



Conservation of Brazilian freshwater biodiversity: Thinking about the next 10 years and beyond

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Abstract

In 2021 the countries of the world will discuss a framework under the Convention on Biological Diversity (CBD) for a new environmental agenda for the next 10 years (“post-2020”). Parties should consider Brazil to be a central nation in these discussions. The country holds a large freshwater biodiversity that needs to be conserved, but current policies imperil species and ecosystems. Here we present topics to guide other CBD parties in discussing with Brazil a better agenda to conserve freshwater biodiversity post-2020. These initiatives include: (1) a national plan to reduce threats, (2) restoration of freshwater ecosystems, (3) protected areas, (4) more investment in research, and (5) science communication. Brazil’s participation in these CBD negotiations is fundamental for a new agreement, but the country is under a presidential administration with little concern for the environment. While our suggestions are intended for participants in the CBD negotiations, they will also be relevant to other international actors in the coming years. Nations, international investors, private companies and NGOs around the world must therefore use their influence to press the current administration to protect the country’s environment, including its enormous freshwater biodiversity.

Keywords Freshwater protected areas · Laws · Mining · Post-2020 · Restoration · Biological invasions

Introduction

Since February 2020, parties to the Convention on Biological Diversity (CBD) have been discussing the challenges of conserving biodiversity in a world that is undergoing climate change and increasing human population and consumption (CBD 2020). The parties will

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formulate a new global framework, scheduled to be agreed in 2021. These decisions will provide a global environmental agenda for the next 10 years (“post-2020”).

The parties should consider Brazil to be central to the discussion of the post-2020 period due to its vast biodiversity, especially those in inland waters. The country contains a large percentage of the planet’s freshwater species (Agostinho et al. 2005). For example, the country holds 3148 freshwater fish species (ICMBio 2018), a larger richness than North America, Central America, Europe, and Oceania combined (Dagosta and de Pinna 2019). Another example is freshwater Cladocera, with more than 140 species (Brito et al. 2020), a number that corresponds to $\sim 23\%$ of the world’s total for this group (Forró et al. 2008).

Brazil’s high freshwater biodiversity is in constant peril (e.g., Pelicice et al. 2017; ICMBio 2018). An assessment of the state of conservation of Brazilian freshwater species organized by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) is being done through voluntary collaboration of national and international researchers. These evaluations have shown that many Brazilian fish species are extinct at the regional level (ICMBio 2018); this is alarming because the extinction of local or regional populations eliminates genetic variability. Brazilian diversity is being imperiled as dams, agricultural expansion, pollution, and other impacts take their toll on Brazil’s aquatic ecosystems. Other threats include invasive species, a danger that is augmented by planned inter-basin water transfer projects and by unsustainable aquaculture and sport fishing (e.g., Ribeiro et al. 2017; Garcia et al. 2018; Daga et al. 2020; Nobile et al. 2020).

Although threats to Brazil’s flora and fauna have been increasing for years (e.g., Ferreira et al. 2014; Azevedo-Santos et al. 2017; Fernandes et al. 2017), Brazil’s current president (Jair Bolsonaro), who took office in January 2019, has greatly worsened the situation (e.g., Supplementary Material A). For example, the president has submitted a proposed law to the National Congress (PL 191/2020) that would legalize mining and dam construction in indigenous areas (Congresso Nacional 2020). The collapse of the Brumadinho and Mariana mine-tailings dams (Fernandes et al. 2016; Cionek et al. 2019) made it very clear that Brazil is not able to monitor and ensure proper functioning of its mines (Nazareno and Vitule 2016). Impacts of mining in indigenous areas are likely to disrupt biodiversity in both terrestrial and freshwater ecosystems.

The Ministry of Environment was not abolished altogether, as had been promised by the president during his electoral campaign (Supplementary Material B). However, the person President Bolsonaro appointed to head the ministry (Ricardo Salles) has acted to set the environment back on many fronts. For example, Salles recently repealed important resolutions of the National Environment Council (CONAMA), including revoking a resolution on licensing for irrigation projects (284/2001; see Supplementary Material C), thus imperiling many waterbodies and their biodiversity. This further reinforces the conclusion that Brazil must be placed at the center of the negotiations for a new agreement for the next decade and beyond. In view of this possibility, we present suggestions for the CBD signatory nations outlining the main actions that are necessary to conserve Brazilian freshwater biodiversity.

Post-2020: Examples of needed actions

A national plan to reduce threats

We believe that Brazil needs a national plan to reduce threats to biodiversity. Here we will provide examples of threats that should be considered in a discussion by the parties to the CBD.

