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An overview of fish stocking in Brazil

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Fish stocking is a common management strategy in Brazil, yet no assessment has examined its real extent and features. The present work investigated fish stocking practices in Brazil between 2010 and 2019 to characterize propagule pressure, species composition, the use of non-native species, geographical and temporal trends, environment types, and responsible agencies. Based on information disseminated on the internet, the study detected 1,155 stocking events (*ca*. 115 events/year). In total, *ca*. 56.4 million fish were stocked, with an average of *ca*. 90 thousand fish/event. We found events in all Brazilian regions involving 436 municipalities and 21 states. Most events occurred in the Northeast region (66.3%), which received alone *ca*. 41 million fish. Reservoirs were the primary target environment, and the public sector conducted most events. Fish stocking involved 63 taxa, including 14 non-native taxa and three hybrids. Considering the events that informed composition, 62.4% released non-native species, which summed 19.7 million fish. These results provide a broad overview of fish stocking practices in Brazil, and reveal that this action is widely disseminated. Its frequent use, associated with the lack of proper criteria and the illegal stocking of non-native species, raise concerns about technical aspects, outcomes, and potential environmental impacts.

Keywords: Fishery, Fishing stocks, Impact, Management, Non-native species.

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A estocagem de peixes é uma estratégia de manejo comum no Brasil, mas nenhum estudo investigou sua real extensão e características. O presente trabalho investigou práticas de estocagem de peixes realizadas no Brasil entre 2010 e 2019, para caracterizar a pressão de propágulos, composição de espécies, participação de espécies não-nativas, variação espaço-temporal, ambientes e órgãos responsáveis. Com base em informações divulgadas na internet, o estudo detectou 1155 eventos de estocagem (*ca*. 115 eventos/ano). No total, *ca*. 56,4 milhões de peixes foram liberados, com média de *ca*. 90 mil peixes/evento. Encontramos eventos em todas as regiões brasileiras, envolvendo 436 municípios e 21 estados. A região nordeste somou a maioria dos casos (66,3%), e sozinha recebeu cerca de 41 milhões de peixes. Os reservatórios foram o principal ambiente alvo, sendo o setor público o principal responsável pelas ações. A estocagem de peixes envolveu 63 táxons, incluindo 14 táxons não-nativos e três híbridos. Considerando os eventos que informaram a composição das espécies, 62,4% liberaram espécies não-nativas, que somaram 19,7 milhões de peixes. Estes resultados fornecem um amplo panorama das práticas de estocagem de peixes no Brasil, e revelam que essa ação de manejo é amplamente disseminada. Seu uso frequente, associado com a falta de critérios apropriados e a soltura ilegal de espécies não-nativas, suscita preocupações quanto a aspectos técnicos, resultados, e potenciais impactos ambientais.

Palavras-chave: Espécie não-nativa, Estoque pesqueiro, Impacto, Manejo, Pesca.

INTRODUCTION

Fish stocking is a common management action used worldwide. Its basic principle consists in releasing fish in the environment with the objective of enhancing, recovering or conserving fish populations, fishery stocks, and biodiversity in natural and anthropic ecosystems (Cowx, 1999). When based on technical information and scientific criteria, it can achieve positive results, contributing with nature conservation and the maintenance of natural resources (Blankenship, Leber, 1995). Desirable outcomes have been recorded in some specific situations, which include stock enhancement (Holmlund, Hammer, 2004) and ecosystem management (Skov *et al*., 2002). However, its uncritical and trivial use can generate multiple negative consequences and unintended results, leading to the loss of economic resources, efforts, and opportunity, with social and economic implications (Agostinho *et al*., 2010). The incorrect justification and practice of fish stocking can threaten native biodiversity and ecosystems, compromising management programs and conservation initiatives, as it may enhance competition, predation, genetic introgression, inbreeding, the introduction of non-native species and pathogens, contamination, and habitat loss (*e.g*., Spencer *et al*., 1991; Holmlund, Hammer, 2004; Agostinho *et al*., 2007; Araki *et al*., 2007; Johnson *et al*., 2009; Vitule *et al*., 2009; Terui *et al*., 2023). Due to its popularity, feasibility, and lack of technical criteria, fish stocking has paradoxically contributed to erode wild stocks (Eby *et al*., 2006; Johnson *et al*., 2009; Agostinho *et al*., 2010).

In the Neotropical region, home to the greatest fish diversity on the planet (> 6,000 freshwater species; Albert *et al*., 2020), fish stocking is very popular, conducted by authorities and the public (Pelicice *et al*., 2017). In Brazil, the first initiatives took place during the first half of the twentieth century (Gurgel, Fernando, 1994), but it soon became a regular management action. Millions of native and non-native fish have been released in natural and artificial environments, with the objective of recovering stocks and mitigating human impacts, particularly river damming (Agostinho *et al*., 2007). The expansion of human activities and the increasing degradation of ecosystems, with negative effects on fish diversity and fishery stocks (*e.g*., Pelicice *et al*., 2017; Loures, Pompeu, 2018; D'avilla *et al*., 2021), have stimulated the use of fish stocking to compensate or mitigate losses (Agostinho *et al*., 2016). However, several inadequacies have characterized fish stoking in Brazil, marked by the lack of technical support, assessments, clear goals, protocols, and monitoring (Agostinho *et al*., 2010). The outcomes of fish stocking have been highly controversial, considering that they did not result in the recovery of native fish stocks in degraded environments, while several non-native species have been introduced and spread (Britton, Orsi, 2012; Ortega *et al*., 2015; Bueno *et al*., 2021). Intensive fish stocking in some basins (*e.g*., Paraná River Basin) resulted in no tangible benefit for fisheries and native populations, particularly migratory fishes, which have declined progressively or even disappeared from many rivers, reservoirs, and regions (AES Tietê, 2007; Agostinho *et al*., 2010; Pelicice *et al*., 2018; Loures, Pompeu, 2018; Smith *et al*., 2018).

