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COMMENTARY

The same old mistakes in aquaculture: the newly-available striped catfish *Pangasianodon hypophthalmus* is on its way to putting Brazilian freshwater ecosystems at risk

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Abstract

In the state of São Paulo in southeastern Brazil, a dangerous decree allows the culture of hybrids and non-native extralimital fish species in the Paraná and East Atlantic River basins. We recorded the illegal importation and sale of the non-native striped catfish *Pangasianodon hypophthalmus* in northeastern, central-western, southeastern, and southern areas of the country. This species is already consumed across Brazil and is cultivated for ornamental purposes. Besides escapes from fish farms and 'fish and pays', *P. hypophthalmus* can reach natural environments through aquarium dumping and ornamental ponds, motivated by its large size that reach after being sold at small size. The species has been introduced in many countries, and if established in Brazil, could put native Brazilian biodiversity and ecosystems at risk. Although importing specimens of *P. hypophthalmus* is prohibited by law, Decree 62.243/2016 in the state of São Paulo creates a new opportunity for invasion. In fact, once a novel fish species is moved to a new continent, it is irrational to supposed that it will stay static just in the area for which it was intended. In general, the fish disperse in the novel area on their own, by escapes from captivity or deliberate and illicit releases by persons or associations. The unwise attitude of Brazilian decision-makers and lay people in their attempt to develop aquaculture with non-native species goes against the objectives of responsible aquaculture based in native species.

Keywords Alien dispersion · Aquaculture · Aquarium dumping · Biological invasions · Legislation · Propagule pressure

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Symphony of destruction by decree

The freshwater fish fauna of South America is the most diverse in the world, and it includes a high variety of taxonomic, phylogenetic, and functional types (Barletta et al. 2010; Reis et al. 2016; Vitule et al. 2017a, b). However, the traditional preference in Brazil is for culturing non-native species from other continents (e.g., tilapia *Oreochromis niloticus*, African catfish *Clarias gariepinus*, and channel catfish *Ictalurus punctatus*) as well as species from other Brazilian basins (i.e., intra-country extralimital introductions) (e.g., pirarucu *Arapaima gigas*), and hybrids (i.e., new genomes and phenotypes) (e.g., *Pseudoplatystoma corruscans*×*Pseudoplatystoma fasciatum*), making the country the proportionally largest international repository of non-native species (Casal 2006; Lima Junior et al. 2012; Pelicice et al. 2014, 2017; Lima et al. 2018). Legal facilities for importing and rearing non-native fish species and poor technology development for cultivating native species have created opportunities for massive impacts from non-native species, novel invasions, and novel interactions between invaders (e.g., Pelicice et al. 2014, 2017; Tófoli et al. 2016; Magalhães and Jacobi 2017; Padial et al. 2017; Braga et al. 2018). In general, once a novel fish species is moved to a new continent, it is irrational to assume it will stay static just in the specific area for which it was intended. Non-native fish get around on their own, by escapes or by few influent people engage in rogue introductions (Vitule et al. 2009).

In fact, government agencies have encouraged the cultivation of non-native species in public waters (i.e., free-rivers and reservoirs), among other areas (Vitule et al. 2009; Lima Junior et al. 2012; Pelicice et al. 2017; Lima et al. 2018). According to Article 5 of the State Decree 62.243 dated November 2016, the release of hybrids and non-native species for farming in the Paraná and East Atlantic River basins is carried out in the state of São Paulo by the Instituto de Pesca, responsible for fostering aquaculture in that state. The institute's recent ordinance (November 30, 2016) releasing the striped catfish *Pangasianodon hypophthalmus* (Siluriformes, Pangasiidae) results in a new threat looming over the regional aquatic biota.

