A Serious New Threat to Brazilian Freshwater Ecosystems: The Naturalization of Nonnative Fish by Decree

Fernando Mayer Pelicice[1], Jean Ricardo Simões Vitule[2], Dilermando Pereira Lima Junior[3], Mário Luis Orsi[4], & Angelo Antonio Agostinho[5]

[1] Núcleo de Estudos Ambientais, Universidade Federal de Tocantins, Porto Nacional, TO, Brasil, Rua 3, Quadra 17, Jardim dos Ipês, Porto Nacional, TO 77500-000, Brasil
[2] Laboratório de Ecologia e Conservação (LEC), Departamento de Engenharia Ambiental, Setor de Tecnologia, Universidade Federal do Paraná, Curitiba, Brasil
[3] Departamento de Ciências Biológicas e da Saúde, Universidade Federal do Mato Grosso/Campus Médio Araguaia, Pontal do Araguaia, MT, Brasil
[4] Museu de Zoologia, Departamento de biologia animal e vegetal, Universidade Estadual de Londrina, Londrina, PR, Brasil
[5] Núcleo de Pesquisas em Limnologia, Ictiologia e Aqüicultura (NUPELIA)/DBI, UEM, Maringá, PR, Brasil

Keywords
Aquaculture; biological invasion; biodiversity; management; alien fish; politics; South America.

Correspondence
Fernando Mayer Pelicice, Núcleo de Estudos Ambientais, Universidade Federal de Tocantins, Porto Nacional, TO, Brasil. Rua 3, Quadra 17, Jardim dos Ipês, Porto Nacional, TO 77500-000, Brasil.
Tel: 55 63 3363-0575; fax: 55 63 3363-0501.
E-mail: fmpelicice@gmail.com

Received
20 November 2012
Accepted
29 March 2013

Editor
David Strayer

doi: 10.1111/conl.12029

Abstract

As Brazil undergoes rapid economic growth, short-sighted political decisions can threaten biological diversity and ecosystem services. Recently, the Brazilian Congress proposed a law to allow the rearing of nonnative fish in aquaculture cages in any hydroelectric reservoir of the country. This initiative may "naturalize by decree" some of the worst invasive species in the world (e.g., carps and tilapias) as a means of developing inland aquaculture and economy. The spread of aquaculture facilities will create opportunities for fish invasions to occur throughout the country, with the risk of damaging native biodiversity, ecosystem services, and environmental quality on a continental scale. The proposal ignores ecological theory, historical and/or empirical data concerning fish invasion, including dispersal, establishment, propagule pressure, invasiveness and invasibility, and all the negative consequences that may follow the invasion and establishment of nonnative organisms. This situation inspires reflection about the future of tropical biodiversity worldwide, particularly because Brazil, like many other developing countries, possesses a remarkable diversity of fish and other freshwater organisms yet has taken some political measures that are in conflict with important conservation issues.

Introduction

Biological invasion is a complex phenomenon, and its negative impacts have intensified greatly (Essl *et al.* 2011; Vitule *et al.* 2012a; Simberloff *et al.* 2013). The challenges involved in preventing new invasions can be particularly difficult for emerging or developing countries. As these countries experience rapid economic development, decisions may be based on political issues or short-term economic demands. Within this context, the overall costs associated with species introductions can be minimized or broadly misrepresented, particularly if interest groups or corporations intend to explore the commercial potential of nonnative species. Indeed, the long-term consequences to the environment, economy, and society in such a scenario have been easily ignored (Vitule *et al.* 2009; Lövei *et al.* 2012).