Although fish stocking has been widely criticized (Spencer *et al*., 1991; Eby *et al*., 2006; Johnson *et al*., 2009; Agostinho *et al*., 2010), this action continues to be common in Brazil – with strong popular and political support. No study, however, has investigated basic characteristics of this activity, such as stocking effort, geographical extent, and target species. In this sense, the present work investigated stocking practices conducted in inland waters of Brazil, based on information collected from websites published on the internet between 2010 and 2019. The study conducted a systematic search to investigate propagule pressure (number of events and fish released), species composition, the contribution of non-native species, temporal and geographic variation, target environments, and the main responsible agencies. This work is the first overview of fish stocking in Brazil, and the information generated is essential to characterize the activity and guide managers towards better practices.

MATERIAL AND METHODS

Data collection. There is no official census of fish stocking carried out in Brazil, as there is no management system responsible for planning and recording events. A few individual fish stocking actions can be found in technical documents (*e.g*., Agostinho *et al*., 2007), especially if they have been required by environmental agencies. The vast majority, however, has been conducted independently by multiple agents without planning, registration or documentation. Official information is largely incomplete, fragmented, difficult to access (gray literature), or nonexistent. On the other hand, fish stocking events usually receive public exposition and media coverage, as they have popular appeal and are conducted during celebration days or public events. Due to its popularity and common political use, it is easy to find news about these events, which may constitute a relevant source of information. Based on this context, this research scanned websites published on the internet to collect data about fish stocking conducted in Brazil.

Searches were conducted on the Google platform (www.google.com.br/) using keywords in Portuguese that refer to fish stocking: 'peixamento', 'soltura de peixes', 'estocagem' and 'repovoamento'. We searched the web with the following string: "peixamento OR soltura de peixes OR estocagem OR repovoamento". All resulting pages were searched for websites reporting fish stocking events in Brazil published between 1st January 2010 and 31 December 2019, which included various sources, such as blogs, official agencies, private and public companies, and the press. Websites reporting fish stocking events in Brazil were selected for examination and data collection. The survey was carried out between April and June 2023, conducted separately for each year (2010 to 2019). We decided not to include 2020 and subsequent years in our survey to avoid the effects of the Covid pandemic.

Every website that reported fish stocking events in Brazil was checked, and the following information was collected: (i) Agent: name of the responsible agent, and its level of operation (local, state or federal); (ii) Locality: municipality, state and region where the action took place; (iii) Date: date of publication; (iv) Status: if the event had been conducted or planned; (v) Date of the event: date on which the event occurred; (vi) Quantity: the number of fish released; (vii) Taxa: name of the taxa released; (viii) Environment: environment where the stocking occurred; (ix) Electronic source: address of the website where the information was collected.

The responsible agent had three levels: private, public or public-private sectors. Region considered: North, Northeast, Midwest, Southeast and South Brazil. Environments mentioned in the website were grouped into three categories: River = lotic environments, such as creeks, streams, and rivers; Lake = natural lentic environments, such as floodplain lakes and wetlands; Reservoir = artificial lentic environments, such as small ponds (locally known as 'açudes'), reservoirs, and impoundments.

The scientific or popular names of the fish species were recorded as mentioned in the original source; later, synonyms were combined. The probable scientific name (species or genus) was appointed to popular names, considering the region and the hydrographic basin where the action took place. The list of taxa was organized taxonomically following Fricke *et al.* (2020). Non-native taxa were assigned considering the release site, based on Attayde *et al*. (2011), Graça, Pavanelli (2007), Bueno *et al*. (2021), and D'avilla *et al*. (2021). The species were also classified according to the reproduction mode: non-migratory (NM) and long-distance migratory (LDM) (following Carolsfeld *et al*., 2003 and chapters therein).

Each stocking event was considered an independent event (sampling unit), and all available information was recorded. When different websites reported the same event, the information was combined; yet, they were checked for complimentary information. Multiple stocking events reported in the same website were separated and considered as independent events.

Data analysis. Three response variables associated with propagule pressure were calculated (*sensu* Lockwood *et al*., 2005): one associated with propagule number (number of stocking events), and two associated with propagule size (total number of fish stocked and number of fish/event). To provide an overview of fish stocking in Brazil, we described variations and trends in propagule pressure considering years, regions, environments and responsible agents. We also investigated taxa composition in each stocking event, the contribution of native and non-native taxa for the propagule pressure, and the most frequent taxa stocked in each region.