Mining is an activity that has disrupted Brazilian aquatic ecosystems, especially mining for gold, which releases a lot of mercury (Malm et al. 1998), and those associated with tailings dams (Fernandes et al. 2016). More inspections and restrictions on mining near waterbodies are needed (Pelicice et al. 2017); the same applies to tailings dams because they have a gigantic potential for biodiversity destruction (Fernandes et al. 2016; Cionek et al. 2019). Also needed is improved inspection to prevent illegal mining, including better control at the country's borders to avoid entry of mercury and other illegal inputs used in this activity.

Hydroelectric dams have fragmented major rivers for years (Fearnside 2016a; Agostinho et al. 2008), and Brazil has ambitious plans for new Amazon dams. Brazil must consider investing more in alternatives with less impact than Amazon dams, such as halting export of electro-intensive commodities (especially aluminum), improved transmission and use efficiency, and generation from the country's abundant wind and solar sources (Fearnside 2016a; Pelicice et al. 2017).

Agriculture must respect the limits of ecosystems so that it is promoted with sustainability. For example, numerous agricultural chemicals are currently allowed, hundreds of them approved during the current presidential administration (Supplementary Material D). Many of these poisons are banned in more-developed nations (Thomaz et al. 2020). The sale of these chemicals for agriculture, and their irregular use, can cause disturbances in freshwater ecosystems, since pesticides can reach waterbodies in the runoff of rainwater. When these chemicals reach aquatic ecosystems, they can cause serious harm to the freshwater biota (Miranda et al. 2008).

Many decisions, especially through new laws, have the capacity to expose Brazilian freshwaters to introduced species from the most varied locations of the planet (Pelicice et al. 2014; Coelho and Henry 2017). The Aichi Targets have been ignored in this regard in various ways (Lima Junior et al. 2018), with harmful consequences for ecosystems (Vitule et al. 2009). Invasive species should be treated more seriously by authorities and by society in general.

Pollution of the country's ecosystems has been taking place for a long time. Hundreds of cities in the country still discharge domestic effluents into urban streams without any prior treatment. In addition, many Brazilian ecosystems (and the species within them) have received unprecedented amounts of plastic waste (e.g., Andrade et al. 2019; Giarrizzo et al. 2019). The full extent of the impacts of this on Brazilian freshwater biota is unknown. Brazil has failed to adopt rigorous measures to prevent the input of synthetic polymers and other types of waste in the country's ecosystems.

Restoration of freshwater ecosystems

Restoration of freshwater ecosystems has barely been discussed in the country and is still a topic largely restricted to the academic community. Brazilian authorities need to rethink opportunities for depollution, following trends in a number of other countries.

Protected areas

Most Brazilian protected areas are inefficient for protecting freshwater environments and their biodiversity (e.g., Frederico et al. 2018; see also Azevedo-Santos et al. 2019). More-efficient protected areas therefore need to be implemented to protect this diversity (Azevedo-Santos et al. 2019). However, this depends on the good will of political agents.

More investment in research

Brazil is far from knowing the entirety of its freshwater biodiversity. For example, even at this point in the 21st century, scientists described a large aquatic mammal (Hrbek et al. 2014). In addition to the country's outstanding diversity of fish and other freshwater vertebrates, aquatic invertebrate diversity is enormous over a wide range of taxonomic groups (Hamada et al. 2018, 2019). We are likely to lose species before we even know of their existence. Thus, basic studies (e.g., surveys) on biodiversity should receive adequate investment in Brazil. In addition, bureaucratic barriers that hinder this type of research need be removed (Bockmann et al. 2018); in this regard, we recommend a revision of the biodiversity law (Law 13,123, May 20, 2015).

More investments are needed in biological collections, as these are essential for taxonomic revisions and discoveries of new species. The September 2018 fire that destroyed Brazil's National Museum in Rio de Janeiro (Supplementary Material E) suggests the extent to which important collections have been neglected by the country's political authorities.

Science communication

Many of Brazil's public policies promote development without regard for impacts on biodiversity (Fearnside 2016b; Pelicice et al. 2017). Environmental policies, including those involving freshwater ecosystems, must be guided by scientific knowledge, which also requires the participation of scientists in the policy-elaboration process (Azevedo-Santos et al. 2017).

Only a small fraction of the country's scientific knowledge of biodiversity is provided to society at large. Although important examples of science outreach exist (see França et al. 2019), these are still relatively few. Providing scientific knowledge to society at large (and government investments for this purpose) is essential to conserving freshwater biodiversity.