Brazil is a fitting example for reflection and discussions about the challenges imposed by biological invasions and other conservation issues in developing countries. As the country undergoes rapid economic growth, several political decisions have seriously threatened its biological diversity and ecosystem services. We may cite, for example, the recent changes in the Forestry Code (Nazareno *et al.* 2011) or the construction of many new dams in Amazonia (Nazareno & Lovejoy 2011; Tollefson 2011), measures that will allow deforestation and cause strong environmental changes across the country, possibly with

continental or even global consequences. Amid this wave of policies that prioritize fast economic growth over sustainability, the Brazilian Congress has proposed another controversial law (PL 5989/09) that want to allow the rearing of nonnative fish in aquaculture cages to be installed in hydroelectric reservoirs (Lima Junior *et al.* 2012; Vitule *et al.* 2012b). The belief that nonnative fish in aquaculture cages may increase food supply and decrease the demand for natural stocks, promoting economic growth and reducing poverty, has led developing countries and international agencies (i.e., the World Bank) to undertake major investments in these topics. Although the spread of aquaculture with nonnative species will certainly foster economy, especially in emergent countries, this system also will create opportunities for massive fish invasions, with the risk of promoting the loss of native biodiversity, ecosystem services, and environmental quality.

In this letter, we briefly explain this situation and discuss the problems that may ensure should this law be approved. This event inspires reflection about the future of tropical and global biodiversity, particularly because Brazil possesses an extraordinary megadiversity of fish and other aquatic organisms.

Proposed law 5989/09

The first version of the Proposed Law (hereafter referred to as PL) dates from 2009. The main objective is to allow the rearing of nonnative fish in aquaculture cages installed in the reservoirs of large hydroelectric dams. Because the introduction of nonnative species is prohibited by law in Brazil, the PL intends to remove the legal obstacles for fish production. The original version proposed the rearing of carps (i.e., *Aristichthys nobilis*, *Ctenopharyngodon idella, Cyprinus carpio*, and *Hypophthalmichthys molitrix*) and Nile tilapia (*Oreochromis niloticus*), which would be "naturalized by decree" to attain a native status. Naturalization in PL means that these nonnative fish will be considered legally native in Brazil, based on the argument that carps and tilapias have been registered or established populations in some Brazilian inland water bodies.

Following several revisions, the new version of the law does not indicate the species that will be legalized, but that decision will be made by the Brazilian Aquaculture and Fisheries Secretary (Ministério da Pesca e Aquicultura)—a government agency concerned with the production of fish and other aquatic organisms. At present, the proposal has been approved by three commissions of the Brazilian Congress and remains under analysis pending final approval (i.e., Brazilian Senate and the President).

Upcoming fish invasion

The original version of the PL included nonnative species with high invasiveness and recognized invasion history (carps and tilapias), but the most recent version does not indicate the species that will be naturalized. Considering the current trends in Brazilian aquaculture (see figure 1a in Vitule *et al.* 2009 and table 3 in Casal 2006), we expect intense pressure to allow the use of catfishes (e.g., *Clarias gariepinus* and *Ictalurus punctatus*) and especially, tilapias (e.g., *O. niloticus*, *Tilapia rendalli*). It has occurred in the aquaculture parks and aquatic farms created in some regions of the country, which obtained specific licenses to raise tilapia in confinement (e.g., Furnas Reservoir, Grande River; Azevedo-Santos *et al.*, 2011).

Regardless of the chosen species, the possible widespread release of nonnative fish into Brazilian ecosystems is a major concern. There is no safe confinement in aquaculture, and such endeavors have been considered a main vector for the release of nonnative fishes worldwide (Naylor *et al.* 2001; Casal 2006; Gozlan 2008). Escapes are inevitable, and cage aquaculture may create a constant and intensive flow of nonnative propagules into the wild (Azevedo-Santos *et al.* 2011). Numerous scientific publications show that negative effects follow the invasion and establishment of nonnative fish (e.g., Vitule *et al.* 2009; Cucherousset & Olden 2011). Specifically, in Brazil, there are studies reporting eutrophication, species loss, changes in community structure, faunal homogenization, the introduction of parasites, and alterations in fishery systems (e.g., Agostinho *et al.* 2007; Attayde *et al.* 2011; Figueiredo & Giani 2005; Menezes *et al.* 2012; Novaes & Carvalho 2011; Pelicice & Agostinho 2009; Vitule *et al.* 2012c). These problems are recognized by scientists and include the effects caused by tilapias (e.g., McKaye *et al.* 1995; Starling *et al.* 2002; Canonico *et al.* 2005; Figueiredo & Giani 2005). Yet, these concerns were neglected in discussions of PL, even though Brazil has experienced a long history of fish invasion via aquaculture and other activities (Agostinho *et al.* 2007; Vitule *et al.* 2009; Britton & Orsi 2012).