Events were plotted on a map to report their occurrence across Brazil, considering the number of events within municipalities. We obtained the shapefile of Brazilian states and municipalities, version 2022, through the Brazilian Institute of Geography and Statistics (IBGE, 2023). The geospatial procedures and map building were performed in the QGIS software, v. 3.10 (QGIS Development Team, 2023).

RESULTS

The search resulted in 19,503 websites published between 2010 and 2019 (Tab. **S1**), of which 573 (2.9%) reported information about fish stocking events conducted in Brazil (Tab. **S2**). These websites provided information about 1,115 fish stocking events (Fig. 1); 77% of the events had been conducted, and 23% were planned.

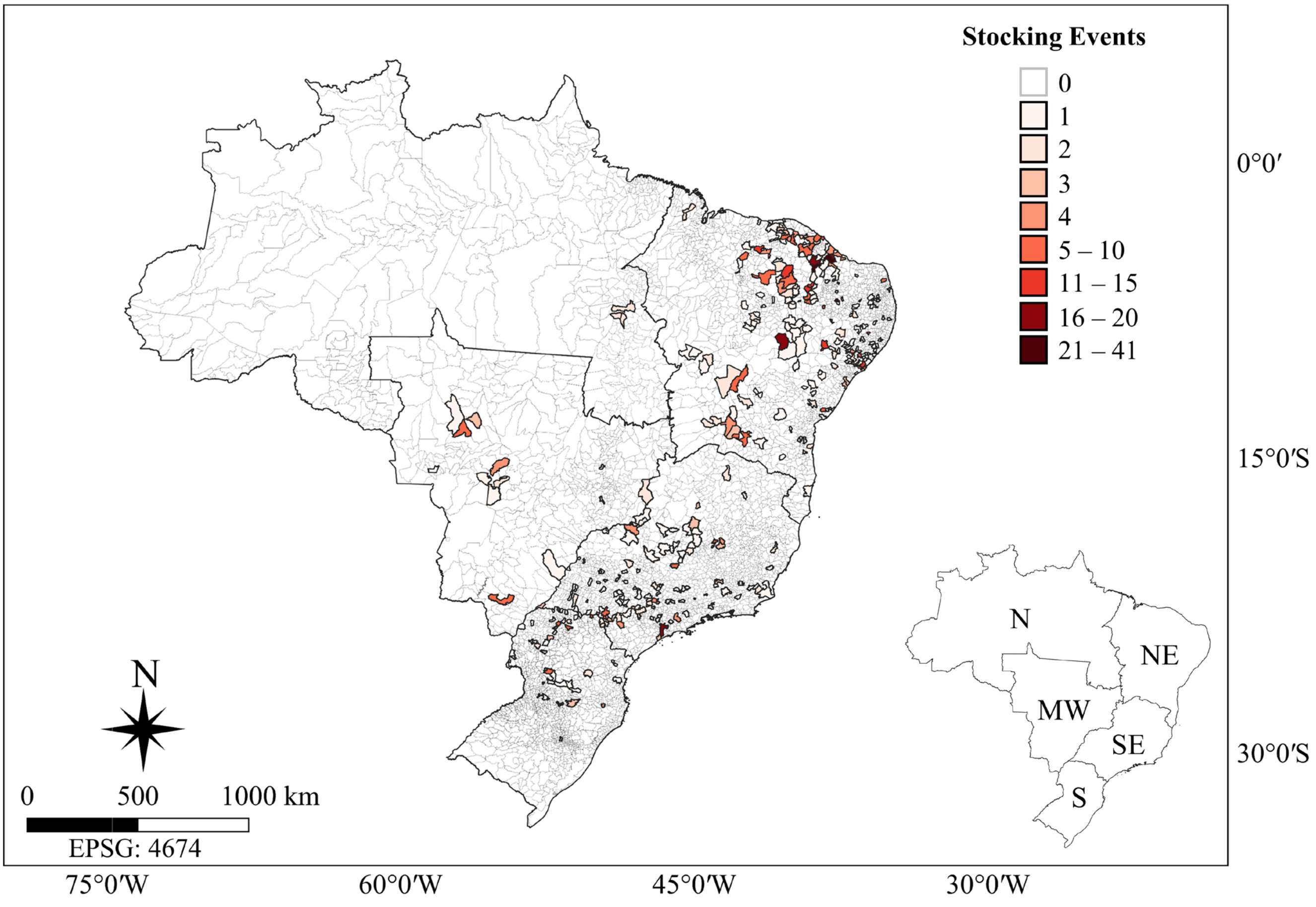

FIGURE 1 | Fish stocking events in Brazil, reporting the number of events recorded in each municipality between 2010 and 2019.

Stocking events were regularly observed over the years; however, we recorded more events in the last three years (2017 to 2019), exceeding 170 events/year (Fig. 2A). Considering the entire period, we recorded an average of 115 events/year. The number of stocked fish was reported for 54.3% of the events, and involved the release of approximately 56.4 million fish. The total number of fish released varied over time, with higher values between 2016 and 2018 (Fig. 2B). The average number of fish/event was more stable over the years, with higher values in 2011 and 2016 (Fig. 2C). Considering the whole period, we calculated an average of 89,863 fish/event.

