, 2022; Wacheleski and da Silva, 2022), although this in no way guarantees a favorable decision on the ADI. In any case, the need for increased care of urban ecosystems goes beyond the need to revoke the recently enacted law.

We believe that the forest code (Law 12,651/2012) needs to be improved such that the legal mechanisms reflect scientific evidence related to conservation of environments and biodiversity (e.g., Casatti, 2010; Magalhães et al., 2011; Brancalion et al., 2016; Valera et al., 2018; Pissarra et al., 2019; Brito et al., 2020; Dala-Corte et al., 2020). Increasing the size of established APPs based on scientific knowledge is therefore a point to be improved in Law 12,651/2012 and applied to urban ecosystems (Thomaz et al., 2021).

Urban watercourses are already impacted by nonnative species, effluents, deforestation, canalization, and other factors (e.g., Gubiani et al., 2010; Cunico et al., 2009; Martins et al., 2017; Azevedo-Santos et al., 2018; Giarrizzo et al., 2019; Ottoni et al., 2023). Therefore, beyond a future improvement of Law 12,651/2012 based on scientific evidence, we recommend immediate implementation of projects to restore aquatic and riparian ecosystems in urban areas. Needed initiatives include removal of public and private constructions in or near watercourses, recuperation of original riparian vegetation, installation of ecological culverts to allow the free movement of aquatic organisms (e.g., Makrakis et al., 2012), and control of pollution, including installation of surface barriers to remove at least the floating solid wastes that come from the city.

## 5. Conclusion

The recently approved Law 14,285/2021 is a clear assault on Brazil's Forest Code (Law 12,651/2012). The recent law's allowing municipal (county) governments to define the widths of the strips of protected vegetation (APPs) along watercourses allows local politicians to reduce or eliminate urban APPs. Reduction or elimination of APPs would result in numerous negative effects on aquatic ecosystems, including increased siltation and pollution and the loss of biodiversity, both in the watercourses and in the APPs. Therefore, a main step is revocation of Law 14,285/2021. Greater attention should be given to the conservation of urban ecosystems, including fauna and flora.

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**SUPPLEMENTARY MATERIAL**

**Brazil's urban ecosystems threatened by law**

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**SUPPLEMENTARY MATERIAL 1**

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**SUPPLEMENTARY MATERIAL 2**

Case A. https://g1.globo.com/mg/minas-gerais/noticia/2021/07/26/construcao-ilegal-na-varzea-das-flores-e-demolida-em-operacao-da-prefeitura-de-contagem.ghtml

Case B. https://g1.globo.com/rj/regiao-dos-lagos/noticia/2019/08/15/pm-e-inea-fazem-operacao-para-demolir-casas-irregulares-em-arraial-do-cabo-no-rj.ghtml

Case C. https://ndmais.com.br/justica-brasileira/stf-determina-demolicao-da-estrutura-de-beach-clubs-de-jurere-internacional/

Case D. https://g1.globo.com/rj/rio-de-janeiro/noticia/2020/07/01/construcoes-irregulares-sao-demolidas-na-gardenia-azul-condominio-erguido-pela-milicia-tem-200-apartamentos.ghtml

Case E. https://g1.globo.com/ce/ceara/noticia/2019/07/09/justica-determina-demolicao-de-restaurante-e-remocao-de-familias-em-area-de-preservacao-no-ceara.ghtml

Case F. http://g1.globo.com/sao-paulo/sao-jose-do-rio-preto-aracatuba/noticia/2017/02/justica-determina-retirada-de-familias-de-area-de-preservacao.html

**SUPPLEMENTARY MATERIAL 3**

Case A. https://g1.globo.com/sp/sao-paulo/noticia/2023/02/18/forte-chuva-causa-alagamento-e-afeta-circulacao-de-trens-na-grande-sao-paulo.ghtml

Case B. https://g1.globo.com/sp/ribeirao-preto-franca/noticia/2023/01/31/corregos-transbordam-e-agua-invade-vias-durante-forte-chuva-em-franca-sp.ghtml

Case B. https://cbn.globoradio.globo.com/media/audio/399308/bairros-da-zona-leste-de-sp-estao-sofrendo-com-enc.htm

