Marine or freshwater: hobbyists' preferences and its role in ornamental fish conservation in Brazil

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Background. The use of ornamental fish as pets has important implications for the conservation of the species used in fishkeeping, particularly in relation to overexploitation. Understanding aquarists' relationship with the hobby can provide important information for assessing the potential impacts of the activity. In this work, we analyzed the profile of Brazilian aquarists and evaluated their preferences and their consequences from the conservationist point of view.

Methods. The information was obtained by applying questionnaires to 906 aquarists participating in fishkeeping groups in a social network. The applied questionnaire contained questions about the species of fish kept (freshwater and marine), techniques used, soeio-economic aspects, and associated conservation perspectives.

Results. Most aquarists were young men (20-40 years old), with higher education and monthly income above US$530.00. Participants predominantly kept freshwater fish (86%), but marine fish only (5%) or both marine and freshwater hobbyists (9%) were also recorded. A total of 523 species of ornamental fish were kept by hobbyists, most of which comprised freshwater (76% of the total) and exotic species (73%). About a third of the species recorded were under national trade restrictions. Marine aquariums require a greater financial investment than freshwater aquariums and are also almost entirely based on exotic species. The aesthetic factor is the main motivation associated with practicing this hobby, being color and behavior key factors in choosing fish. A total of 14% of aquarists have already released fish into the wild, highlighting concerns about potential biological invasions. We urge the need to enforce regulations towards restricting aquarists' access to threatened and potentially invasive species, as well as measures aimed at informing and raising aquarists' awareness of conservation measures related to the hobby.

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Abstract

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Keywords: Social media; marine fish; freshwater fish; invasive species, trade regulations.

Introduction

The ornamental use of animals, whether for entertainment or company, is currently ~~considered~~ one of the main hobbies in the world (Alves & Rocha, 2018; Alves et al., 2019), generating a global trade of about US$15-30 billion (Evers et al., 2019). The practice of raising fish for ornamental purposes, known as fishkeeping, has been practiced for at least a thousand years (Stern et al., 2016; Walster et al., 2015) and has become a segment of the pet market which has continuously grown since 1970 at an annual rate of 14% (Evers et al., 2019).

Fish ~~currently~~ ranks third ~~among~~ the most popular pets in the world (Kumar et al., 2015; Pate et al., 2019; Reynoso et al., 2012). Fishkeeping is also a very popular hobby in Brazil, with

an estimated 19.1 million ornamental fish being kept as pets in 2018 (ABINPET, 2019). Considering only the domestic online trade, Brazilian fishkeeping involves at least 609 species of marine and freshwater fish (Borges et al., 2021). In addition, Brazil occupies an important place in the world aquarium scene, being one of the main exporters of ornamental fish (Rhyne et al., 2012a), reaching third place in the world market in the sector (ABINPET, 2015).

Consumer preferences are considered the major drivers of the ornamental market (Hisnley et al., 2015; Sung & Fong, 2018). Aquarists' preferences, for instance, are linked to species ~~considered~~ rare or threatened, with striking colors, peculiar shapes, and/or behaviors (Borges et al., 2021; Dhar & Ghosh, 2015; Morcom et al., 2016). This applies to both marine and freshwater species, despite a much larger number of freshwater species being used for aquariums (Evers et al., 2019). It is estimated that ~~aquarium~~ worldwide involves more than 5,300 freshwater and 1,802 marine fish species (Raghavan et al., 2013), of which at least 80% are from the tropics (Stern et al., 2016).

Such motivations for fishkeeping raise particular conservation concerns, as several of the species involved in the ornamental trade are ~~threatened and/or~~ vulnerable to overexploitation (Banha et al., 2019; Evers et al., 2019; Sadovy & Vincent, 2002). These concerns are also applied to exotic species (Patoka et al., 2016, 2018), since ~~aquarium~~ is considered an important source of invasive species, either through intentional release (Maceda-Veiga et al., 2019), the unintentional introduction of 'hitchhiking' species (Duggan, 2010; Patoka et al., 2016), or the introduction of disease vectors (Maceda-Veiga et al., 2013; Magalhães & Jacobi, 2013). On the other hand, if fishkeeping is well managed, it can be an ally for biodiversity conservation. In addition to being considered a crucial source of income for several local economies (Evers et al., 2019; Zehev et al., 2015), it can offer a possibility to protect endangered species by ~~encouraging the development of~~ strategies for captive breeding and sustainable trade (Rhyne et al., 2017).