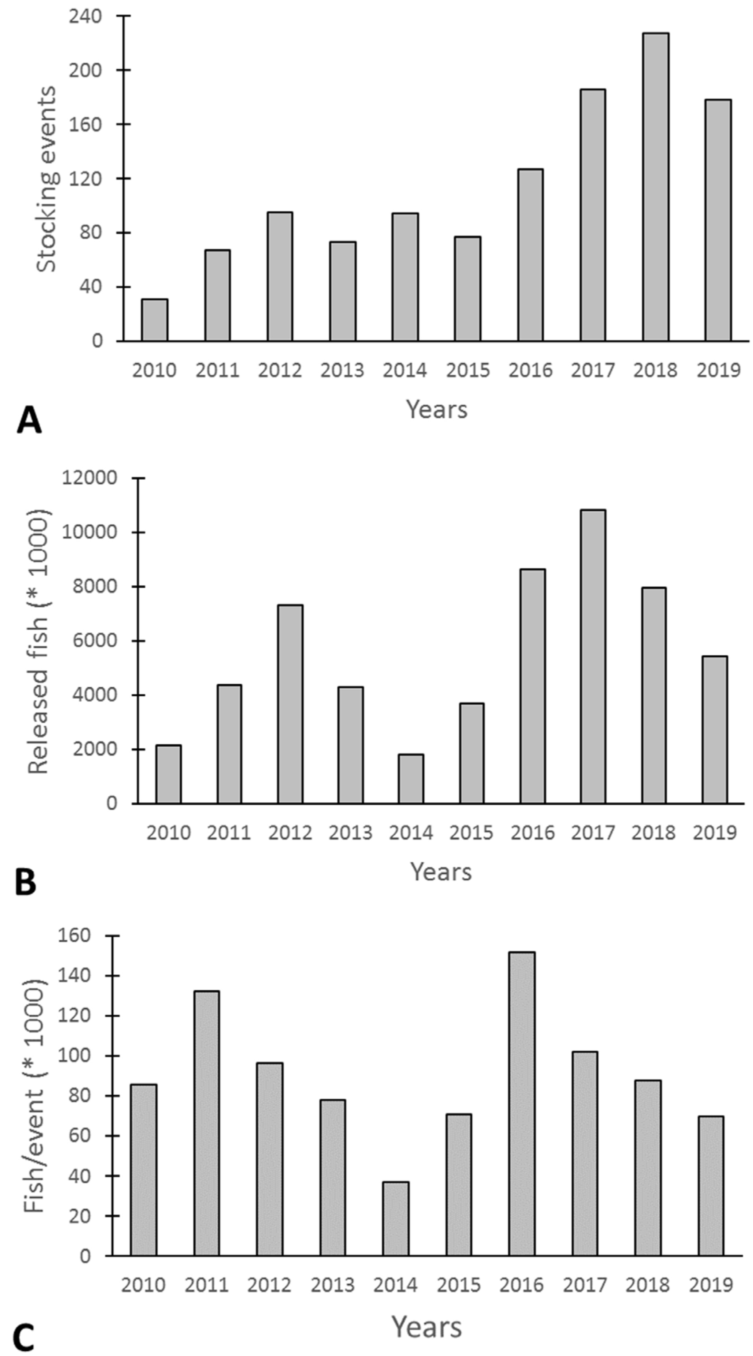

FIGURE 2 | Fish stocking effort (propagule size and number) in Brazil between 2010 and 2019, measured as the number of stocking events (**A**), the total number of fish released (**B**), and the average number of fish/event (**C**).

We found fish stocking events in all regions of the country, involving 436 municipalities and 21 states (Fig. 1). The Northeast region summed most of the records (66.3%), followed by the Southeast region (20.8%) (Fig. 3A). The Northeast region also accounted for most of the fish released, with *ca*. 41 million fish (73.4%; Fig. 3B). The average number of fish/event varied less among regions (Fig. 3C).