The striped catfish is native to the Mekong, Chao Phraya, and Maeklong River basins (Vietnam and Thailand), and comes with the old and misleading promise that it will boost the commercial and ornamental aquaculture in Brazil (Agostinho et al. 2007; Article 5 of the State Decree 62.243/2016), as well as already been seen with *C. gariepinus* and *I. punctatus*, with the unsuccessful promotion as being ideal species for a new aquaculture package. However, the culture of *C. gariepinus* and *I. punctatus* were only examples of bad management of fish farm responsible for introduction of the species in Brazil and other countries (Vitule et al. 2006, 2009; Weyl et al. 2016). In terms of species invasiveness, we can envisage that the same characteristics that led the striped catfish to become the world's largest aquaculture phenomenon in the last decades are also those that predict its success in the invasion process, i.e. environmental tolerance or rusticity (Cassemiro et al. 2018), migratory habits (Agostinho et al. 2015), and omnivorous diets (Tonella et al. 2018). It is noteworthy that the Normative Instruction 203/2008 (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) prohibits the import of *P. hypophthalmus* into Brazil. Even so, the Brazilian Association of *Pangasius* Aquaculturists (Panga BR) encourages its raising (Fig. 1), which is freely marketed throughout the country.

São Paulo is the most populous and the richest state in Brazil and is also the third-largest captive fish producer in the country (Associação Brasileira de Piscicultura 2017). Due to the leadership in aquaculture, by allowing the culture of *P. hypophthalmus* in this state, its raising should be encouraged in other Brazilian regions as well. The striped catfish is

Fig. 1 Workshop publication on the culture of striped catfish *Pangasianodon hypophthalmus* in the state of São Paulo, southeastern Brazil (in Portuguese). Translation into English: **a** first Pangasius Workshop, Program, 8:00–8:45: "Registration"; 8:45–9:00: "Welcome"; 9:00–9:30: "History and perspectives of aquaculture 'Escama Forte Fish Farm'"; 9:30–10:00: "Analysis of the potential market of panga in Brazil 'Pão de Açúcar Group'"; 10:00–10:40: "Coffee Break"; 10:40–11:10: "Nutritional challenges for exotic fish 'Trouw Nutrition'"; 11:10–11:40: "Environmental licensing for panga culture 'Secretaria da Agricultura e Abastecimento do Estado de São Paulo'"; 11:40–12:15: "Productive management: myths and truths 'Colpani Fish Farm'"; 12:15–13:30: "Round table"; 13:30–15:00: "Lunch"; 15:00–15:30: "Technological innovations in intensive fish production systems 'Sansuy'"; 15:30–16:00: "Aquaculture credit lines 'Banco do Brasil de Araras'"; and **b** second Pangasius Workshop, Invitation: The Government of the state of Rio Grande do Norte, through the Secretaria da Agricultura, Pecuária e da Pesca – SAPE, in partnership with the Serviço Brasileiro de Apoio às Micro e Pequenas Empresas – SEBRAE, invite all interested parties to participate in the Second Brazilian Pangasius Workshop

freely marketed as an imported food across the country by Ministerial Notice 38/2015 (Seafood Brasil 2015; Fig. 2a), and it is also traded as pet fish in aquarium stores in many states and regions of Brazil (Magalhães 2015). Specifically, these states are Maranhão, Ceará, Pernambuco, Sergipe, and Bahia in the northeastern region, Goiás in the central-western region, Minas Gerais, São Paulo, and Rio de Janeiro in the southeastern region, and Paraná and Santa Catarina in the southern region (Freitas 2012; Magalhães and Jacobi 2013; Assis et al. 2014; Magalhães 2015; Santa Catarina 2016; Figs. 2b, 3; Supplementary Material). The allow could serve as the main route of entry for a newly-introduced or invasive species in the state of São Paulo (Fig. 2c) because aquaculture and the aquarium trade are among the primary promoters of non-native species in Brazil (Azevedo-Santos et al. 2015; Ortega et al. 2015; Frehse et al. 2016; Pelicice et al. 2017). Furthermore, fish introduced into public waters in the state of São Paulo can directly reach other Brazilian states or southern countries of South America through connected waterways. For example, the states of Paraná and Minas Gerais have good laws and take measures against invading fish (e.g., Casimiro et al. 2016), but they are useless when people in a neighboring state such as São Paulo engage in releasing and promoting new or non-native species. Therefore, this is a great political problem because logically, legislation should respect the ecological and geographical concept of a watershed.