**SUPPLEMENTARY MATERIAL 4**

**METHODS**

We performed a systematic search to find fish-based articles that have been applied in urban areas in Brazil. Thus, on September 2, 2021, we conducted a topic search in Clarivate Analytics Web of Science (http://www.webofknowledge.com) to retrieve articles published up to 2021, in all of the databases. The following terms and Boolean operators were used in our search: Topic: (Urban* OR Metropolitan OR city OR municipal* OR cities) AND Topic: (Fish*) AND Topic: (Freshwater* OR stream* OR river* OR creek* OR aquatic* OR estuar* OR Mangrove*) AND Topic: (Brazil). This search resulted in an initial pool of 507 articles. After, we refined the search by study type (article) and this step resulted in 493 articles. We included only articles that were performed with fish in urban areas in Brazil, and 148 articles were selected for further analysis. We did not include review articles. As we had a special interest in obtaining information on the occurrence of urban area endemic fish species in Brazil, we added four articles to review based on the knowledge of the authors of this study. Thus, we systematically evaluated the 152 publications using qualitative and quantitative topics to summarize the information on fish-based studies in Brazilian urban areas as following: i) the location (city, state and basin); ii) type of habitat (e.g., river/stream/creek, lake, estuary, lagoon, etc.); and iii) occurrence of endemic species. For each hydrographic basin, we used the data obtained in the articles (e.g., coordinates of a river) and considered the delimitation provided by IBGE (2021).

## RESULTS

Table S1 – List of articles included in the review.

| *Authors* | *Article Title* | *Source Title* | *Publicat* |
|---|---|---|---|
| Jia, J; Gomes-Silva, G; Plath, M; *et al.* | Shifts in bacterial communities and antibiotic resistance genes in surface water and gut microbiota of guppies (*Poecilia reticulata*) in the upper Rio Uberabinha, Brazil | Ecotoxicology And Environmental Safety | 2021 |
| Lehun, AL; Mendes, AB; Takemoto, RM; *et al.* | Genotoxic effects of urban pollution in the Iguaçu River on two fish populations | Journal of Environmental Science and Health Part A-Toxic/Hazardous Substances & Environmental Engineering | 2021 |
| Silva, JS; Alves, RN; de Paulo, DV; *et al.* | Biliary polycyclic aromatic hydrocarbons and enzymatic biomarkers in *Eugerres brasilianus* along four tropical estuaries | Marine Pollution Bulletin | 2021 |
| Camargo, MP; Forneck, SC; Dutra, FM; *et al.* | Fish fauna in low-order streams of the Piquiri River, Upper Paraná River basin, Brazil | Biota Neotropica | 2021 |
| Pereira, LM; Dunck, B; Benedito, E | Human impacts alter the distribution of fish functional diversity in Neotropical stream system | Biotropica | 2021 |
| Costa, W. J. E. M., Feltrin, C.R. M., Katz, A.M. | Filling distribution gaps: Two new species of the catfish genus *Cambeva* from southern Brazilian Atlantic Forest (Siluriformes, Trichomycteridae) | Zoosystematics and Evolution | 2021 |
| Barreto, LS; Souza, ATD; Martins, CC; *et al.* | Urban effluents affect the early development stages of Brazilian fish species with implications for their population dynamics | Ecotoxicology and Environmental Safety | 2020 |
| Andrades, R; Guabiroba, HC; Hora, MSC; *et al.* | Early evidences of niche shifts in estuarine fishes following one of the world's largest mining dam disasters | Marine Pollution Bulletin | 2020 |
| Cruz, LC; Pompeu, PS | Drivers of fish assemblage structures in a Neotropical urban watershed | Urban Ecosystems | 2020 |
| Garcia, TD; Cardozo, ALP; Quirino, BA; *et al.* | Ingestion of Microplastic by Fish of Different Feeding Habits in Urbanized and Non-urbanized Streams in Southern Brazil | Water Air and Soil Pollution | 2020 |
| Ghisi, ND; Larentis, C; de Oliveira, EC; *et al.* | Environmental assessment of Neotropical streams using fish as bioindicators: a multibiomarker and integrated approach | Hydrobiologia | 2020 |
| Barbosa, AS; Pires, MM; Schulz, UH | Influence of Land-Use Classes on the Functional Structure of Fish Communities in Southern Brazilian Headwater Streams | Environmental Management | 2020 |
| Zawadzki CH, Penido IdS, de Oliveira JC, Pessali TC | Rediscovery and redescription of the endangered *Hypostomus subcarinatus* Castelnau, 1855 (Siluriformes: Loricariidae) from the Rio São Francisco basin in Brazil | PLoS ONE | 2019 |
| Costa, WJEM, Mattos, JLO, Amorim, PF. | Rediscovery of *Leptopanchax splendens* (Cyprinodontiformes: Aplocheilidae): a seasonal killifish from the Atlantic Forest of south-eastern Brazil that was recently considered extinct. | Journal of Fish Biology | 2019 |