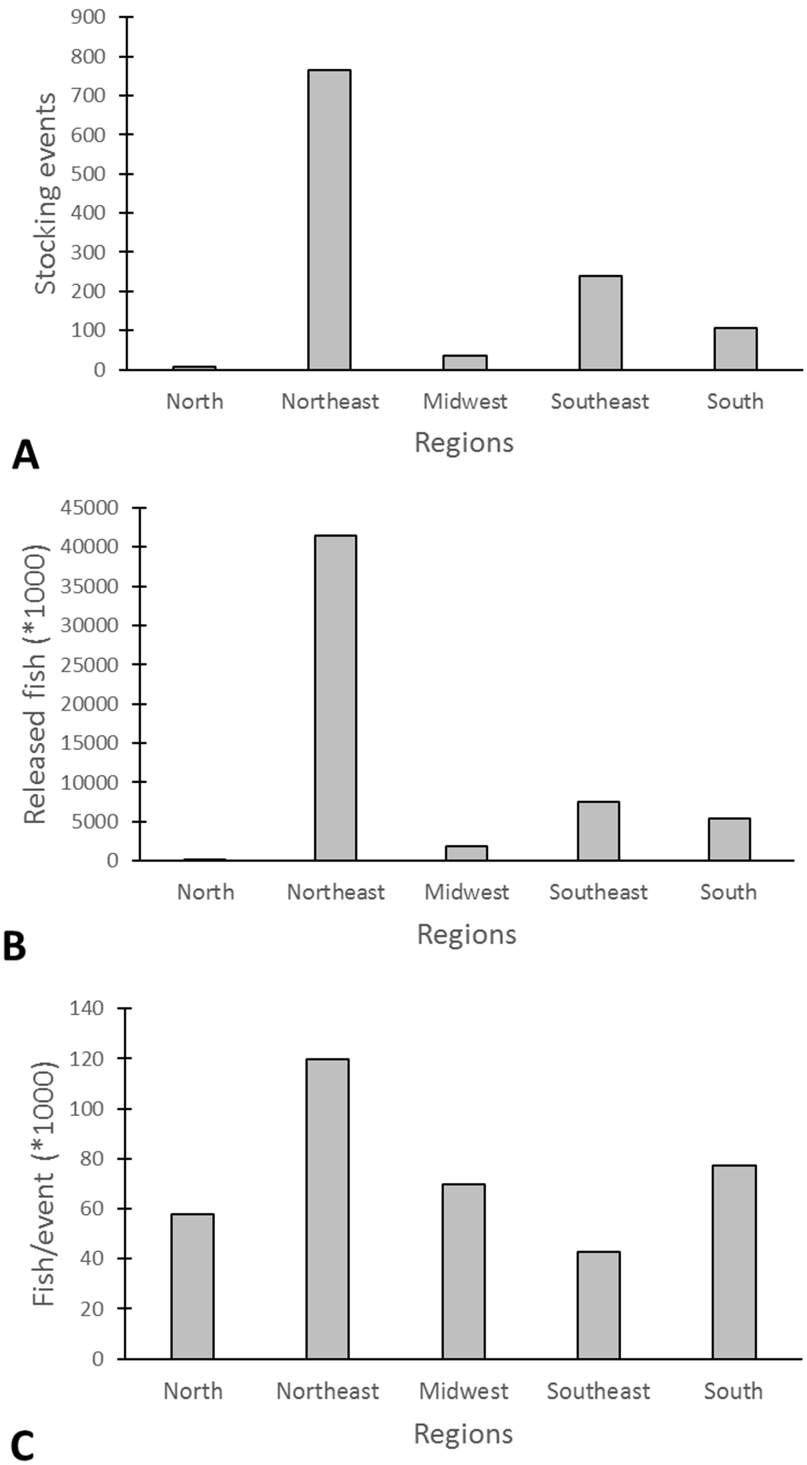

FIGURE 3 | Fish stocking effort (propagule size and number) in different regions of Brazil, measured as the number of stocking events (**A**), the total number of fish released (**B**), and the average number of fish/event (**C**).

Most events occurred in Reservoir environments (Tab. 1), accounting for 640 events (56.4%). Almost all fish were released in Reservoir (47.1%) and River (44.8%) environments, but the average number of fish/event was similar among environment types. The public sector alone conducted 938 events (81.2%), and released 80.1% of all fish (Tab. 1). The average number of fish/event was more similar among sectors (Tab. 1). State-level public agents conducted most events (43.5%, *e.g.*, state agencies and secretaries), followed by local (22.9%, *e.g.*, prefectures) and federal-level agents (20.9%, *e.g.*, national agencies, companies, and ministries). Private agents (*e.g.*, hydropower companies, fishing clubs) were basically local-level, and summed 11.9% of all stocking events (Tab. **S2**).

Of the 1,155 events recorded, 763 (66.1%) provided information about taxa composition. Based on the common and scientific names provided, we compiled the list of fish taxa, which totaled 63 taxa belonging to 8 orders and 16 families (Tab. **S3**); two taxa could not be identified and classified. The composition included native (S = 49) and non-native taxa (S = 14, considering the release site), in addition to three hybrids. Among native taxa, most were sedentary fish (35 taxa), but many migratory fish were also released (26 taxa). Among non-native taxa, we recorded fish from other continents, such as carps (*Cyprinus carpio* Linnaeus, 1758, *Hypophthalmichthys nobilis* (Richardson, 1845), *Ctenopharyngodon idella* (Valenciennes, 1844)) and tilapia (*Oreochromis niloticus* (Linnaeus, 1758)), and several Neotropical taxa stocked in sites outside their native distribution, such as tambaqui *Colossoma macropomum* (Cuvier, 1816), piauçu *Megaleporinus macrocephalus* (Garavello & Britski, 1988), and the spotted sorubim *Pseudoplatystoma corruscans* (Spix & Agassiz, 1829).