Furthermore, PL ignored other general information concerning fish invasion. For example, it ignored that tilapias and carps are among the worst invasive species in the world (Lowe *et al.* 2000) and that these organisms present high invasiveness, disturbance potential, negative impacts and invasion history in Brazilian ecosystems, as shown by historical and empirical data (Canonico *et al.* 2005; Vitule *et al.* 2009), risk analysis (Britton & Orsi 2012) and ecological modelling (Zambrano *et al.* 2006). In addition, PL ignored the evidence that tilapia, carp and many other nonnative species are not established in most Brazilian river

basins and in many reservoirs; for example, nonnative fish species are largely absent in the Amazon Basin. In this context, the expansion of aquaculture activities will accelerate fish introduction, establishment and dispersion events across the country. Furthermore, at sites where nonnative fish are established, PL ignored the potential effects of propagule pressure on the demography of the invader, which, in turn, determines the consequences and dynamics of invasion (Simberloff 2009). Moreover, cages will be installed in reservoirs, environments that facilitate invasions (Havel *et al.* 2005; Johnson *et al.* 2008): once in the reservoir, fish may reach contiguous areas, including reserves and protected areas. Lastly, the introduction of nonnative pathogens or parasites is a real possibility, particularly because cages remain in close contact with the surrounding environment. The spread of new parasites may harm the native biota and affect the natural dynamics of diseases (Peeller & Feist 2011, Poulin *et al.* 2011).

Therefore, if sanctioned, this law may trigger numerous invasion events that threaten resident biodiversity and damage ecosystem functions/services. We emphasize that fish invasion and its related consequences due to this specific law will not be restricted to Brazil: hydroelectric reservoirs are found in all large basins of the country (there are more than 700 large dams; Agostinho *et al.* 2007; Agostinho *et al.* 2008), several of these basins are shared with other countries (e.g., the Amazon and Paraná Rivers, Pantanal), and fish, obviously, do not recognize political borders.

Aquaculture as a solution

The PL states that natural fish stocks of most Brazilian rivers are depleted and that fish production must increase. Indeed, South American freshwater ecosystems have been deeply modified by human activities (Agostinho *et al.* 2005). For example, large migratory fish (catfishes and characins with high commercial value), once so conspicuous, have become rare or have disappeared from many rivers (Petrere *et al.* 2002; Hoeinghaus *et al.* 2009). In addition, recent studies reported biotic homogenization and shifts in the longitudinal and latitudinal body size patterns (Vitule *et al.* 2012c). These losses and changes are the result of several types of human disturbance, including habitat loss, pollution, overfishing, biological invasions and, in particular, river damming. Thus, in this scenario of decreasing biodiversity and fishery yield, aquaculture is being proposed as a tool to enhance economy, fish production, and ecosystem services.

Promoting the aquaculture of nonnative species as a conservation action, however, is an equivocal approach to mitigate or compensate for environmental problems. Human disturbances will not disappear with the incentive for aquaculture, an activity that risk complicating the situation via additional negative impacts—including stressors that go beyond the invasion issue (e.g., eutrophication, visual and chemical pollution). Effective actions to conserve or restore aquatic diversity should consider the establishment and police of protected areas, preserve and restore natural hydrological regimes, re-evaluate the national hydroelectric plan and, obviously, prevent the introduction and establishment of nonnative species. In this sense, the conservation of fish diversity in Brazil and South America, as well in other developing and megadiverse regions of the world, demands urgent measures, particularly because all large rivers are regulated by hydroelectric dams or will be in coming years. In this scenario of profound ecological change, PL is ineffective as a solution to environmental problems, dangerous for Neotropical fish diversity and beneficial only to the production sector (i.e., during a short period).

