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ORIGINAL RESEARCH

Unintended consequences of valuing the contributions of non-native species: misguided conservation initiatives in a megadiverse region

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Abstract
The introduction of non-native species (NNS) and the resulting biological invasions are conspicuous features of the Anthropocene Epoch. Parallel to these phenomena, some initiatives (political, social and scientific) have sought to value and protect invasive populations, recognizing some benefits that NNS may deliver to people and nature. Given this growing trend of valuing NNS, we considered opportune to address this issue in the context of megadiverse tropical countries. We investigated an emerging trend that has advocated the protection of highly invasive fishes by legal instruments, i.e., the protection of invasive peacock basses (genus *Cichla*) in Brazil. We recorded 16 bills or laws proposed between 2017 and 2022 that determine fishing restrictions to protect invasive *Cichla* spp. from overfishing and other impacts, in order to favor population recruitment, growth, colonization and spread. Specifically, they establish restrictions on fishing, capture, transport, trade, and processing, including quotas, compulsory catch and release, length limits, use of gears, and temporal interdictions. They also determine the naturalization of peacock basses in some main basins of South America, which include different watersheds and ecoregions, with risk of intercountry invasions. This particular case is instructive to unveil the risks of positions that emphasize positive contributions of NNS to society and nature, as these misguided conservation actions favor invasive organisms with high potential to cause environmental degradation, biodiversity losses, and social conflicts. These positions find fertile ground in some contexts, especially in tropical developing countries, where economic constraints, poor access to information, opportunism, and bad political behavior have been the norm.

Keywords Alien invasive species · Fish · Recreational fishing · Impact · Legislation · Social conflicts

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Introduction

Humans have favored the introduction, establishment, and spread of non-native species (hereafter NNS) since prehistoric times, but only recently this process has become a global and accelerated phenomenon (Seebens et al. 2017). In fact, the introduction of NNS and the resulting biological invasions are conspicuous features of the Anthropocene (Waters et al. 2016) or Homogenocene (Padial et al. 2020) periods. Introductions of NNS have been conducted either intentionally or accidentally by multiple vectors operating at local, regional and global scales, which make surveillance, monitoring and control very difficult (Simberloff 2003; Novoa et al. 2020; Ricciardi and MacIsaac 2022). As a result, the detection of new NNS have increased exponentially around the world (Seebens et al. 2017), especially involving organisms that have some desirable effects to humans from some specific angle, such as fish (e.g., Casal 2006; Johnson et al. 2009; Vitule et al. 2009; Toussaint et al. 2018; Bueno et al. 2021; Doria et al. 2021).

Parallel to the introduction and spread of NNS, some initiatives (political, social and scientific) have sought to value and protect invasive populations of non-native organisms (e.g., Gozlan 2008; Johnson et al. 2009; Vitule et al. 2009, 2012; Davis et al. 2011; Schlaepfer et al. 2011; Ribeiro et al. 2017; Garcia et al. 2022; Sax et al. 2022). This position recognizes some real or potential benefits that NNS may deliver to people and nature. However, initiatives that emphasize some particular values of NNS and protect invasive populations tend to hold a simplistic view about biodiversity, ecosystem functioning and degradation, underestimating or ignoring social, economic and environmental issues that translate into negative effects, disturbances, costs, and conflicts (Vitule and Pelicice 2023). It is worth noting that the introduction of NNS is a main factor driving the current biodiversity crisis, threatening the maintenance of ecosystems and their services on a planetary scale (Mack et al. 2000; Clavero and Garcia-Berthou 2005; Vitule et al. 2009; Simberloff et al. 2013). Moreover, NNS have caused substantial economic losses to nations (Pimentel et al. 2000; Essl et al. 2011; Walsh et al. 2016; Adelino et al. 2021), and their management, control or eradication demand expensive, complex, and sometimes unfeasible actions. From the perspective of nature conservation and sustainability, the protection of NNS is non-sensical (Ricciardi and Simberloff 2009; Vitule et al. 2009; Lövei and Lewinsohn 2012), as it favors processes (i.e., biological invasions and biotic homogenization) that are complex, unpredictable and contingent, which can interact synergistically with other human disturbances in multiple ways and scales (Essl et al. 2011; Havel et al. 2015; Ricciardi et al. 2021; Vitule and Pelicice 2023). The valuation and protection of NNS may compromise legitimate conservation programs and the management of natural resources; they represent typical cases of misguided conservation initiatives, as conservation efforts are directed towards the protection and spread of invasive NNS. Such actions have the potential to affect human well-being and sustainability in the long-term, which are generally difficult to assess without taking into account qualified information, scale issues (spatial and temporal), and value judgment (e.g., Ricciardi et al. 2021; Catford et al. 2022). These initiatives are also prone to confound public opinion and cause cultural degradation (Pfeiffer and Voeks 2008; Speziale et al. 2012; Santos et al. 2019a), as society, stimulated by immediate benefits, tend to support these actions. Moreover, the protection of NNS may attenuate the perception of negative effects and encourage actions and manifests (e.g., animal rights, local movements) to act against the control and eradication of invasive organisms (Crowley et al. 2017).

Conservation initiatives to protect NNS based on limited perspectives or a strict point of view have been recorded in different parts of the planet (Johnson et al. 2009; Weyl et al.