The number of stocked taxa varied among regions (Tab. **S3**). Higher values were observed in the Southeast region (49 taxa, 8 of which are non-native), followed by the Northeast (24 taxa, 9 non-native), South (23 taxa, 8 non-native), Midwest (15 taxa, 4 non-native) and North (6 taxa, 3 non-native). Considering the events that informed taxa composition, 473 (62.4%) involved the release of non-native species, summing 19.7 million fish (46.3% of all fish released) – being 98.5% of the events conducted by the public sector. The contribution of non-native species varied over the years (Fig. 4), summing between *ca*. 15 and 70% of all fish stocked annually. The most frequent taxa varied among regions (Tab. 2), but some were widely stocked, such as Serrasalmidae fish (*e.g.*, pacu, tambacu, *Colossoma macropomum*), Prochilodontidae (*e.g.*, *Prochilodus lineatus* (Valenciennes, 1837), curimatãs), Anostomidae (piau, piauçu), tilapias, lambaris, and carps. Non-native taxa were among the most stocked in all regions, particularly in the North and Northeast.

TABLE 1 | Stocking effort (propagule size and number) among different environment types and agent sectors, measured as the number of stocking events, the total number of fish released, and the average number of fish/event.

Variable	Events	Fish released	Fish/event
Environment			
River	324	24,662,564	120,080.4
Lake	171	4,507,310	338,618.6
Reservoir	640	25,938,500	71,010.3
Agent			
Public	938	45,207,144	94,378.2
Private	148	8,344,100	80,231.7
Private/Public	69	2,883,130	73,926.4

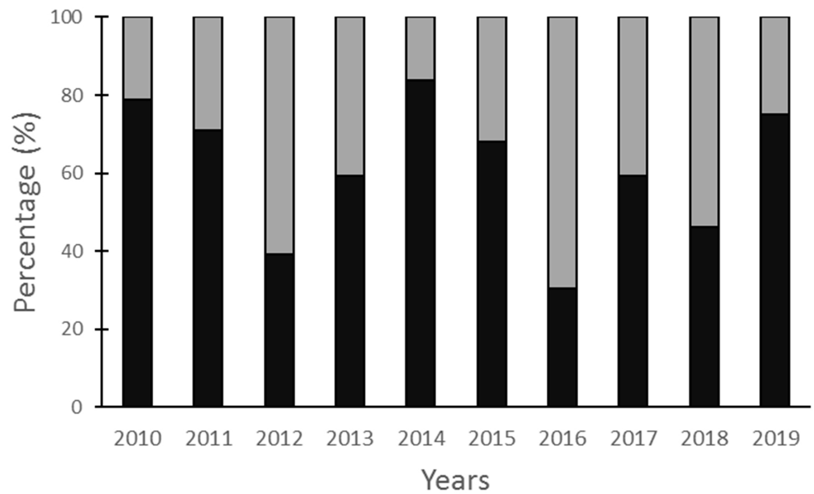

FIGURE 4 | Proportion of native (black) and non-native fish (gray) stocked over the years, calculated from the events that informed taxa composition and the number of fish released.

TABLE 2 | The most frequent taxa stocked in each region, present in more than 10% of stocking events. The complete taxa list and more information about names and synonyms is provided in Tab. S3. X = taxa stocked in the region, but with frequency < 10 % of events. Gray shading depicts non-native taxa in the region.

Name reported	Scientific name	North	Northeast	Mid-West	Southeast	South
Caranha	*Piaractus brachypomus*	50				
Cyprinus carpio			**17.9**	**x**	**x**	**x**
Carpa capim	*Ctenopharyngodon idella*				**x**	**10.7**
Colossoma macropomum		25	**19.1**	**19.0**	**x**	
Curimatã	*Prochilodus* spp.		18.5			
Lambari				x	17.1	38.7
Matrinxã	*Brycon* spp.		x	19.0	11.6	
Pacu				42.9	21.3	34.7
Piapara	*Megaleporinus obtusidens*				x	14.7
Piaractus mesopotamicus				14.3	x	
Piau			x	38.1	x	16.0
Piauçu	*Megaleporinus macrocephalus*	**25**	**x**		**x**	**17.3**
Piracanjuba	*Brycon orbygnianus*			x	15.2	x
Pirapitinga	*Brycon* spp.			14.3	x	
Piraputanga	*Brycon hilarii*			14.3	x	x
Prochilodus lineatus				23.8	42.7	34.7
Pseudoplatystoma corruscans		**50**	**x**	23.8	x	x
Rhamdia quelen					x	42.7
Salminus brasiliensis					10.4	x
Surubim	*Pseudoplatystoma* spp.	25	x		x	x
Surubim do Iguaçu	*Steindachneridion melanodermatum*					14.7
Tambacu	hybrid (*Piaractus* spp. x *C. macropomum*)	**25**	**x**		**x**	**x**
Tilápia			**62.9**	**x**	**12.8**	**x**
Tilapia do Nilo	*Oreochromis niloticus*		**13.1**			**x**

DISCUSSION

This is the first overview of fish stocking in Brazil, and the results confirmed that this management action is widespread in the country. We recorded events in all regions, including different river basins and environments. This practice has employed substantial effort between 2010 and 2019, considering the total number of events (1,155 – propagule size) and fish released (*ca*. 56.4 million – propagule number), involving different native and non-native species. However, the real number of events is underestimated, considering that our data is based on internet sources, representing, therefore, only the publicized events. One should consider the existence of unreported events, the eventual removal of content, and the dissemination of imprecise information. The number of stocked fish is also underestimated, considering that only 54.3% of the events provided this information; moreover, quantitative data are probably imprecise as they are rough estimates. In spite of these limitations, results support previous claims (*i.e*., Agostinho *et al*., 2010) that fish stocking has been taken as a trivial management action in Brazil. This action has been motivated primarily by common-sense judgements, *e.g*., lack of fish in the environment demands the release of fish to enhance catches and improve fisheries (Agostinho *et al*., 2007). The loss of fishery resources has also encouraged authorities and the public to stock fish in different environments (Agostinho *et al*., 2010; Pelicice *et al*., 2017). As a result, fish stocking has become a main management action during the twentieth century, and our results show that this trend is persistent.