Politics, fishery production and conservation

The Brazilian Government has repeatedly announced that fisheries and aquaculture production must increase in the country and that political measures will be taken accordingly (e.g., US$ 2 billion will be invested through 2014; see Plano Safra, at http://www.mpa.gov.br/safra/). Paralleling this support, PL has been approved by three commissions of the Brazilian Congress and is steadily proceeding towards final approval, in other words, is in the end of process. Because it encourages the use of nonnative fish to foster the development of aquaculture, the position of the Brazilian Government is, indeed, a paradox. Many developed countries have spent millions of dollars on programmes to prevent, control and eradicate nonnative species. Furthermore, Brazil is a signatory of the Convention on Biological Diversity and must, therefore, engage in avoiding new introductions and controlling/eradicating nonnative species (article 8h; United Nations 1992). A more precautionary solution would naturally use the best available knowledge to evaluate long-term negative or impeditive effects of planned introductions (Strayer 2012), especially because the issue is not trivial. If PL is approved, therefore, Brazil will set an official fishery program with low environmental responsibility, security and sustainability.

We do not deny the need/opportunity for aquaculture in Brazil, nor do we disagree that fishery production may become a means to alleviate poverty in the country. Instead, our view is that political decisions need to be founded on a balance among environmental, economic and cultural principles and that effective production solutions should be achieved through real innovation. Better

political decisions would naturally look towards strategic planning to ensure that aquaculture is developed as a network across the entire landscape and society rather than as a series of isolated and/or short-sighted projects with no commitment to regional biological diversity and future generations. We emphasize that Brazil has a megadiverse native fish fauna, it is the ninth largest producer of freshwater fish through aquaculture, but production is almost entirely based on nonnative species (>80% of 94,844 mt; Casal 2006; Vitule *et al.* 2009). This picture is again a paradox and more curious if compared with Myanmar, for example, a much smaller country with a poorer fish diversity, in which total production is similar to Brazil (93.948 mt), but totally based on native species (Casal 2006). In this sense, we believe that Brazil's fish diversity must be appreciated: it may allow a variety of cultivation techniques and market options, involving an array of regional/local opportunities. There is a number of native species already in use (e.g., *Rhamdia quelen*, *Piaractus mesopotamicus*, *Colossoma macropomum*, *Arapaima gigas*, species of the genus *Pseudoplatystoma* and *Brycon*; see Kubitza *et al*. 2007), and more research should be destined to improve, enhance and promote the use of local/regional species through the aquaculture chain (Vitule 2009; Lima-Junior *et al*. 2012). Regionalization is an important issue, because Brazil has a continental extension and its basins, sub-basins and localities present particular fish species and/or assemblages. In this context, research must pursue ways to implement sustainable aquaculture according to regional or even local particularities (i.e., species selection, genetic structure, methods of production, market aspects)—"small is beautiful," in other words, local small-scale aquaculture may be a good sustainable alternative. There are good examples coming from participatory management in the Amazon basin, in which local people have exploited and managed local resources for decades (e.g., pirarucu—*Arapaima gigas* in natural reserves; tambaqui—*Colossoma macropomum* in tanks; or ornamental fishes collected in the Rio Negro basin). These systems are obviously less productive and profitable in the short term, but they are more sustainable and environmental friendly than tilapia aquaculture or any other intensive system. Such differences cannot be ignored if we ask about the real goals of the fishery program, particularly if incentives are destined to develop small-scale aquaculture (Alleviate poverty? Source of protein? Family income?) or to satisfy large-scale corporations (Commodity production? Exportation?).