2016; Ribeiro et al. 2017), including megadiverse tropical regions (Lövei and Lewinsohn 2012; Van Damme et al. 2015; Frehse et al. 2016; Santos et al. 2019a; Marková et al. 2020). In South America, some initiatives have sought to protect non-native fishes that are highly valued by fisheries (Online Resource 1), including species with confirmed invasive and harmful potential (Lazzaroto and Caramaschi 2009; Vitule et al. 2009; Sepúlveda et al. 2013; Ribeiro et al. 2017; Magalhães et al. 2018; Geller et al. 2020; Franco et al. 2021; Cataneo et al. 2022). In Brazil, invasive populations of peacock basses (genus *Cichla* Bloch & Schneider, 1801—Cichliformes, Cichlidae) have received significant attention from sectors associated with the development of recreational fisheries. This movement has been responsible for the illegal introduction and spread of *Cichla* spp. in different drainages across the country, but it has also used political and economic power to lobby for protective measures that favor invasive populations, as a means of fostering fishing activities and tourism (Magalhães et al. 2018; Franco et al. 2022a). As a result, some legal instruments have been proposed to protect non-native species of *Cichla*, pointing to the emergence of a social and political movement that defends the preservation of invasive NNS whose environmental and social impacts are well known (e.g., Pelicice and Agostinho 2009; Bezerra et al. 2019; Catelani et al. 2021a; Franco et al. 2021). Initiatives to protect *Cichla* spp. are emblematic cases of misguided conservation actions, as they favor non-native invasive organisms with high potential to cause environmental degradation, biodiversity losses, and social conflicts, emphasizing the multiple risks associated with positions that value NNS.

Given this growing trend of valuing NNS, which has been observed even among researchers and experts in invasion science (e.g., Gozlan 2008; Davis et al. 2011; Schlaepfer et al. 2011, 2012; Sax et al. 2022), we considered opportune to address this issue in the context of megadiverse or hyperdiverse tropical regions of the planet. These regions or nations hold disparate biodiversity and provide a myriad of ecosystem services to humanity (e.g., Groot et al. 2012; Brandon 2014; Rodrigues et al. 2021; Pelicice et al. 2022a), but they have been massively invaded by different NNS, especially fishes (Lövei and Lewinsohn 2012; Frehse et al. 2016; Vitule et al. 2019; Bueno et al. 2021; Doria et al. 2021). Moreover, tropical biodiversity has been progressively eroded by the expansion of human activities, poor conservation actions, and unfavorable environmental policies (e.g., Winemiller et al. 2016; Kleinschroth et al. 2019; Pelicice and Castello 2021), which make these regions vulnerable to initiatives that promote the use or the protection of NNS. To explore this context, we investigated an emerging trend that has advocated the protection of invasive fishes by legal instruments, i.e., the protection of invasive populations of peacock basses in different drainages and geopolitical regions of Brazil. In particular, we gathered and analyzed bills and laws (hereafter B&L) proposed in the last five years that establish measures to protect these highly invasive fish. We use this particular case to explore the consequences and risks associated with positions that value NNS and support misguided conservation initiatives and policies that favor non-native invasive organisms.

Peacock bass: a powerful invasive NNS

Peacock basses (Fig. 1a) are tropical fishes native to different drainages of the Amazon region, i.e., Amazon, Essequibo, Orinoco and Tocantins-Araguaia river basins (Franco et al. 2022b). There are 16 valid species (Kullander and Ferreira 2006; Sabaj et al. 2020), although molecular studies indicate the existence of nine species and seven regional varieties (Willis et al. 2012; Winemiller et al. 2021). Several traits make these species highly

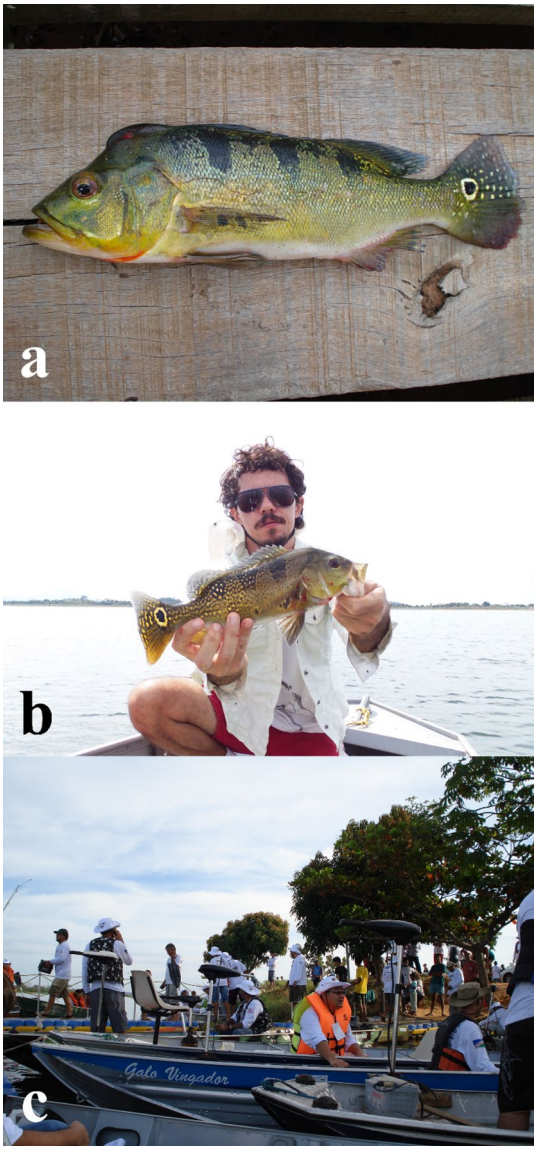

Fig. 1 The peacock bass (genus *Cichla*), a Neotropical fish highly appreciated by sport and recreational fishing. **a** *Cichla kelberi*, a fish widely introduced in Brazil; **b** sport fishing based on catch and release; **c** fishing tournament focused on the catch and release of *Cichla* species

appreciated by recreational fishing (Fig. 1b), such as beauty, size, vitality, strength, and ferocity; they are piscivores, voracious and visually-oriented, apex predator with high per capita effects (Jepsen et al. 1997; Sabino and Zuanon 1998; Carvalho et al. 2021). They are also valued for other uses, including consumption, aquaculture, and fish keeping. Their economic and social significance has motivated the introduction of different species around the world (Sastraprawira et al. 2020; Franco et al. 2022b).