The study recorded fish stocking in all regions of the country, although most events occurred in the semi-arid Northeast (66.3%), especially in the Middle and Lower São Francisco River and in several small Atlantic drainages. This region has supported official stocking programs for decades, carried out by many public institutions such as the Departamento Nacional de Obras Contra a Seca (DNOCS), Companhia do Desenvolvimento do Vale do São Francisco (CODEVASF), Companhia Hidrelétrica do São Francisco (CHESF), SUDEPE (Superintendência de Desenvolvimento da Pesca), in addition to local authorities and other official agencies. There are thousands of small artificial ponds in the semi-arid region (locally known as "açudes"), originally built for water storage, but which have acquired relevance for fishing and aquaculture (Gurgel, 1990; Valenti *et al*., 2021). The Brazilian semi-arid is characterized by restricted social and economic opportunities and development. In this region, the construction of reservoirs and ponds to provide drinking water for man, livestock and agriculture has been associated with the promotion of small-scale fisheries, which is considered a strategy to alleviate poverty. The history of fish stocking in these small water bodies dates back to the beginning of the twentieth century, when several non-native fish were successfully introduced (Attayde *et al*., 2011). This initial experience was seminal and paved the way for fish stocking in Brazil. Considered a model of fish management, this experience was exported to other regions. It was the case of hydroelectric companies and public fishery agencies in the Southeast and South, which have conducted fish stocking in large reservoirs and other waterbodies in the Upper Paraná (*e.g*., Paranapanema, Tietê, Grande and Paranaíba), Paraíba do Sul, and São Francisco basins. One important finding was the virtual absence of stocking activities in the North region, probably because it still preserves large fish stocks in the vast Amazon system. The current degradation associated with hydropower and agriculture expansion is changing this scenario, and fish stocking may become increasingly more common in some impacted basins, such as the Tocantins River (Pelicice *et al*., 2021).

A remarkable aspect has been the use of non-native species or hybrids, a trend observed in all regions of the country. We recorded at least 14 non-native taxa (plus three hybrids), which totaled *ca*. 19.7 million fish (46.3% of all fish stocked, considering the events that informed fish composition). Some taxa were among the most frequently stocked in some regions, such as tilapias and tambaqui (*C. macropomum*). It should be noted that these numbers are underestimated, as only 66.1% of events provided information on fish composition. Moreover, illegal fish stocking is a growing trend in the country (Bueno *et al*., 2021; Franco *et al*., 2022), which remains unreported, as evidenced by the lack of some widely stocked species in our dataset, *e.g*., yellow peacock-basses *Cichla monoculus* Agassiz, 1831 and *C. ocellaris* Bloch & Schneider, 1801, black-bass *Micropterus salmoides* (Lacepède, 1802), and rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792). The stocking of non-native fish has been motivated by the development of fisheries and aquaculture, responsible for disseminating exotic organisms in different ecosystems around the world (Eby *et al*., 2006; Johnson *et al*., 2009; Vitule *et al*., 2009). In Brazil, official and illegal actions introduced several fish species (Britton, Orsi, 2012; Ortega *et al*., 2015; Vitule *et al*., 2019; Bueno *et al*., 2021), including carps, tilapias and several Neotropical species (*e.g*., Serrasalminae, *Cichla*, hybrids). Our results showed that stocking non-native fish is still common (in spite of its prohibition in Brazil), and has involved a variable propagule size and number over the years, being an initiative of the public sector. The release of tilapia deserves attention, as this fish has been intensely stocked in different regions, especially in the Northeast, where environmental impacts have been reported (Attayde *et al*., 2011). The stocking of non-native fish entails many risks associated with the dissemination of invasive organisms, which impact aquatic ecosystems, biodiversity, and the generation of ecosystem services – as recorded in Brazil and elsewhere (Spencer *et al*., 1991; Canonico *et al*., 2005; Cucherousset, Olden, 2012; Franco *et al*., 2021; Leal *et al*., 2021). This scenario raises important concerns, considering that the Neotropical region is a hotspot of freshwater fish diversity (Toussaint *et al*., 2016a; Albert *et al*., 2020), implying that the stocking of non-native fishes has strong potential to erode fish biodiversity and induce biotic homogenization at local, regional and global scales (Pelicice *et al*., 2017; Toussaint *et al*., 2018; Bezerra *et al*., 2019).