We also believe that more information should precede any attempt to increase fishery production in Brazil. The fishery issue involves many social, technical, economical and environmental components, so political force alone cannot deal with such a complex system. Effective plans should rely on basic ecological/fishery data, such as the status of wild stocks, the capacity of inland ecosystems to sustain an increasing fishing effort, the carrying capacity of reservoirs to implement cage aquaculture, and all potential negative impacts that may succeed (e.g., pollution). In addition, attempts to increase aquaculture productivity should be accompanied by improvements in the production system as a whole. It would include safe confinement, quarantine procedures, waste treatment, use of space and technical orientation—to name a few. Considering that government incentives concern especially with procedures to increase fish production, we predict that conflicts in the use of freshwater resources will aggravate in the near future. In this sense, to preserve ecosystem processes and services in the long term, an ecosystem approach, at the basin scale, would be a promising alternative to manage freshwater resources and develop sustainable aquaculture (United Nations 1992).

Concluding, the incentive to promote aquaculture with nonnative species (together with other recent political retreats) favors especially the private production of commodities, with the appropriation of natural capital and the consequent loss of natural resources. In fact, the false dichotomies termed "economy versus ecology" or "environment versus economic growth," whereby the maintenance of natural ecosystems is viewed as an impediment to social and economic well-being, are constantly cited in political debates about these issues (e.g., the official plan to accelerate development, PAC, held by Brazilian government; http://www.pac.gov.br). This scenario is not restricted to Brazil, considering that the uncritical use of nonnative species to achieve short-term economical gain has been recorded around the world (Casal 2006; Lövei *et al.* 2012; Simberloff *et al.* 2013), especially in emerging/developing countries that rely on aquaculture. In case of Brazil, however, this equivocal stance is trivialising and may alter or deliberately squander one of the richest natural resources in the world to explore a venture with lower value that is less fair, equitable and sustainable. We emphasize that the country has the greatest diversity of freshwater fish in the world, a precious heritage that maintains ecosystem goods and services and is expressed in terms of its economic, cultural, aesthetic, and scientific value. We also emphasize that biodiversity covers phenomena that extends beyond simple species number, as it is related to our understanding of genotypes, phenotypes, organisms, species, interactions, and evolutionary processes that historically occur in a heterogeneous and integrative biosphere. In Brazil and other tropical countries, such in-depth concepts are comparatively poorly understood, particularly for freshwater environments. Therefore, if Brazilian society is concerned

with its well being in the long term and is committed to flourishing in cultural terms, regional biodiversity must be appreciated as a natural capital and preserved (United Nations 1992; Millennium Ecosystem Assessment 2005). This attitude is most certainly in conflict with management policies that facilitate the introduction and spread of nonnative species or ignore its consequences.

Acknowledgments

This research has been supported by CNPq research productivity grants.

References

Agostinho, A.A., Thomaz, S.M. & Gomes L.C. (2005) Conservation of the biodiversity of Brazilian's inland waters. *Conserv. Biol.*, **19**, 646-652.

Agostinho, A.A., Gomes, L.C. & Pelicice, F.M. (2007) *Ecologia e manejo de recursos pesqueiros em reservatórios do Brasil*. Eduem, Maringá.

Agostinho, A.A., Pelicice, F.M. & Gomes, L.C. (2008) Dams and the fish fauna of the Neotropical region: impacts and management related to diversity and fisheries. *Braz. J. Biol.*, **68**, 1119-1132.

Attayde, J.L., Brasil, J. & Menescal, R.A. (2011) Impacts of introducing Nile tilapia on the fisheries of a tropical reservoir in North-eastern Brazil. *Fisher. Manag. Ecol.*, **18**, 437-443.

Azevedo-Santos, V.M., Rigolin-Sá, O. & Pelicice, F.M. (2011) Growing, losing or introducing? Cage aquaculture as a vector for the introduction of nonnative fish in Furnas Reservoir, Minas Gerais, Brazil. *Neotrop. Ichthyol.*, **9**, 915-919.