In Brazil, the first introductions of *Cichla* occurred officially in the semiarid region during the 1930s, with the aim of establishing new fisheries and providing animal protein for the local population (Paiva and Mesquita 2013; Bezerra et al. 2019). In the following

decades, different species were introduced illegally in other Brazilian drainages, through the action of different vectors (e.g., fishing, aquaculture, aquarium trade; Espínola et al. 2010; Britton and Orsi 2012; Ortega et al. 2015; Magalhães et al. 2017; Bueno et al. 2021). The introduction of peacock basses accelerated after the 1990s with the expansion of recreational fishing (Vitule 2009; Franco et al. 2022b; Hillesheim et al. 2022), a diverse segment that includes sport fishing, anglers, underwater fishing, associations, and tournaments; sport fishing, in particular, is deeply connected with peacock basses. Currently, introduced populations of *Cichla* spp. are widely established and spread in Brazil (Fig. 2a)—an increasing trend, although these numbers can be underestimated (Vitule et al. 2019). These fishes colonized successfully hydroelectric impoundments of the upper Paraná, Iguaçu, Paraíba do Sul, and São Francisco river basins (Espínola et al. 2010; Daga et al. 2016; Franco et al. 2018; Garcia et al. 2018; Bezerra et al. 2019; Loures and Pompeu 2019; D'avilla et al. 2021), mainly in cascade dam systems (Pelicice et al. 2018).

The genus *Cichla* has been a successful invader, considering that different species have colonized different environments (e.g., rivers, lakes, canals, floodplains, large and small impoundments, ponds, and estuaries), biomes (e.g., savannas, rainforests) and ecoregions (Sastraprawira et al. 2020; Franco et al. 2022b). Propagule pressure has probably played a role, but *Cichla* species have some functional traits that grant high invasiveness (Magalhães et al. 2017). Like most cichlids, peacock basses prefer lentic environments, where they find food, breeding sites, and refuge; this behavior has enabled the successful colonization of hydroelectric impoundments (Espínola et al. 2010; Franco et al. 2022c). *Cichla* species are voracious and generalist top-predators that consume preferentially small fish (Jepsen et al. 1997; Novaes et al. 2004; Marto et al. 2015; Winemiller et al. 2021), a common and abundant resource in freshwater environments. In addition, they are able to consume secondary resources when food supply is low, such as invertebrates or practicing cannibalism (Santos et al. 2001; Teixeira and Bennemann 2007; Fugi et al. 2008; Villares Junior and Gomiero 2010; Mendonça et al. 2018; Rosa et al. 2021). They are efficient visual apex predators, with a type II functional response curve and higher consumption rates when compared to other predators (Carvalho et al. 2021), which suggests that its ecological impacts emerge from strong per capita effects (i.e., Parker et al. 1999). They can use different strategies to feed, including opportunism, ambushing, stalking, chasing, and shoaling (Sabino and Zuanon 1998; Marto et al. 2015; Andrade and Pelicice 2022). These fish are territorial and aggressive during reproduction, when they build nests and guard their offspring (Magalhães et al. 1996; Winemiller et al. 2021). They have multiple-batch spawning and high fecundity (Souza et al. 2008; Normando et al. 2009; Vieira et al. 2009), and can adjust their reproductive period when conditions are favorable, including continuous reproduction (Marto et al. 2015). *Cichla* species are also less vulnerable to predation, especially when they reach large sizes (> 40 cm) in hydroelectric reservoirs, where large predators are virtually absent. They also present cryptic coloration when young and eyespots near the caudal fin (Pelicice et al. 2022b), which constitute defense mechanisms against predators (Winemiller 1990). These fish are also eurytopic animals, tolerating wide environmental variation and different water types (i.e., black, white and clear waters), being able to colonize a variety of environments; they can even tolerate temperate climates (Franco et al. 2022b) and high salinity (Catelani et al. 2021b).

The introduction of peacock basses has been followed by severe environmental disturbances (Franco et al. 2021). The scientific literature is clear about multiple ecological effects at different levels of organization, from populations to ecosystems. Studies have reported reductions in population size or the extirpation of small fish (e.g., Latini and Petrere 2004; Pelicice and Agostinho 2009; Sharpe et al. 2017; Franco et al. 2022c),

top-down control (e.g., Pinto-Coelho et al. 2008), changes in the diet of native species (Pompeu and Godinho 2001), competition with native predators (Fugi et al. 2008), and local extinction of carnivores (Pompeu and Alves 2003)—with effects on food web structure and on the generation of ecosystem functions and services (e.g., Zaret and Paine 1973; Leal et al. 2021; Souza et al. 2021). An overview of impacts can be checked in Franco et al. (2021), but the existing scientific literature about the issue is provided in Franco et al. (2022d).