Our results indicate that fish stocking has been conducted uncritically in Brazil. In fact, it is widely disseminated across the country, with no coordination or supervision, and extensively based on the illegal release of non-native species. In principle, fish stocking practices in Brazil must be authorized by federal or state agencies, but this regulation has not been sufficient to control its use. The regular involvement of public development agencies (at local, municipal and federal levels) has probably facilitated its use. The trivialization of the action has been criticized previously (Agostinho *et al*., 2007, 2010; Pelicice *et al*., 2017), as fish stocking has been taken as a panacea in fishery management and conservation, disregarding goals, planning, protocols, and monitoring. The decision to conduct fish stocking has been based on questionable demands (*e.g*., opinions, common sense, equivocal legislation) and interests (*e.g*., electoral, commercial). The action has been accessible, especially because it has been concerned only with fish release (usually fingerlings), with no consideration about environmental, biological, demographic, or genetic constraints, disregarding also differences and peculiarities among regions, biota, and ecosystems (Agostinho *et al*., 2007). In this scenario, the meaning and outcome of fish stocking have been widely questioned, especially because (i) successful cases involve the introduction of non-native fish (*e.g*., Attayde *et al*., 2011; Novaes, Carvalho, 2013; Garcia *et al*., 2018; Bezerra *et al*., 2019), and (ii) the regular and substantial stocking effort in reservoirs located in the South and Southeast has never resulted in positive effects for commercial and artisanal fisheries (AES Tietê, 2007; Agostinho *et al*., 2010). The failure of fish stocking can also be assessed by the current conservation status of fish diversity and fisheries, which have declined consistently in basins subjected to severe environmental degradation, including the collapse of migratory fishes (Loures, Pompeu, 2018; Pelicice *et al*., 2018; Smith *et al*., 2018; D'avilla *et al*., 2021) – a main target of fish stocking initiatives. This scenario is not restricted to Brazil, as fish stocking has been increasingly used in the United States (Halverson, 2008), for example, and adverse effects or lack of positive outcomes have been recorded elsewhere (*e.g*., Spencer *et al*., 1991; Araki *et al*., 2007; Diana, Whal, 2008; Johnson *et al*., 2009; Radinger *et al*., 2023; Terui *et al*., 2023).

Contrasting with this scenario, fish stocking practices must meet stringent criteria to play some positive role in fisheries management and stock enhancement. The scientific literature indicates essential steps that must precede and guide every action (Blankenship, Leber, 1995; Cowx, 1999; Agostinho *et al*., 2010), which include previous assessments, clear and measurable goals, strict protocols, decision trees, post-stocking evaluation, in addition to several technical issues. Good practices take into account detailed information about wild populations (*e.g*., the target species and its population size), the environment (*e.g*., carrying capacity, stressors, habitats, release site, season), and the stocked fish (fish size, genetic diversity) (Blankenship, Leber, 1995). Progress in stocking practices have been recorded in countries with a long history of fisheries management, such as USA and Australia (Halverson, 2008; Hunt, Jones, 2018), indicating that stocking practices can improve when based on technical information and continuous learning. Therefore, environmental agencies and authorities must revise these actions in Brazil, restricting its application to specific situations motivated by definable problems, clear objectives, and sufficient information. Equally, authorities must improve inspection and regulation across the country, in order to prevent misguided actions, unnecessary stocking, and the release of non-native species. It is worth noting that the public sector alone (at local, state and federal levels) was responsible for 81% of the events, often involving the participation of environmental agencies. A more stringent licensing system could coordinate stocking activities, controlling authorizations and collecting standardized data for each event (*e.g*., locality, date, species, number, and fish size). We must emphasize that the present overview is based on inaccurate and incomplete data (websites) because there is no official effort to collect, standardize, and systematize information. Underreported cases, species misidentifications, imprecise numbers, and the lack of geographical information add potential bias to the results. A better understanding of fish stocking in Brazil will require improvements in management, documentation, and data availability. We must emphasize that, due to the lack of data, Brazilian authorities have learned almost nothing from over a century of fish stocking practices in the country.

Given the current degradation of aquatic ecosystems in Brazil and South America (Reis *et al*., 2016; Pelicice *et al*., 2017), it is expected that fish stocking will continue to be a main management strategy adopted by authorities and the public. However, it is unrealistic to expect that fish stocking alone can solve or alleviate the problem. This practice is very complex, and every action must be based on solid justifications, technical information, and clear goals. Moreover, the uncritical use of fish stocking entails several social and environmental risks that may aggravate the current status of fish diversity and fishery stocks in the country. The equivocal release of either native or non-native species has triggered processes associated with biotic competition, predation, genetic introgression, habitat modification, contamination, and species invasions. Therefore, fish stocking needs better regulation in the country, and other management and conservation alternatives should be considered (Radinger *et al*., 2023), especially the restoration of river connectivity, flow regimes and water quality, the protection of riparian vegetation, and the control of invasive species.

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Yasmin Martins Pelissoli: Data curation, Formal analysis, Methodology, Writing-original draft, Writing-review and editing.

Angelo Antonio Agostinho: Formal analysis, Investigation, Validation, Writing-original draft, Writing-review and editing.

Marcelo Henrique Schmitz: Formal analysis, Software, Validation, Writing-review and editing.

Fernando Mayer Pelicice: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing-original draft, Writing-review and editing.

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The author declares no competing interests.

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