Britton, J.R. & Orsi, M.L. (2012) nonnative fish in aquaculture and sport fishing in Brazil: economic benefits versus risks to fish diversity in the upper River Paraná Basin. *Rev. Fish Biol. Fish.*, **22**, 555-565.

Canonico, G.C., Arthington, A., McCrary, J.K. & Thieme, M.L. (2005) The effects of introduced tilapias on native biodiversity. *Aquat. Conserv.: Mar. Fresh. Ecosyst.*, **15**, 463-483.

Casal, C.M.V. (2006) Global documentation of fish introductions: the growing crisis and recommendations for action. *Biol. Invas.*, **8**, 3-11.

Cucherousset, J. & Olden, J.D. (2011) Ecological impacts of nonnative freshwater fishes. *Fisheries*, **36**, 215-230.

Essl, F., Dullinger, S., Rabitsch, W. *et al.* (2011) Socioeconomic legacy yields an invasion debt. *Proc. Natl. Acad. Sci. USA*, **108**, 203-207.

Figueredo, C.C. & Giani, A. (2005) Ecological interactions between Nile tilapia (*Oreochromis niloticus*, L.) and the phytoplanktonic community of the Furnas Reservoir (Brazil). *Fresh. Biol.*, **50**, 1391-1403.

Gozlan, R.E. (2008) Introduction of nonnative freshwater fish: is it all bad? *Fish Fish.*, **9**, 106-115.

Havel, J.E., Lee, C.E. & Vander Zanden, M.J. (2005) Do reservoirs facilitate invasions into landscapes? *BioScience*, **55**, 515-525.

Hoeinghaus, D.J., Agostinho, A.A., Gomes, L.C. *et al.* (2009) Effects of river impoundment on ecosystem services of large tropical rivers: embodied energy and market value of artisanal fisheries. *Conserv. Biol.*, **23**, 1222-1231.

Johnson, P.T.J., Olden, J.D. & Vander Zanden, M.J. (2008) Dam invaders: impoundments facilitate biological invasions into freshwaters. *Front. Ecol. Environ.*, **6**, 357-363.

Kubitza, F., Ono, E.A. & Campos, J.L. (2007) Os caminhos da produção de peixes nativos no Brasil: uma análise da produção e obstáculos da piscicultura. *Panorama da Aqüicultura*, **102**, 14-23.

Lima Jr., D.P., Pelicice, F.M., Vitule, J.R. & Agostinho, A.A. (2012) Aquicultura, política e meio ambiente no Brasil: Novas propostas e velhos equívocos. *Nat. Conserv.*, **10**, 88-91.

Lövei, G.L. & Lewinsohn, T.M., Invasions in Megadiverse Regions Network (2012) Megadiverse developing countries face huge risks from invasives. *Trends Ecol. Evol.*, **27**, 2-3.

Lowe, S., Browne, M., Boudjelas, S. & De Poorter, M. (2000) *100 of the world's worst invasive alien species: a selection from the global invasive species database*. The Invasive Species Specialist Group (ISSG), World Conservation Union (IUCN), Auckland.

McKaye, K.R., Ryan, J.D., Stauffer Jr., J.R., Lopez Peres, L.J., Vega, G.I. & Van Den Bergue, E.P. (1995) African tilapia in Lake Nicaragua: ecosystem in transition. *BioScience*, **45**, 406-411.

Menezes, R.F., Attayde, J.L., Lacerot, G. *et al.* (2012) Lower biodiversity of native fish but only marginally altered plankton biomass in tropical lakes hosting introduced piscivorous Cichla cf. ocellaris. *Biol. Inv.*, **14**, 1353-1363.

Millennium Ecosystem Assessment, (2005) *Ecosystems and human well-being: wetlands and water synthesis*. World Resources Institute, Washington, D.C.

Naylor, R.L., Williams, S.L. & Strong, D.R. (2001) Aquaculture—a gateway for exotic species. *Science*, **294**, 1655-1656.