Misguided conservation initiatives

Peacock basses (native and introduced) have been highly appreciated by sport fishing and other modalities (Lubich et al. 2021; Winemiller et al. 2021; Hillesheim et al. 2022), with a strong social, touristic and economic appeal (Fig. 1c). In fact, introduced populations have supported fishing activities and tourism in different regions of Brazil, particularly in hydroelectric reservoirs. In this scenario, the sport fishing segment has pushed authorities to protect non-native stocks, with the allegation that they support local economies. This strong lobby has resulted in the proposition of B&L that determined a series of actions to protect these invasive fishes (Magalhães et al. 2018; Franco et al. 2022a).

Between 2017 and 2022, we recorded 16 B&L proposed at the municipal and state levels (Online Resource 2) with the objective of protecting and maintaining stocks of invasive peacock basses. Some bills remain under analysis while a few have been discarded; the majority, however, has been sanctioned as law (62.5%; Online Resource 2). These B&L cover 12 municipalities from four states in the southern, southeastern, and northeastern regions of Brazil (Fig. 2b); most of them (N = 9) were proposed in the State of São Paulo. Although each B&L was proposed independently, they are mere textual copies and propose identical legislation. In essence, they determine fishing restrictions to protect stocks of *Cichla* spp. from overfishing and other impacts, in order to favor population recruitment, growth, colonization and spread. Specifically, they establish restrictions on fishing, capture, transport, trade, and processing, including quotas, compulsory catch and release, length limits, use of gears, and temporal interdictions (Fig. 3). They determine the naturalization of peacock basses, by assigning the status of native species, or natural, cultural and touristic heritage. Target species included *Cichla piquiti* Kullander & Ferreira 2006, *Cichla kelberi* Kullander & Ferreira 2006, and *Cichla monoculus* Spix & Agassiz, 1831, but many B&L only mentioned common names (e.g., tucunaré, blue peacock bass, yellow peacock bass) or the genus (*Cichla*). The geographic extent and scope of these B&L were variable, ranging from certain ecosystems (e.g., dams and rivers) to all water bodies within a geopolitical unity (i.e., municipalities and states). Together, these B&L establish the protection of invasive peacock basses in different watersheds and ecoregions of South America (Fig. 2c), including large river systems (i.e., Paraíba do Sul, Ribeira de Iguape), some of which shared among different countries (i.e., La Plata Basin), in addition to several Atlantic coastal drainages.

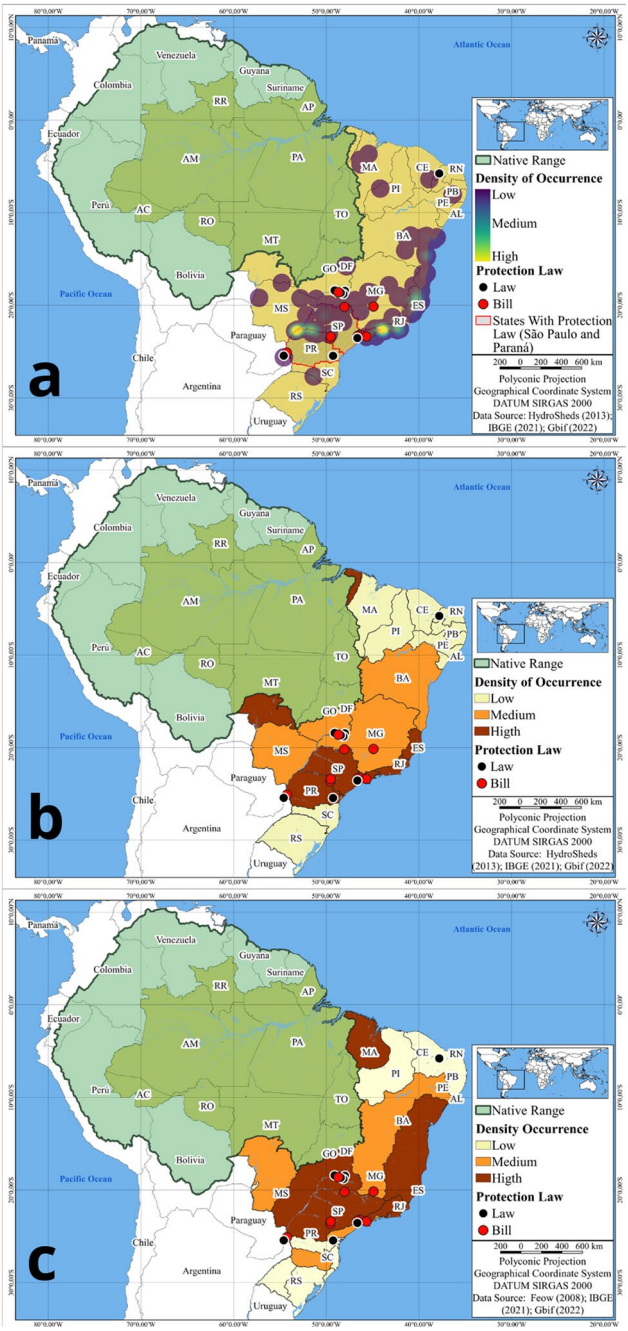

Fig. 2 Natural distribution of species of *Cichla* in South America (green area), occurrence records of non-native populations in Brazil, and the distribution of bills and laws that protect non-native populations. **a** density occurrence of non-native species of *Cichla*; **b** the distribution of bills and laws across Brazilian states; **c** the distribution of bills and laws across ecoregions. Methods, procedures and data source are provided in Online Resource 3