Understanding the trade-offs between hobbyists' preferences and ornamental fish conservation may ~~comprise~~ an invaluable tool for advancing the protection and sustainable use of the exploited species (Hinsley et al., 2015), especially in countries that play an essential role in the trade, such as Brazil. Here, we evaluated the preferences for marine and freshwater ornamental fish species by Brazilian aquarium hobbyists from Facebook groups We assessed Facebook as it comprises one of the most popular online platforms worldwide where users feel comfortable sharing their ideas and experiences about the hobby (Pi et al., 2013) and has been identified as one of the most used in the wild animal trade (Canlas et al., 2017; Haysom, 2018; Sy, 2018). We aimed to: (1) identify the motivations behind hobbyists' choices in keeping fish as pets; (2) describe the hobbyists' profile and their behavior in relation to the hobby and animals; (3) relate their preferences and behaviors to conservation issues; and (4) compare all these aspects between marine and freshwater aquarists.

Materials & Methods

Data collection

Data were gathered through online questionnaires applied to 906 aquarium hobbyists from six Brazilian aquarism groups on the Facebook social network (https://www.facebook.com/), between January and March 2019. For determining the Facebook group to be sampled, we performed searches using the keywords fishkeeping, fish+ornamental, aquarium+ornamental (in Portuguese, aquarismo, peixes+ornamentais, aquário+ornamentais), considering that they bring together people who keep ornamental fish and use the social network to exchange information about the hobby. Our search resulted in 83 groups, of which six were selected for being more active (higher frequency of publications). Then, we individually contacted all profiles (n = 4,630) from those six groups over three months through private messages (Alves et al., 2019), in which the objectives of the study were explained, and the aquarist was invited to answer a semi-structured questionnaire (Albuquerque et al., 2014). Once the invitation was accepted and the person expressed in writing their consent to participate in the research, each aquarist received a new message containing the link that directed them to the online questionnaire. The questionnaire contained closed, open, and mixed questions about socio-economic aspects and the hobby (supplementary material). All questionnaires were applied online using the Google Forms platform tool (https://www.google.com/intl/pt-BR/forms/about/). The study was approved by the Research Ethics Committee of Hospital Universitário Lauro Wanderley (CEP/HULW, authorization # 3.062.563).

The income of the research participants was determined based on the Brazilian minimum monthly wage in force at the time of data collection. These values were converted to US dollars considering the exchange rate for the period in which the data were collected (Brazilian minimum ~~monthly salary~~ in 2019: BR$998 = US$266).

Species were identified based on participants' information and confirming the photographs sent by them. We used the Fishbase database (Froese and Pauly, 2019) and consulted specialists for those species whose identification was problematic. To verify if the recorded species were allowed to be traded for ornamental purposes and their conservation status, we consulted the legislation applied in Brazil during the period covered by this study, as previously described in Borges et al. (2021), and also the Red List of the International Union for the Conservation of Nature (IUCN, 2019), and the list of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES, 2019).

Data analysis

We used descriptive statistics to describe the profile of survey participants and their responses to aquarium-related questions. Percentages were calculated based on the number of citations. Thus, the sum of n may exceed the total number of participants (n = 906) in case of the questions allowed more than one answer option. Chi-Squared tests were used to assess associations between socioeconomic factors (e.g., gender, age, monthly income) and hobby characteristics (e.g., marine-only or freshwater-only aquarists, number of fish kept, experience time in the aquarium hobby, monthly spending on the hobby) ~~($p \leq 0.05$ value was considered significant~~). For analyzes comparing responses from freshwater-only and marine-only aquarists, responses from aquarists who claimed to have both types of aquariums were not considered. We

also used a word cloud analysis to visually evaluate aquarists' perceptions regarding the release of ornamental fish in the wild. This technique makes it possible to identify which words were most frequently cited by the participants (McNaught and Lam, 2010; Barbosa-Filho et al., 2020). All analyzes were performed using the R software ver.3.6.1 program (R Core Team, 2019).