Final remarks

Parties to the CBD need to consider our suggestions for conserving Brazilian freshwater biodiversity in discussions on the new treaty for the post-2020 period. While our suggestions are directed to the CBD parties, they also apply to other international actors, including governments, businesses and non-governmental organizations (NGOs). Brazil's environmental setbacks under the current presidential administration have reached a magnitude suggesting that measures needed to protect the country's biodiversity will not be taken in the absence of influence from international actors (Ferrante and Fearnside 2019). Countries importing Brazilian soy, beef and timber must condition their purchases on adequate safeguards, among other economic inducements to change the Brazilian

government's behavior (Kehoe et al. 2019). Private companies and NGOs, both national and international, among other actors such as international investors, must also exert influence on environmental conservation in Brazil.

Parties to the CBD also need to consider creating an international fund for countries with megadiversity, such as Brazil. Such a fund must not only focus on conservation of forests, but also on freshwater biodiversity. Decisions for the next 10 years are crucial for biodiversity and future generations in Brazil.

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Compliance with ethical standards

Conflict of interest The author declares that they have no conflict of interest.

References

- Agostinho AA, Thomaz SM, Gomes LC (2005) Conservation of the biodiversity of Brazil's inland waters. *Conserv Biol* 19:646–652. <https://doi.org/10.1111/j.1523-1739.2005.00701.x>
- Agostinho AA, Pelicice FM, Gomes LC (2008) Dams and the fish fauna of the Neotropical region: Impacts and management related to diversity and fisheries. *Braz J Biol* 68(4):1119–1132. <https://doi.org/10.1590/S1519-69842008000500019>
- Andrade MC, Winemiller KO, Barbosa PS, Fortunati A, Chelazzi D, Cincinelli A, Giarrizzo T (2019) First account of plastic pollution impacting freshwater fishes in the Amazon: ingestion of plastic debris by piranhas and other serrasalmids with diverse feeding habits. *Environ Pollut* 244:766–773. <https://doi.org/10.1016/j.envpol.2018.10.088>
- Azevedo-Santos VM, Fearnside PM, Oliveira CS, Padiál AA, Pelicice FM, Lima-Junior DP, Simberloff D, Lovejoy TE, Magalhães ALB, Orsi ML, Agostinho AA, Esteves FA, Pompeu PS, Laurance WF, Petere M Jr, Mormul RP, Vitule JRS (2017) Removing the abyss between conservation science and policy decisions in Brazil. *Biodivers Conserv* 26:1745–1752. <https://doi.org/10.1007/s10531-017-1316-x>
- Azevedo-Santos VM, Frederico RG, Fagundes CK, Pompeu PS, Pelicice FM, Padiál AA, Nogueira MG, Fearnside PM, Lima LB, Daga VS, Oliveira FJM, Vitule JRS, Callisto M, Agostinho AA, Esteves FA, Lima-Junior DP, Magalhães ALB, Sabino J, Mormul RP, Grasel D, Zuanon J, Vilella FS, Henry R (2019) Protected areas: a focus on Brazilian freshwater biodiversity. *Divers Distrib* 25:442–448. <https://doi.org/10.1111/ddi.12871>
- Bockmann FA, Rodrigues MT, Kohlsdorf T, Straker LC, Grant T, de Pinna MCC, Mantelatto FLM, Datovo A, Pombal JP Jr, McNamara JC, Almeida EAB, Klein W, Hsiou AS, Groppo M, Castro RMC, Amorim DS (2018) Brazil's government attacks biodiversity. *Science* 360:865. <https://doi.org/10.1126/science.aat7540>
- Brito MTS, Diniz LP, Pozzobom UM, Landeiro VL, Sousa FDR (2020) Cladocera (Crustacea: Branchiopoda) from the state of Mato Grosso. *Brazil. Ann Limnol* 56:7. <https://doi.org/10.1051/limn/2020005>
- CBD (Convention on Biological Diversity) (2020) Discussions open in Rome towards a landmark new UN biodiversity framework. CBD. <https://www.cbd.int/doc/press/2020/pr-2020-02-24-post2020-en.pdf>
- Cioneq VM, Alves GHZ, Tófoli RM, Rodrigues-Filho JL, Dias RM (2019) Brazil in the mud again: lessons not learned from Mariana dam collapse. *Biodivers Conserv* 28:1935–1938. <https://doi.org/10.1007/s10531-019-01762-3>