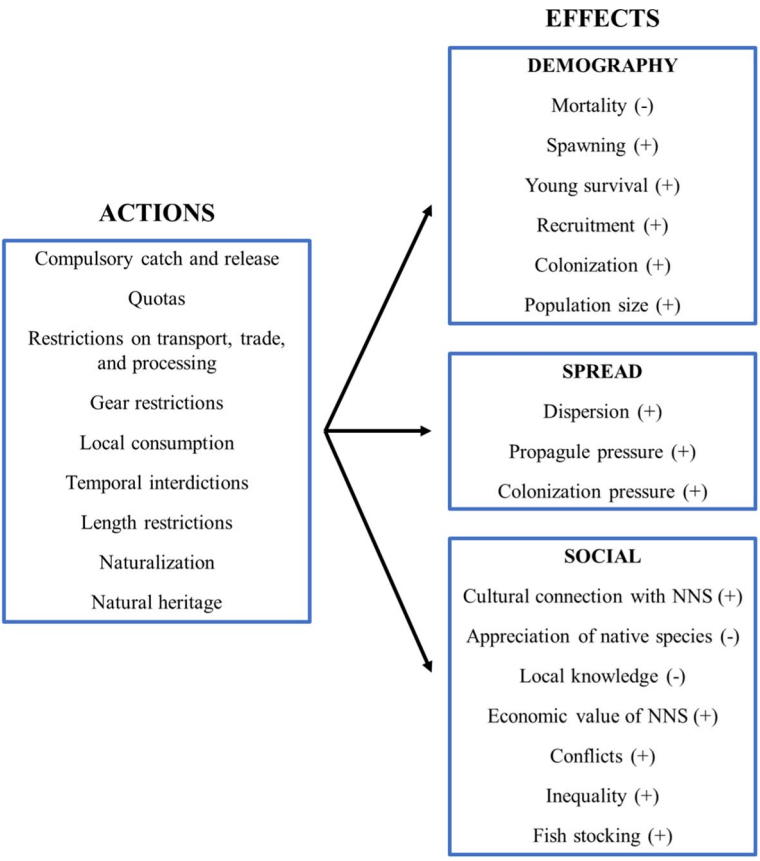

Fig. 3 Actions established by bills and laws to manage and protect non-native peacock basses (genus *Cichla*) in Brazil, and their expected effects (positive or negative) on demography, spread, and social aspects. More information on the bills and laws can be found in Online Resource 1. *NNS* non-native species

Emerging concerns and conflicts

Legislation protecting invasive NNS contributes directly with the persistence and spread of harmful organisms, threatening biodiversity, ecosystem functioning, and weakening environmental policies. In the case of peacock basses, the protection of these powerful predators must intensify predatory effects on biodiversity, with negative consequences on aquatic ecosystems and natural resources (Fig. 4a)—as demonstrated by a vast catalog of scientific studies (i.e., Franco et al. 2022d). The diversity of freshwater fishes, particularly those small-sized, have been highly impacted by these predators (e.g., Pelicice and Agostinho 2009; Franco et al. 2022c), with important cascading consequences (e.g., Zaret and Paine 1973; Leal et al. 2021; Souza et al. 2021). Therefore, the protection of *Cichla* spp. and its spread must result in community disassembly, biotic homogenization, and defaunation. Another important aspect is that B&L conflict with genuine management and conservation policies (i.e., protected areas, habitat restoration, fishery regulations, control of invasive species), as impacts caused by *Cichla* species may overcome positive results emerging from these actions.

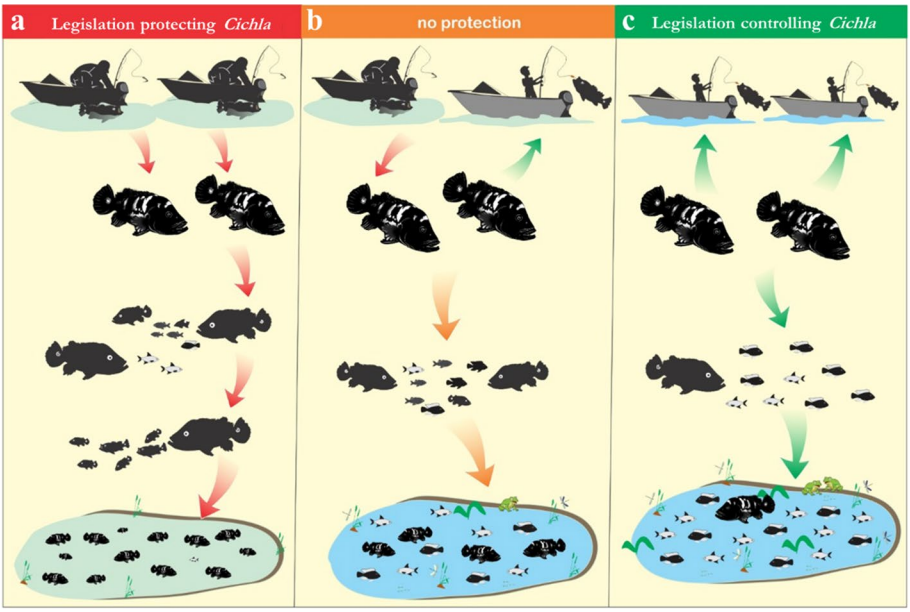

Fig. 4 Different approaches to manage non-native peacock basses: **a** fishery regulations that limit capture to preserve stocks (e.g., compulsory catch and release, quotas); **b** no action towards protection, control, or eradication; **c** management actions to control and eradicate populations. The direction of the arrows indicates propagule release (inward) or propagule removal (outward), while colors indicate the net effect on propagule pressure (red = strong; orange = moderate; green = low). The scenario is merely illustrative, but it demonstrates positive feedbacks in population dynamics emerging from different management actions, which produce different effects on biodiversity, ecosystem functions, and fisheries (e.g., modulating yield and fish size)