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| Gomes, LC; Chippari-Gomes, AR; Miranda, TO; *et al.* | Genotoxicity effects on *Geophagus brasiliensis* fish exposed to Doce River water after the environmental disaster in the city of Mariana, MG, Brazil | Brazilian Journal of Biology | 2019 |
| Salgado, LD; Marques, AEML; Kramer, RD; *et al.* | Integrated assessment of sediment contaminant levels and biological responses in sentinel fish species *Atherinella brasiliensis* from a sub-tropical estuary in south Atlantic | Chemosphere | 2019 |
| Collier, CA; Neto, MSD; de Almeida, GMA *et al.* | Effects of anthropic actions and forest areas on a neotropical aquatic ecosystem | Science of the Total Environment | 2019 |
| Pizzochero, AC; de la Torre, A; Sanz, P; *et al.* | Occurrence of legacy and emerging organic pollutants in whitemouth croakers from Southeastern Brazil | Science of the Total Environment | 2019 |
| Favero, FDT; Araujo, IMD; Severi, W | Structure of the fish assemblage and functional guilds in the estuary of Maracaipe, northeast coast of Brazil | Boletim do Instituto de Pesca | 2019 |
| Peressin, A; *et al.* | Ichthyofauna diet changes in response to urbanization: the case of upper Paranapanema River basin (Brazil) | Urban Ecosystems | 2018 |
| Viana, LF; Suarez, YR; Cardoso, CAL; *et al.* | The Response of Neotropical Fish Species (Brazil) on the Water Pollution: Metal Bioaccumulation and Genotoxicity | Archives of Environmental Contamination and Toxicology | 2018 |
| Lacerda, ACF; Roumbedakis, K; Bereta, JGS; *et al.* | Fish parasites as indicators of organic pollution in southern Brazil | Journal of Helminthology | 2018 |
| Barros, IT; Ceccon, JP; Glinski, A; *et al.* | Environmental risk assessment in five rivers of Parana River basin, Southern Brazil, through biomarkers in *Astyanax spp*. | Environmental Science and Pollution Research | 2017 |
| Sindeaux-Neto, JL; Velasco, M; Santos, P; *et al.* | Infection of the muscle tissue of the filter-feeding cichlid, *Chaetobranchopsis orbicularis* Steindachner, 1875, by *Kudoa orbicularis* (Myxozoa: Multivalvulidae) on Marajó Island in the Brazilian Amazon region | Arquivo Brasileiro de Medicina Veterinária e Zootecnia | 2017 |
| Costa, SYL; Barbosa, JEDL; Viana, LG; *et al.* | Composition of the ichthyofauna in Brazilian semiarid reservoirs | Biota Neotropica | 2017 |
| Dias, KGA; Alves, CA; Da Silva, RJ; *et al.* | Parasitic communities of *Hoplosternum littorale* (Hancock, 1828) as indicators of environmental impact | Anais da Academia Brasileira de Ciências | 2017 |
| Vieira-Menezes, FG; Costa, DPC; Brasil-Sato, MC | Nematodes of *Astyanax fasciatus* (Actinopterygii: Characidae) and their parasitic indices in the São Francisco river, Brazil | Revista Brasileira de Parasitologia Veterinária | 2017 |
| Ghisi, NC; Oliveira, EC; Guiloski, IC; *et al.* | Multivariate and integrative approach to analyze multiple biomarkers in ecotoxicology: A field study in Neotropical region | Science of the Total Environment | 2017 |
| Pinheiro, RHD; Santana, RLS; Melo, FTV; *et al.* | *Gnathostomatidae nematode* parasite of *Colomesus psittacus* (Osteichthyes, Tetraodontiformes) in the Ilha de Marajó, Brazilian Amazon | Revista Brasileira de Parasitologia Veterinária | 2017 |
| Santos, AC; Goncalves, CC; Carvalho, FR | Ichthyofauna of the Cachoeira de São Roberto and fishes of lower Preto River, upper Paraná River basin, Brazil | Biota Neotropica | 2017 |
| Furlan, VJM; de Campos, IP; Centenaro, GS | Characterization of fishing and fishing commercialization in the city of Itaqui-RS, Brazil | Vigilância Sanitária em Debate-Sociedade Ciência & Tecnologia | 2016 |