Fig. 2 Map of Brazil indicating the five geopolitical regions and the states where the striped catfish *Pangasianodon hypophthalmus* is found: **a** marketed as food according to Ministerial Notice 38/2015 in the north region: Acre (AC), Amapá (AP), Amazonas (AM), Pará (PA), Rondônia (RO), Roraima (RR), and Tocantins (TO); in the northeast region: Alagoas (AL), Bahia (BA), Ceará (CE), Maranhão (MA), Paraíba (PB), Pernambuco (PE), Piauí (PI), Rio Grande do Norte (RN), and Sergipe (SE); in the central-west region: Distrito Federal (DF), Goiás (GO), Mato Grosso (MT), and Mato Grosso do Sul (MS); in the southeastern region: Espírito Santo (ES), Minas Gerais (MG), Rio de Janeiro (RJ), and São Paulo (SP); and in the southern region: Paraná (PR), Rio Grande do Sul (RS), and Santa Catarina (SC); **b** marketed as pet fish in aquarium stores in the states of Bahia (BA), Ceará (CE), Maranhão (MA), Pernambuco (PE), Sergipe (SE), Goiás (GO), Minas Gerais (MG), Rio de Janeiro (RJ), São Paulo (SP), Paraná (PR), and Santa Catarina (SC); and **c** where its culture in production ponds was authorized by Article 5 of Decree 62.243/2016 in the state of São Paulo

Decree 62.243/2016 and its annexes (lists of aquatic species released for aquaculture) are devoid of environmental concerns, and they disregard that by increasing the propagule pressure of non-native species, non-established species could transform into established species. They can become invasive species or occur as outbreaks (Simberloff 2009; Vitule et al. 2009; Sampaio et al. 2015). By increasing the establishment and impact of other non-native species, novel interactions or catastrophic invasions can occur (e.g., Simberloff and Von Holle 1999; Braga et al. 2018). Even if detection of the striped catfish in receptor areas does not indicate establishment, and they are raised in ponds built in river margins, previous experience indicates that it will be disseminated to natural water bodies (Orsi and Agostinho 1999; Casimiro et al. 2018). This occur either through escape during management or by fish farm flooding during the wet season, an event increasingly frequent in Brazil (Orsi and Agostinho 1999; Azevedo-Santos et al. 2015; Carvalho et al. 2015; Casimiro et al. 2018). Repeated escapes will allow the establishment and consequent invasion into riverine zones.

Therefore, Decree 62.243/2016 fails to heed national and global knowledge of the negative impacts of biological invasions. In New Zealand, for example, culture of *I. punctatus* was banned by the Ministry of Fisheries after a risk assessment because of its invasiveness and the environmental threat (i.e., predation) that it would pose to native communities (Townsend and Winterbourn 1992). In India, following a risk analysis, Singh and Lakra (2010) suggested that culturing *P. hypophthalmus* be discouraged and prevented in the country because the species could be a threat to native aquatic biodiversity. In Mexico, the Secretariat of Agriculture, Livestock, Rural Development, Fishing and Food (SAGARPA) has suspended imports of alive pangasiids because of the high invasion risk and carriers of various pathogens (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca Y Alimentación 2017). The illegal introduction of *P. hypophthalmus*, already widespread on the Magdalena River basin, is of concern in the Colombian scientific community (Valderrama et al. 2016). In Brazil, the Ministry of the Environment has supported a protocol for fish that includes a risk analysis from the biogeographical, social, and economic aspects as well

Fig. 3 Examples of striped catfish *Pangasianodon hypophthalmus* imported as food and marketed as pet fish in Brazilian regions: **a**, **b** for sale for consumption at a supermarket in the city of Aracaju, state of Sergipe, northeast Brazil (US$ 4.00–4.30/kg); **c** for sale for consumption at a supermarket in the city of Curitiba, state of Paraná, southern Brazil (US$ 3.40/kg); **d** for sale for consumption at a supermarket in the city of Belo Horizonte, state of Minas Gerais, southeastern Brazil (US$ 4.30/kg); **e** for ornamental greenhouse cultivation in the city of Muriaé, state of Minas Gerais, southeastern Brazil; and **f** for sale as common and leucistic varieties in an aquarium store in the city of Rio de Janeiro, southeastern Brazil. Photos by Marcelo F. G. Brito (**a**, **b**), Jean R. S. Vitule (**c**), and André L. B. Magalhães (**d**–**f**)

as evaluation of the biological and ecological characteristics that increase invasion risk. Using this protocol, *P. hypophthalmus* was found to pose a high invasion risk (Instituto Hórus de Desenvolvimento e Conservação Ambiental 2017). Ultimately, in spite of the risk analysis, this protocol for aquaculture was not respected, and environmental agencies and experts were ignored. The result was quite the opposite: the species is now imported, and culture is allowed, threatening the conservation of freshwater ecosystems and local biota (Pelicice et al. 2014; Padial et al. 2017; Lima et al. 2018).