The protection of non-native stocks can trigger new invasion events by favoring survival, reproduction, recruitment, population growth, and spread (Fig. 3), increasing propagule and colonization pressure towards non-invaded areas (Lockwood et al. 2005). Peacock basses are non-migratory fish with low vagility, but able to perform small-scale movements (Hoeinghaus et al. 2003), which allow its diffusion towards tributary rivers, downstream stretches, protected areas, and contiguous impoundments (Ortega 2015; Santos et al. 2016; Catelani et al. 2021b). It should be noted that many B&L focused on reservoirs, a modified environment that favors the colonization and dispersion of *Cichla* species (Espínola et al. 2010; Franco et al. 2018, 2022b). Moreover, most initiatives were proposed for the upper Paraná River basin, a region highly fragmented by hydroelectric dams, which must favor the downstream dispersion towards other drainages and countries (i.e., Paraguay, Argentina and Uruguay). In this context, the presence of cascades of dams must act as stepping stones for fish dispersion (Havel et al. 2005; Johnson et al. 2008), increasing propagule and colonization pressure. In addition, B&L at the state level ensure the protection of all introduced populations within a particular state, regardless of the drainage, environment, and the stage of invasion, creating a pervasive cycle of dispersal, new introductions, and protection. It must be noted that illegal stocking has been the main driver behind the introduction of *Cichla* spp. around the world (Franco et al. 2022a, b, c, d), an ongoing process in Brazil; it means that every new introduced population, although illegal, will become protected by

legislation. In this context, B&L must encourage fish stocking across the country (Fig. 3), especially in areas where peacock basses are protected.

Legislations that protect invasive NNS raise conflicts among stakeholders and contribute to increasing inequality in the use of natural resources (Fig. 3), as they favor specific groups (Sepúlveda et al. 2013; Crowley et al. 2017). This situation can be observed in the case of peacock basses, as B&L favor exclusively sport fishing based on catch and release, which involves a very specialized public (e.g., anglers, equipment industry, hotels, tourism chain, TV shows, and tournaments). In doing so, these B&L ignore other stakeholders that also depend on fisheries and water resources, such as subsistence, artisanal, commercial, and other recreational (e.g., underwater fishing) fishers, all of which are impeded to catch peacock basses. They also ignore basic aspects of the fishing activity, such as gear selectivity and mortality (e.g., hooks and gill nets), which inevitably result in *Cichla* spp. bycatch, fines and penalties. Indirect effects are also predicted, through the loss of local knowledge (e.g., fishing methods), native biodiversity and other fishing stocks (e.g., small to medium-sized fish used as food, bait or ornamentation, or the loss of prey that support large predators). The erosion of biodiversity also translates into ecosystem level effects that impact inland fisheries, such as the loss of insurance and portfolio effects, fishery options, disease control, cultural aspects, among others (Catelani et al. 2021a; Leal et al. 2021; Pelicice et al. 2022a). Therefore, although applauded by sport fishers (Fig. 5), bills that protect invasive species of *Cichla* have the potential to make fishing unfeasible in the long term; in fact, the emergence of dissatisfaction and conflicts among subsistence, artisanal, commercial and recreational fishers have been reported elsewhere (Franco et al. 2022a). These policies, therefore, have little potential to promote social and economic development on a broader scale, as benefits are concentrated among a few elite groups, while environmental costs and economic losses are shared by all—a tragedy of the commons (Hardin 1968).

Another concern relates to the positive outcome of the actions, especially if they can generate persistent long-term benefits (Vitule and Pelicice 2023). In the case investigated here, there was no consideration about the sustainability of stocks and fishing catches in the long-term. Although peacock basses are efficient invaders and can successfully colonize different environments, they are top predators (Jepsen et al. 1997; Marto et al. 2015), therefore, unable to maintain large population sizes. This situation is exacerbated when stocks are subjected to regular fishing effort or when prey availability is limited, a common situation in ecosystems invaded by *Cichla* species (Santos et al. 2019b; Leal et al. 2021). The lack of prey and other stressful conditions (e.g., environmental degradation) can limit stock size, induce temporal oscillations, and reduce the size of individuals—as observed elsewhere in cases of dwarfism or stunting (e.g., Baxter-Gilbert et al. 2020; Amarasinghe and Pauly 2021). In fact, the consumption of secondary food resources (e.g., insects, shrimp, and cannibalism) has been regularly reported for non-native populations of *Cichla* spp. (e.g., Santos et al. 2001; Teixeira and Bennemann 2007; Villares Junior and Gomiero 2010; Mendonça et al. 2018)—a behavior not characterized in native populations (Novaes et al. 2004; Jepsen et al. 1997; Marto et al. 2015). Although the fishery of invasive peacock basses has not been monitored, the yield in reservoirs is highly variable, and most fish are small-sized—a pattern well known to fishers from the upper Paraná River basin. These factors limit the development of recreational fisheries (Fig. 4a), since the activity is attractive when the environment supports large stocks and large specimens, as observed in regions where peacock basses are native (e.g., Rio Negro, Amazon Basin; Lubich et al. 2021).