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| Andrade, MC; Sousa, LM; Ota, RP; *et al.* | Redescription and Geographical Distribution of the Endangered Fish *Ossubtus xinguense* Jegu 1992 (Characiformes, Serrasalmidae) with comments on conservation of the rheophilic fauna of the Xingu River | Plos One | 2016 |
| Pimentel, MF; Damasceno, EP; Jimenez, PC; *et al.*, | Endocrine disruption in *Sphoeroides testudineus* tissues and sediments highlights contamination in a northeastern Brazilian estuary | Environmental Monitoring and Assessment | 2016 |
| Fontoura, NF; Vieira, JP; Becker, FG; *et al.* | Aspects of fish conservation in the upper Patos Lagoon basin | Journal of Fish Biology | 2016 |
| Chivittz, CC; Pinto, DP; Ferreira, RS; *et al.* | Responses of the CYP1A biomarker in *Jenynsia multidentata* and *Phalloceros caudimaculatus* and evaluation of a CYP1A refractory phenotype | Chemosphere | 2016 |
| Ramos, TPA; Lehmann, AP; Barros-Neto, LF; *et al.* | Redescription of the endangered hypoptopomatine catfish *Parotocinclus spilurus* (Fowler, 1941) (Siluriformes: Loricariidae) from the upper rio Jaguaribe basin, northeastern Brazil | Neotropical Ichthyology | 2016 |
| Barrella, W; Ramires, M; Rotundo, MM; *et al.* | Biological and socio-economic aspects of recreational fisheries and their implications for the management of coastal urban areas of south-eastern Brazil | Fisheries Management and Ecology | 2016 |
| Dolbeth, M; Vendel, AL; Pessanha, A; Patricio, J | Functional diversity of fish communities in two tropical estuaries subjected to anthropogenic disturbance | Marine Pollution Bulletin | 2016 |
| Acosta, AA; Caffara, M; Fioravanti, ML; *et al.* | Morphological and Molecular Characterization *of Clinostomum detruncatum* (Trematoda: Clinostomidae) Metacercariae Infecting *Synbranchus marmoratus* | Journal of Parasitology | 2016 |
| Santos, CAB; Alves, RRN | Ethnoichthyology of the indigenous Truka people, Northeast Brazil | Journal of Ethnobiology and Ethnomedicine | 2016 |
| Silva, SVS; Dias, AHC; Dutra, ES; *et al.* | The impact of water pollution on fish species in southeast region of Goiás, Brazil | Journal of Toxicology and Environmental Health-Part A-Current Issues | 2016 |
| Lima, MAL; Freitas, CED; de Moraes, SM; *et al.* | Small-scale fishing in the municipality of Humaitá, middle Madeira River, Amazonas, Brazil | Boletim do Instituto de Pesca | 2016 |
| de Jesus, IS; Cestari, MM; Bezerra, MD; *et al.* | Genotoxicity effects in freshwater fish from a Brazilian impacted river | Bulletin of Environmental Contamination and Toxicology | 2016 |
| Ferreira, RS; Chivittz, CD; dos Santos, GS; Zanette, J | Cytochrome P450 1A mRNA in the guppy *Phalloceros caudimaculatus* and response to beta-naphthoflavone and environmental samples | Aquatic Toxicology | 2016 |
| Morais, CR; Carvalho, SM; Araujo, GR; *et al.* | Assessment of water quality and genotoxic impact by toxic metals in *Geophagus brasiliensis* | Chemosphere | 2016 |
| Ruaro, R; Gubiani, EA; Cunico, AM; *et al.* | Comparison of fish and macroinvertebrates as bioindicators of Neotropical streams | Environmental Monitoring and Assessment | 2016 |
| Batista, NJC; Cavalcante, AADM; de Oliveira, MG; *et al.* | Genotoxic and mutagenic evaluation of water samples from a river under the influence of different anthropogenic activities | Chemosphere | 2016 |
| Correa, LL; Tavares-Dias, M; Ceccarelli, PS; *et al.* | Hematological alterations in *Astyanax altiparanae* (Characidade) caused by *Lernaea cyprinacea* (Copepoda: Lernaeidae) | Diseases of Aquatic Organisms | 2016 |