- Coelho PN, Henry R (2017) The small foreigner: New laws will promote the introduction of non-native zooplankton in Brazilian aquatic environments. *Acta Limnol Bras* 29:e7. <https://doi.org/10.1590/s2179-975x0717>
- Congresso Nacional (2020) PL 191/2020. Câmara dos Deputados. Brasília, DF, Brazil. <https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2236765>
- Daga VS, Azevedo-Santos VM, Pelicice FM, Fearnside PM, Perbiche-Neves G, Paschoal LRP, Cavallari DC, Erickson J, Ruocco AMC, Oliveira I, Padial AA, Vitule JRS (2020) Water diversion in Brazil threatens biodiversity. *Ambio* 49:165–172. <https://doi.org/10.1007/s13280-019-01189-8>
- Dagosta FCP, de Pinna M (2019) The fishes of the Amazon: distribution and biogeographical patterns, with a comprehensive list of species. *Bull Am Mus Nat Hist* 2019:1–163. <https://doi.org/10.1206/0003-0090.431>
- Fearnside PM (2016a) Environmental and social impacts of hydroelectric dams in Brazilian Amazonia: implications for the aluminum industry. *World Devel* 77:48–65. <https://doi.org/10.1016/j.worlddev.2015.08.015>
- Fearnside PM (2016b) Brazilian politics threaten environmental policies. *Science* 353:746–748. <https://doi.org/10.1126/science.aag0254>
- Fernandes GW, Goulart FF, Ranieri BD, Coelho MS, Dales K, Boesche N, Bustamante M, Carvalho FA, Carvalho DC, Dirzo R, Fernandes S, Galetti PM Jr, Millan VEG, Mielke C, Ramirez JL, Neves A, Rogass C, Ribeiro SP, Scariot A, Soares-Filho B (2016) Deep into the mud: Ecological and socio-economic impacts of the dam breach in Mariana, Brazil. *Nat Conserv* 14(2):35–45. <https://doi.org/10.1016/j.ncon.2016.10.003>
- Fernandes GW, Vale MM, Overbeck GE, Bustamante MMC, Grelle CEV, Bergallo HG, Magnusson WE, Akama A, Alves SS, Amorim A, Araújo J, Barros CF, Bravo F, Carim MJV, Cerqueira R, Collevatti RG, Colli GR, Cunha CN, D'Andrea PS, Dianese JC, Diniz S, Estrela PC, Fernandes MRM, Fontana CS, Giacomini LL, Gusmão LFP, Juncá FA, Lins-e-Silva ACB, Lopes CRAS, Lorini ML, Queiroz LP, Malabarba LR, Marimona BS, Junior BHM, Marques MCM, Martinelli BM, Martins MB, Medeiros HF, Menin M, Morais PB, Muniz FH, Neckel-Oliveira S, Oliveira JA, Oliveira RP, Pedroni F, Penha J, Podgaiski LR, Rodrigues DJ, Scariot A, Silveira LF, Silveira M, Tomas WM, Vital MJS, Pillar VD (2017) Dismantling Brazil's science threatens global biodiversity heritage. *Perspect Ecol Conser* 15(3):239–243. <https://doi.org/10.1016/j.pecon.2017.07.004>
- Ferrante L, Fearnside FM (2019) Brazil's new president and 'ruralists' threaten Amazonia's environment, traditional peoples and the global climate. *Environ Conserv* 46:261–663. <https://doi.org/10.1017/S0376892919000213>
- Ferreira J, Aragão LEOC, Barlow J, Barreto P, Berenguer E, Bustamante M, Gardner TA, Lees AC, Lima A, Louzada J, Pardini R, Parry L, Peres CA, Pompeu PS, Tabarelli M, Zuanon J (2014) Brazil's environmental leadership at risk. *Science* 346:706–707. <https://doi.org/10.1126/science.1260194>
- Forró L, Korovchinsky NM, Kotov AA, Petrussek A (2008) Global diversity of cladocerans (Cladocera; Crustacea) in freshwater. *Hydrobiologia* 595:177–184. https://doi.org/10.1007/978-1-4020-8259-7_19
- França JS, Solar R, Hughes RM, Callisto M (2019) Student monitoring of the ecological quality of neotropical urban streams. *Ambio* 48:867–878. <https://doi.org/10.1007/s13280-018-1122-z>
- Frederico RG, Zuanon J, Marco PM Jr (2018) Amazon protected areas and its ability to protect stream-dwelling fish fauna. *Biol Conserv* 219:12–19. <https://doi.org/10.1016/j.biocon.2017.12.032>
- Garcia DAZ, Magalhães ALB, Vitule JRS, Casimiro ACR, Lima-Junior DP, Cunico AM, Brito MFG, Petreire-Junior M, Agostinho AA, Orsi ML (2018) The same old mistakes in aquaculture: The newly-available striped catfish *Pangasianodon hypophthalmus* is on its way to putting Brazilian freshwater ecosystems at risk. *Biodivers Conserv* 27:3545–3558. <https://doi.org/10.1007/s10531-018-1603-1>
- Giarrizzo T, Andrade MC, Schmid K, Winemiller KO, Ferreira M, Pegado T, Chelazzi D, Cincinelli A, Fearnside PM (2019) Amazonia: the new frontier for plastic pollution. *Frontiers Ecol Environ* 17:309–310. <https://doi.org/10.1002/fee.2071>
- Hamada N, Thorp JH, Rogers DC (2018) *Keys to Neotropical Hexapoda. Thorp and Covich's Freshwater Invertebrates*. Volume III. 4 ed. Elsevier.
- Hamada N, Nessimian JL, Querino RB (2019) Insetos Aquáticos na Amazônia Brasileira: Taxonomia, Biologia e Ecologia, Instituto Nacional de Pesquisas da Amazônia (INPA)
- Hrbek T, Silva VMF, Dutra N, Gravena W, Martin AR, Farias IP (2014) A new species of river dolphin from Brazil or: how little do we know our biodiversity. *PLoS One* 9:e83623. <https://doi.org/10.1371/journal.pone.0083623>
- ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade) (2018) Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume VI - Peixes. ICMBio, Brasília, DF, Brazil.
- Kehoe L, Reis T, Virah-Sawmy M, Balmford A, Kuemmerle T, 604 signatories (2019) Make EU trade with Brazil sustainable. *Science* 364:341. <https://doi.org/10.1126/science.aaw8276>