Nazareno, A.G., Feres, J.M., Carvalho, D., Sebbenn, A.M., Lovejoy, T.E. & Laurence, W.F. (2011) Serious new threat to Brazilian forests. *Conserv. Biol.*, **26**, 5-6.

Nazareno, A.G. & Lovejoy, T.E. (2011) Giant dams threatens Brazilian rainforest. *Nature*, **478**, 37.

Novaes, J.C.L. & Carvalho, E.D. (2011) Artisanal fisheries in a Brazilian hypereutrophic reservoir: Barra Bonita Reservoir, Middle Tietê River. *Braz. J. Biol.*, **71**, 821-832.

Peeller, E.J. & Feist, S.W. (2011) Human intervention in freshwater ecosystems drives disease emergence. *Fresh. Biol.*, **56**, 705-716.

Pelicice, F.M. & Agostinho, A.A. (2009) Fish fauna destruction after the introduction of nonnative predator

(*Cichla kelberi*) in a Neotropical reservoir. *Biol. Inv.*, **11**, 1789-1801.

Petrere, M., Agostinho, A.A., Okada, E.K. & Júlio Junior, H.F. (2002) Review of the fisheries in the Brazilian portion of the Paraná/Pantanal basin. Pages 123–143 in I.G. Cowx, editor. *Management and ecology of lake and reservoir fisheries*. Fishing New Books,Osney Mead.

Poulin, R., Paterson, R.A., Townsend, C.R., Tompkins, D.M. & Kelly, D.W. (2011) Biological invasions and the dynamics of endemic diseases in freshwater ecosystems. *Fresh. Biol.*, **56**, 676-688.

Simberloff, D. (2009) The role of propagule pressure in biological invasions. *Ann. Rev. Ecol. Evol. Syst.*, **40**, 81-102.

Simberloff, D., Martin, J.L. & Genovesi, P. (2013) Impacts of biological invasions: what's what and the way forward. *Trends Ecol. Evol.*, **28**, 58-66.

Starling, F.L.R.M., Lazzaro, X., Cavalcanti, C. & Moreira, R. (2002) Contribution of omnivorous tilapia to eutrophication of a shallow tropical reservoir: evidence from a fish kill. *Fresh Biol.*, **47**, 2443-2452.

Strayer, D.L. (2012) Eight questions about invasions and ecosystem functioning. *Ecol. Lett.*, **15**, 1199-1210.

Tollefson, J. (2011) A struggle for power. *Nature*, **479**, 160-161.

Vitule, J.R.S. (2009) Introdução de peixes em ecossistemas continentais brasileiros: revisão, comentários e sugestões de ações contra o inimigo quase invisível. *Neotrop. Biol. Conserv.*, **4**, 111-122.

Vitule, J.R.S., Freire, C.A. & Simberloff, D. (2009) Introduction of nonnative freshwater fish can certainly be bad. *Fish Fish.*, **10**, 98-108.

Vitule, J.R.S., Freire, C.A., Vazquez, D.P., Nuñez, M.A. & Simberloff, D. (2012a) Revisiting the potential conservation value of nonnative species. *Conserv. Biol.*, **26**, 1153-1155.

Vitule, J.R.S., Lima Junior, D.P., Pelicice, F.M., Orsi, M. & Agostinho, A.A. (2012b) Preserve Brazil's aquatic biodiversity. *Nature*, **485**, 309.

Vitule, J.R.S., Skóra, F. & Abilhoa, V. (2012c) Homogenization of freshwater fish faunas after the elimination of a natural barrier by a dam in Neotropics. *Diversity Distrib.*, **18**, 111-120.

United Nations (1992) *Convention on biological diversity*. United Nations, Rio de Janeiro. Available from http://www.cbd.int/convention/text/. Accessed January 18, 2013.

Zambrano, L., Martínez-Meyer, E., Menezes, N. & Peterson, A.T. (2006) Invasive potential of common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) in American freshwater systems. *Can. J. Fish. Aquat. Sci.*, **63**, 1903-1910.