Aquaculture, sport angling, fish keeping and ornamental ponds: four paths of introduction

Decree 62.243/2016 authorizes the culture of *P. hypophthalmus* in ponds that are generally built within protected areas connected to streams or rivers (i.e., an Environmental Protection Area—riparian vegetation; Forneck et al. 2016). In addition to food production, the species has an interest in sport fishing, since it is also found in specialized sites that provide angling opportunities for paying anglers ('fish and pay' sites) in the state of São Paulo (Peixe Pangasius 2018; Pesca Esportiva 2018). Escapes of aquatic species from aquaculture are unavoidable because control systems for avoiding them are inefficient. Escapes are considered the primary means by which non-native fishes are released worldwide (e.g., Welcomme 1988; Naylor et al. 2001; Azevedo-Santos et al. 2011; Carvalho et al. 2015; Ortega et al. 2015; Pelicice et al. 2017; Casimiro et al. 2018). Once introduced in few places close to the natural water bodies, non-native species escape (e.g., *C. gariepinus*, and tilapias *O. niloticus* and *Coptodon rendalli*) can promote impacts even without establishment (Cunico and Vitule 2014) or if established can cause the biotic homogenization at the interbasin scale (Daga et al. 2015). In fact, if compared with the release of nutrients and organic wastes, the escape of non-native species has received less attention in the context of best management practices in aquaculture (Tuckett et al. 2016). Among the causes that favor escapes are: (i) neglect in confinement; (ii) precariousness at fish farm facilities; (iii) locating fish farms in flood-prone areas; (iv) lack of technical support and information about the risks; and (v) unwise management actions, such as deliberate releases (Orsi and Agostinho 1999; Naylor et al. 2001; Azevedo-Santos et al. 2011, 2015; Britton and Orsi 2012; Ortega et al. 2015; Pelicice et al. 2017; Casimiro et al. 2018). In Brazil, these situations are amplified because aquaculture facilities are subject to inefficient and simplified environmental licensing processes, and concern for managing non-native species and their escapes is scarce (Lima Junior et al. 2014). Therefore, Decree 62.243/2016 only reinforces that Brazilian national policy encourages unsustainable aquaculture practices that conflict with the Aichi Biodiversity Targets. Also, clearly the decree conflicts mainly with Aichi Targets 1—educate people about biodiversity, 3—ceasing incentives to harmful activities, 7—sustainable management of aquaculture, and 9—prevention, control or eradication of non-native species (Lima Junior et al. 2018).

Since 2006, *P. hypophthalmus* has become one of the most popular among Brazilian aquarium hobbyists (Magalhães and Jacobi 2013; Assis et al. 2014; Magalhães 2015). Because the most highly-traded ornamental species are, in general, more frequently found in environments outside their natural distribution range (Fuller et al. 1999; Duggan et al. 2006), it is expected that this species could be established if released by aquarists through aquarium dumping (Assis et al. 2014; Magalhães 2015). This unhealthy practice can be boosted by trade in small-sized fishes (i.e., juveniles < 10 cm total length) in aquarium

stores (Assis et al. 2014; Magalhães 2015; Santa Catarina 2016) and among hobbyists (Magalhães et al. 2017). Unfortunately, they can reach large sizes (> 1 m), requiring more space, and encouraging further aquarium dumping (Magalhães 2015; Froese and Pauly 2017). Examples of *P. hypophthalmus* being introduced through aquarium dumping were documented in a small pond in a park within the city limits of Szczecin, Poland (Wiecaszek et al. 2009), in Ibn Najim marsh and Shatt Al-Basrah canal, Iraq (Khamees et al. 2013), and in Lake Kinneret, Israel (Snovsky and Golani 2012). In the latter, this practice initiated establishment of the species in a lacustrine ecosystem. In addition to *P. hypophthalmus*, another species of pangasiid, the giant pangasius *Pangasius sanitwongsei*, was also introduced through aquarium dumping in the Breede River, Western Cape Province, South Africa (Mäkinen et al. 2013). The future scenario with continued aquarium dumping in Brazil is worrisome: the northeastern state of Pernambuco commercializes, in addition to *P. hypophthalmus,* pangas catfish *Pangasius pangasius* (=*Pangasius buchanani*) juveniles, and this species, which reaches 3 m standard length (Davidson 1975). This species was the sixth most selling by fish farmers between 2006 and 2008, according to Freitas (2012). Due to lack of information on impacts of pangasiids introduced through aquarium dumping in the world, if *P. hypophthalmus* is introduced in Brazil its impacts are still unpredictable. Recently, the species is beginning to be used in ornamental ponds in several states (Alimentando os Pangasius 2018; Pangasius Gigantes 2018), adding more propagules for future introductions.