- Lima Junior DP, Magalhães ALB, Pelicice FM, Vitule JRS, Azevedo-Santos VM, Orsi ML, Simberloff D, Agostinho AA (2018) Aquaculture expansion in Brazilian freshwaters against the Aichi biodiversity targets. *Ambio* 47:427–440. <https://doi.org/10.1007/s13280-017-1001-z>
- Malm O (1998) Gold mining as a source of mercury exposure in the Brazilian Amazon. *Environ Res* 77(2):73–78
- Miranda AL, Roche H, Randi MAF, Menezes ML, Ribeiro CAO (2008) Bioaccumulation of chlorinated pesticides and PCBs in the tropical freshwater fish *Hoplias malabaricus*: Histopathological, physiological, and immunological findings. *Environ Int* 34(7):939–949. <https://doi.org/10.1016/j.envint.2008.02.004>
- Nazareno A, Vitule J (2016) Too many mining disasters in Brazil. *Nature* 531:580. <https://doi.org/10.1038/531580e>
- Nobile AB, Cunico AM, Vitule JRS, Queiroz J, Vidotto-Magnoni AP, Garcia DAZ, Orsi ML, Lima FP, Acosta AA, Silva RJ, Prado FD, Porto-Foresti F, Brandão H, Foresti F, Oliveira C, Ramos IP (2020) Status and recommendations for sustainable freshwater aquaculture in Brazil. *Aquaculture* 12:1495–1517. <https://doi.org/10.1111/raq.12393>
- Pelicice FM, Azevedo-Santos VM, Vitule JRS, Orsi ML, Lima Junior DP, Magalhães ALB, Pompeu PS, Petreire M Jr, Agostinho AA (2017) Neotropical freshwater fishes imperiled by unsustainable policies. *Fish Fish* 18:1119–1133. <https://doi.org/10.1111/faf.12228>
- Pelicice FM, Vitule JRS, Lima Junior DP, Orsi ML, Agostinho AA (2014) A serious new threat to Brazilian freshwater ecosystems: the naturalization of nonnative fish by decree. *Conserv Lett* 7:55–60. <https://doi.org/10.1111/cons.12029>
- Ribeiro VR, Silva PRL, Gubiani EA, Faria L, Daga VS, Vitule JRS (2017) Imminent threat of the predator fish invasion *Salminus brasiliensis* in a Neotropical ecoregion: eco-vandalism masked as an environmental project. *Perspect Ecol Conser* 15:132–135. <https://doi.org/10.1016/j.pecon.2017.03.004>
- Thomaz SM, Gomes Barbosa L, de Souza Duarte MC, Panosso R (2020) The future of nature conservation in Brazil. *Inland Waters* 10:295–303. <https://doi.org/10.1080/20442041.2020.1750255>
- Vitule JRS, Freire CA, Simberloff D (2009) Introduction of non-native freshwater fish can certainly be bad. *Fish Fish* 10:98–108. <https://doi.org/10.1111/j.1467-2979.2008.00312.x>

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