The protection of non-native organisms also conflicts with legislation, jurisprudence and modern political trends that value the environment, native biodiversity, ecosystems, and sustainability. These B&L protecting non-native species of *Cichla*, for example,

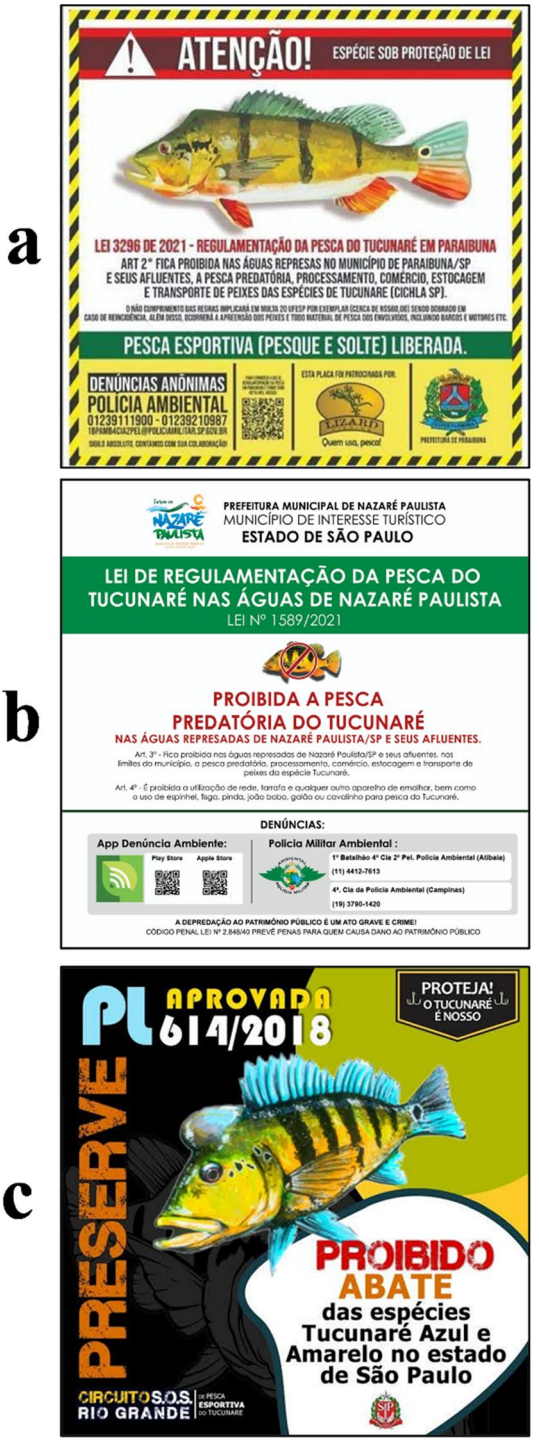

Fig. 5 Examples of advertisements about legislation that protect *Cichla* spp. (non-native), which have been widely disseminated on the internet and social media. **a** fishing regulations in the Paraibuna Reservoir, Paraíba do Sul River Basin, with emphasis on catch and release (source: https://www.turmadobigua.com.br/, accessed November 2, 2022); **b** fishing regulations in reservoirs of Nazaré Paulista, São Paulo, with a call for the development of sustainable fisheries (source: https://atlanticusfishing.com.br/, accessed November 2, 2022); **c** the preservation of *Cichla* spp. in São Paulo State, advertising prohibitions and the need to preserve this fish (source: https://www.facebook.com/pescaesportivabrasil/, accessed November 2, 2022)

conflict with Brazilian legislation and international agreements. Federal Law 9605/1998 precludes the introduction of exotic species in the country, while the Federal Constitution (Article 225) ensures the right to an ecologically balanced environment. They are also in disagreement with several federal instruments focused on the control, prevention and prohibition of non-native organisms (ca. 85 instruments, in the form of decrees, laws, regulations, among others; Faria et al. 2022). In Brazil, federal laws are hierarchically above state and municipal laws, which make these B&L unconstitutional. Moreover, these B&L favor illegal actions such as clandestine fish stocking, because populations introduced illegally become paradoxically protected by law. They also conflict with international treaties of which Brazil is signatory, such as the Convention on Biological Diversity, the Aichi Targets, and the Escazu Agreement. The Aichi Targets and the Post-2020 treaty, for example, stated important goals related to the control and eradication of NNS (Lima-Junior et al. 2018; Azevedo-Santos et al. 2021). The recent political scenario in Brazil must be taken into account, as these B&L add to other setbacks in environmental policies (e.g., Fearnside 2016; Azevedo-Santos et al. 2017; Dobrovolski et al. 2018; Metzger et al. 2019), intensified during the mandate of President Jair Bolsonaro (e.g., Ferrante and Fearnside 2019; Pelicice and Castello 2021). It indicates that some contexts are highly vulnerable to policies and suggestions that encourage the use and protection of NNS, pointing to the existence of political and social settings (commonly found in tropical developing countries) where these initiatives find fertile ground.

Finally, the lack of scientific knowledge supporting these B&L is a serious concern, as mismanagement and wrong actions impact native biodiversity (Pelicice and Agostinho 2008; McLaughlin et al. 2013). The main justification in favor of these B&L lies in the potential economic benefits emerging from recreational fishing and tourism. However, no initiative presented data, results, risk analysis, or assessments that balanced costs and benefits for different stakeholders. Moreover, these B&L were not based on stock assessments and planning, indicating that actions are isolated and not part of a fishery management program. The lack of technical basis is notorious, if we consider that B&L are based on naïve and incoherent claims, e.g., peacock basses do not cause impacts to the environment, they belong to the native fauna of the region, their protection will bring economic development, their presence contributes with the maintenance of ecological integrity and environmental quality. The scientific literature on the impacts caused by peacock basses was not consulted (i.e., Franco et al. 2022d), as well as basic information and concepts on biogeography, invasion biology, fish ecology, population dynamics, fishery management, multiple uses of natural resources, and sustainability. The chance of failure, unpredictable results and unintended consequences is, therefore, high. Moreover, the lack of technical advice poses serious limitations on approaches that recommend concern only with invasive NNS (e.g., Schlaepfer et al. 2011), considering that many non-invasive NNS apparently do not impact the environment and society. The peacock bass case is clear about the inability of stakeholders in discriminating between native and non-native species, which precludes further considerations about the invasive species concept.