A past and a future that condemns

The striped catfish *P. hypophthalmus* in its native range inhabits large water bodies, reaching 44 kg in weight and 130 cm in total length (Froese and Pauly 2017). It is a high fecundity (> 1,000,000 eggs) migratory species that moves long distances upstream to reproduce during the flood season, spawning in rapids, sand banks, and channels. Larval hatching corresponds to the beginning of the monsoon season (Van Zalinge et al. 2002; Jayaneththi 2015; Froese and Pauly 2017). Therefore, because it is migratory, i.e., greater dispersion ability, and omnivorous, feeding upon zooplankton, insects, crustaceans, fish, and fruits, it has a high capacity to alter water quality and threaten aquatic ecosystems and native species (Lakra and Singh 2010; Singh and Lakra 2011). In this case, if *P. hypophthalmus* is established, there may be direct effect on the predation of eggs and larvae of native species, alteration of habitat by bioturbation in lentic waters, and transmission of pathogens (Baska et al. 2009; Wiecaszek et al. 2009; Thuy et al. 2010; Singh and Lakra 2012). If it becomes established in Amazonian rivers, it could directly compete with species with similar trophic guilds and spawning grounds (Barthem et al. 2017).

The inopportune and intentional introduction of non-native species from other zoogeographic regions has been a common occurrence since the 1940s, generally motivated by a small but influential group of people engaged in promoting, selling, or buying foreign ready-made aquaculture packages (e.g., Chamberlain 1947; Myers 1947). The striped catfish culture in the Mekong Delta (Vietnam) is the largest culture sector based on a single species in one geographic area, overcoming within a decade any form of aquaculture development in the world (Phan et al. 2009). In the Mekong Delta, the pond became the primary means to produce *P. hypophthalmus* because of its rapid growth (nearly a kilogram in 90 days) and quality of flesh (Phan et al. 2009; Phuong and Oanh 2009). Over 90% of the farmed striped catfish is exported to more than 100 countries (Phuong and Oanh

2009), and it is considered one of the most consumed fish in the United States (National Fisheries Institute 2017). Furthermore, environmental tolerance and resistance to extreme values of dissolved oxygen, salinity, pH, temperature and the uncommon body shape like a shark (the name of the species in aquarium trade is iridescent shark), also contribute to its popularity commercial and ornamental in aquaculture (Van Zalinge et al. 2002; Ali et al. 2013; Jayaneththi 2015). Its rusticity allows the species to be cultivated intensely in highly-polluted rivers (Srivastava et al. 2014; Murk et al. 2018). Despite the advantages of large-scale production, the striped catfish has been portrayed by the media to be unsafe for consumption (Bush and Duijf 2011; Little et al. 2012). Fish farmed in contaminated areas in India were found to be capable of accumulating heavy metals, and their consumption could lead to high levels of carcinogenic risk to humans (Srivastava et al. 2014). The species continues to be suspect as a host to several parasites such as trematode metacercariae, monogenoidean, myxosporean species, and *Trichodina* (Baska et al. 2009; Wiecaszek et al. 2009; Lakra and Singh 2010; Thuy et al. 2010; Sandilyan 2016). Therefore, intensive monoculture of *P. hypophthalmus* can be a serious sanity problem for Brazilian fish farmers. In India, an intensive system is associated with severe diseases such as hemorrhagic septicemia and bacillary diseases (Lakra and Singh 2010). Thus, management practices would be necessary in fish farms and industrial processing to reduce infection levels (Thuy et al. 2010). However, the production of *P. hypophthalmus* would become more expensive with antibiotics and chemicals whose inappropriate uses could also have impacts on the environment and human health (Lakra and Singh 2010). With sources negative impacts for human health and ecosystems is very important that precautionary principle be used. There is a Federal Brazil government: the Normative Instruction 203/2008 (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) prohibits the import of *P. hypophthalmus* into Brazil. Even so, the state Decree 62.243/2016 encourages raising *P. hypophthalmus* and disrespect the hierarchy between federal and state laws.