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| de Campos, EO; Pereira, BB; Morelli, S | Monitoring genotoxicity potential in the Mumbuca Stream, Minas gerais, Brazil | Journal of Toxicology and Environmental Health-Part A-Current Issues | 2015 |
| Rocha, RS; Pelegrini, LS; Camargo, AD; *et al.* | *Sphincterodiplostomum musculosum* (Digenea, Diplostomidae) in *Geophagus brasiliensis* (Perciformes, Cichlidae) collected in a lake at Dois Córregos, São Paulo, Brazil | Ciência Rural | 2015 |
| Bourdineaud, JP; Durrieu, G; Sarrazin, SLF; *et al.* | Mercurial exposure of residents of Santarém and Oriximiná cities (Pará, Brazil) through fish consumption | Environmental Science and Pollution Research | 2015 |
| Bianchi, E; Goldoni, A; Trintinaglia, L; *et al.* | Evaluation of genotoxicity and cytotoxicity of water samples from the Sinos River Basin, southern Brazil | Brazilian Journal of Biology | 2015 |
| Freire, CA; Souza-Bastos, LR; Chiesse, J; *et al.* | A multibiomarker evaluation of urban, industrial, and agricultural exposure of small characins in a large freshwater basin in southern Brazil | Environmental Science and Pollution Research | 2015 |
| Mathews, PD; Silva, MRM; Maia, AAM; *et al.* | Ultrastructure and ssrRNA sequencing of *Myxidium amazonense* n. sp a myxosporean parasite of *Corydoras melini* from the Rio Negro river, Amazonas state, Brazil | Parasitology Research | 2015 |
| Campos, CP; Freitas, CED; Amadio, S | Growth of the *Cichla temensis* Humboldt, 1821 (Perciformes: Cichlidae) from the middle rio Negro, Amazonas, Brazil | Neotropical Ichthyology | 2015 |
| Pedde, V; Figueiredo, JAS; Nunes, MF; *et al.* | Environment and society: the Sinos River Basin and public policies | Brazilian Journal of Biology | 2015 |
| Santos, KPP; Soares, RR; Barros, RFM | Fishing activity and construction of craft in colony of fishermen z-18 in União/PI, Brazil | Holos | 2015 |
| Collier, CA; Neto, MSD; Aretakis, GMA; Santos, RE; *et al.* | Integrated approach to the understanding of the degradation of an urban river: local perceptions, environmental parameters and geoprocessing | Journal of Ethnobiology and Ethnomedicine | 2015 |
| Schulz, UH; Costa, PF | The effects of press and pulse disturbance by long and short-term pollution on the fish community in the Sinos River, RS, Brazil | Brazilian Journal of Biology | 2015 |
| Costa-Silva, DG; Nunes, MEM; Wallau, GL; *et al.* | Oxidative stress markers in fish (*Astyanax* sp and *Danio rerio*) exposed to urban and agricultural effluents in the Brazilian Pampa biome | Environmental Science and Pollution Research | 2015 |
| Bueno-Krawczyk, ACD; Guiloski, IC; Piancini, LDS; *et al.* | Multibiomarker in fish to evaluate a river used to water public supply | Chemosphere | 2015 |
| Oliveira, LC; Ribeiro, MO; Dutra, ES; *et al.* | Karyotype structure of *Hypostomus cf. plecostomus* (Linnaeus, 1758) from Tapajós River basin, Southern Amazon: occurrence of sex chromosomes (ZZ/ZW) and their evolutionary implications | Genetics and Molecular Research | 2015 |
| da Costa, MR; Moreti, T; Araujo, FG | Length-weight relationships of 20 fish species in the Guandu River, Rio de Janeiro State, Southeastern Brazil | Journal of Applied Ichthyology | 2014 |
| dos Santos, JAP; Esteves, KE | The fish fauna of an Atlantic Forest conservation area in the largest urban center of South America (São Paulo, SP, Brazil) and its relationship to some environmental factors | Studies on Neotropical Fauna and Environment | 2014 |
| Ribeiro, DL; Barcelos, GRM; d'Arce, LPG | Genotoxic Effects of Water from So Francisco River, Brazil, in *Astyanax paranae* | Bulletin of Environmental Contamination and Toxicology | 2014 |

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