Conclusions

Political, social and scientific initiatives that value and protect invasive NNS are emblematic examples of misguided conservation strategies, as they favor the spread of invasive organisms with high potential to cause environmental degradation and social conflict—as

typified in the B&L investigated here. These actions contribute to erode native biodiversity, damage ecosystems, affect the conservation status of threatened species, and induce cultural changes in the appreciation and use of natural capital, in addition to complicating or compromising effective environmental policies and conservation plans. This scenario is especially concerning for tropical regions (Lövei and Lewinsohn 2012; Vitule and Pelicice 2023), where invasive organisms may affect hundreds to thousands of species in a single ecosystem—the Neotropical region alone is home to more than 6200 freshwater fishes (Albert et al. 2020). Due to the growing environmental, social and economic risks associated with NNS and biological invasions, public policies and technical positions should prioritize the prevention, management, control and eradication of invasive organisms (Johnson et al. 2009; Simberloff & Vitule 2014; Robertson et al. 2020). In the case of peacock basses, fishing (Fig. 4b, c) could help controlling population size and its effects on native biodiversity (Sepúlveda et al. 2013; Santos et al. 2019b).

The peacock bass case is instructive to unveil the risks of positions that emphasize positive contributions of non-native species (Vitule and Pelicice 2023), especially when experts in invasion biology are involved (e.g., Gozlan 2008; Davis et al. 2011; Schlaeapfer et al. 2011, 2012; Sax et al. 2022). Society is naturally biased towards the benefits delivered by some non-native organisms (e.g., Jhonson et al. 2009; Vitule et al. 2009; Pelicice et al. 2014), so positive views promptly encourage inadequate policies and opportunism. This is particularly true for tropical countries, like Brazil, where economic constraints, poor access to information, and bad political behavior are the norm (Ferrante and Fearnside 2019; Pelicice 2019). Emphasis on potential benefits may also confound public opinion and encourage the use of NNS (Fig. 5), sometimes with persistent cultural consequences (Pfeiffer and Voeks 2008; Speziale et al. 2012; Melo et al. 2021). Many Brazilian initiatives have sought to protect and use non-native fishes (Online Resource 1), including invasive tilapias and panga (Pelicice et al. 2014; Padial et al. 2017; Garcia et al. 2018). Yet, it is understandable that some NNS acquire social and economic relevance, inspiring popular support and care; however, because biological invasions are a complex phenomenon and may cause different negative effects at multiple spatiotemporal scales, a precautionary approach is needed (Vitule et al. 2012; Vitule and Pelicice 2023). Science has been clear about the risks posed by invasive organisms and the role played by humans in this process (e.g., Ricciardi 2007; Blanchet et al. 2009; Seebens et al. 2017). Moreover, we cannot overlook the fact that the current catalogue of concepts and management policies related to NNS emerged in particular contexts, i.e., Western, temperate and economically rich regions of the globe, so this potential bias may affect the way in which humans perceive and interact with NNS. All recent reviews and synthesis about invasion science have indicated a demand for more studies in tropical and hyperdiverse regions (e.g., Lövei and Lewinsohn 2012; Frehse et al. 2016), so the current knowledge about NNS may not provide a general pattern applicable to developing hyperdiverse regions (Blanchet et al. 2009). Potential differences in data quality and availability may preclude comparative analyses between developing and developed nations, hindering global strategies to combat invasions. This understanding should stand before every claim or analysis that explore potential benefits of NNS.

Public policies and society are vulnerable to suggestions that offer easy roads to success, which emphasize the need for continuous technical support to evaluate environmental, social and economic risks associated with every initiative and legislation. Society (e.g., legislators, researchers, fishers, public) must have access to the best knowledge available, so negative and positive outcomes can be balanced among stakeholders. This is particularly true for initiatives that involve the use of NNS and the management of natural resources

(e.g., fisheries resources, biodiversity, freshwater), whose loss and degradation impact society as a whole. Potential solutions to address these conflicts require continuous technical assistance and innovative approaches. Tangible results can emerge from this perspective, as observed with the recent initiative to revoke Law 1626, declared harmful after some technical analyses and collaborative support between authorities and scientists (https://mppr.mp.br/Noticia/Municipio-de-Missal-acata-recomendacao-do-MPPR-e-envia-projeto-de-lei-Camara-local-para)—which had the engagement of some authors of this paper. Some promising avenues include increased collaboration and cooperation among stakeholders and scientists, the valuation of indigenous and traditional groups, participatory monitoring and research, and more education and research about NNS (Azevedo-Santos et al. 2015; Maasri et al. 2022). In view of the current situation, where positive views about NNS may continue to inspire policies and social movements that promote the use and protection of invasive organisms, especially in megadiverse countries that struggle against several social issues, we recommend caution and a more sober view about the use and value of NNS.

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Author contributions FMP and JRSV conceived the idea of the article, which was then debated with all authors. All authors contributed with data collection (bills and laws) and literature search. ECG conducted data analyses (Fig. 2). The first draft of the manuscript was written by FMP, and all authors commented on previous versions and developed the document. All authors read and approved the final manuscript.

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Declarations

Conflict of interest There is no conflict of interest to declare.

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