Escapes from fish farms have introduced *P. hypophthalmus* to several regions, such as Taiwan (Welcomme 1988), Singapore (Ng et al. 1993), Philippines (Guerrero 1997), Bangladesh (Barua et al. 2001), Guam, China, Myanmar (Singh and Lakra 2012), India (Zeena and Jameela Beevi 2013), and Sri Lanka (Jayaneththi 2015). In 2015, the species was detected in South America in the Magdalena River basin (Colombia), also from the accidental escape from illegal fish farms (Valderrama et al. 2016). In Brazil, any record of this species' occurrence in natural environments has yet to be recorded.

Last words

Unfortunately, the development trial in commercial aquaculture in Latin America has been based on trial-and-error managerial schemes, on copied foreign "recipes" or simply on improvisation (FAO 2017). The persistence in cultivating non-native species, the disinformation and neglect of fish farmers about the dangers of biological invasions, and the distance between public authorities and the scientific community are characteristic of developing countries (Nuñez and Pauchard 2010; Azevedo-Santos et al. 2017). In South American nations with emerging economies, Brazil for example, environmental issues are often suppressed by economic conditions and favor new invasions of popular non-native species such as tilapia and carp (Vitule et al. 2009; Pelicice et al. 2014). Thus, public awareness is necessary to bring decision-makers and lay people closer to the scientific community (Azevedo-Santos et al. 2015, 2017). Non-native species cultured without commitment to

conservation of the natural heritage in public waters promote damage to the conservation of freshwater ecosystems. Therefore, the Brazilian authorities should turn their attention to the culture of native species (Gargur et al. 2018) instead of encouraging and facilitating the culture of non-native species because they have obligations as signatories to the Convention on Biological Diversity and because the fish in the country are highly diverse. Species such as *P. hypophthalmus* threaten freshwater ecosystems and native species (Pelicice et al. 2017). It is time for Brazil to learn from the unsuccessful experiences in other countries (Zeena and Jameela Beevi 2013; Jayaneththi 2015; Valderrama et al. 2016) as well as its own (Weyl et al. 2016) to avoid mistakes that could jeopardize its biodiversity.

Finally, we want to pose a question: If importing *P. hypophthalmus* is prohibited in Brazil by the Normative Instruction 203/2008, why does Decree 62.243/2016 allow the species entry into the state of São Paulo? Also, according to Federal Law 11.959/2009, which provides for the National Policy of Sustainable Development of the Aquaculture and Fisheries, "in the culture of exotic species, it is the aquaculture farmers responsibility to ensure containment of the specimens in captivity, preventing their access to waters of drainage of the Brazilian watershed." Nevertheless, licensed projects for the establishment of fish farms do not present containment systems to prevent the escapes during periods of potential flooding (Lima Junior et al. 2014; Magalhães and Jacobi 2017; Pelicice et al. 2017; Casimiro et al. 2018). Therefore, the 'polluter pays' principle must be applied to fish farmers because it is his responsibility to avoid such escapes. To safeguard native freshwater fish species in Brazil, the culture of non-native fishes should be discouraged by the governments of the Brazilian states and also by the federal government. In addition, the Brazil is signatory of Biological Diversity Convention and assumed the explicit compromised to combat non-native species (Lima Junior et al. 2018) and the Decree 62.243/2016 is in opposite way.

In view of the imminent invasion, we strongly recommend that the striped catfish *P. hypophthalmus* should be removed from the list of allowed species to be farmed in the state of São Paulo, and its culture expressly prohibited in Brazil, as recently occurred in Mexico (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca Y Alimentación 2017). Thus, it is urgent that Brazil comply with the precautionary principle against new invasions, changing its direction and its commercial and ornamental aquaculture system based predominantly on non-native species. Otherwise, it will not achieve sustainable development in aquaculture. As said by George Santayana "Those who cannot remember the past are condemned to repeat it".

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