Results

Profile of Brazilian aquarists

Most aquarists were male (88%; n = 795), aged between 20 and 40 years (73%; n = 661). Approximately two-thirds of aquarists (69%; n = 627) had higher education and the monthly income of the majority (78%; n = 744) was over US$530 (equivalent to two Brazilian minimum ~~monthly salaries~~). Aquarists residing in 24 Brazilian states participated in the study, most of them from the southeastern region ~~of the country~~ (51%; n = 468), mainly from the states of São Paulo (40%; n = 308) and Rio de Janeiro (12.8%; n = 116; Fig. 1). Most aquarists had practiced the hobby for less than five years (40%; n = 372) and had mainly acquired experience through internet searches (corresponding to 22% of the sources mentioned; Fig. 2).

Most aquarists prefer to acquire their animals through stores or pet shops (55% of the sources mentioned) and owned freshwater aquariums only (86%; n = 776). We also recorded participants who kept both marine and freshwater aquariums (9%; n = 84).

Animals used in the hobby

The aquarists kept fish belonging to 523 species (93 families), most of them freshwater (76%; n = 400 species). The beauty of aquariums and fish (76%; n = 790) was the main motivation for practicing aquarism (Table 1). Behavior (26%; n = 537;) and aesthetics (22%; n = 441) were key factors in choosing fish for the hobby (Figure 2). Most species were not native to Brazil (73%; n = 293) - half of the freshwater species (50%; n = 203) and more than half of marine species (73%; n = 90). In addition, 33% (n = 131) of the species had their exploitation prohibited in the country (see supplementary material).

Aquarists preferred the following freshwater fish families: Cichlidae (34%), Characidae (12%), and Cyprinidae (11%), especially the following species: *Pterophyllum scalare* (4.1%), *Hypostomus plecostomus* (3.7%) and *Poecilia reticulata* (3.5%), all native to Brazil. The preferred families regarding marine fish were Acanthuridae (28%) and Pomacentridae (28%), with a predilection for the following species: *Amphiprion ocellaris* (18%), *Zebrasoma flavescens* (9%), and *Paracanthurus hepatus* (7%), all exotics. ~~Regarding the conservation status,~~ 39 species were included in threatened categories in the IUCN classification, namely: ten species are listed as "Near Threatened", 14 species as "Vulnerable", eight species as "Endangered", and seven species as "Critically Endangered" (Table 2). In addition, six species were included in the CITES Appendices and five species are included in the Brazilian List of Threatened Species (see supplementary material).

Besides keeping fishes, about a third of aquarists (36%; n = 328) declared having invertebrates, mentioning 66 animals belonging to 14 classes, mainly crustaceans (48%; n = 28) and mollusks (33%; n = 22). Invertebrate maintenance was more common among marine (70%

of marine aquarists) than among freshwater aquarists (30%). The most common invertebrates kept by aquarists were snails of the genus *Pomacea* (23%) and shrimps of the genus *Neocaridina* (16%).

Maintenance of the animals

Most participants claimed to keep between 10 and 50 specimens (64%; n = 675; Table 1), mostly in mixed-species tanks (34%; n = 512; Supplementary material). The number of fish kept by hobbyists was related to income (X^2 = 53.787, *df* = 25, *p* = 0.0007) and with the experience time in the aquarium hobby (X^2 = 45.681, *df* = 20, p = 0.0008). Most participants (52%; n = 475) claimed to spend less than US$20 monthly to maintain the hobby (Table 1). Monthly costs were not related to the number of fish kept by the aquarists (X^2 = 105.74, *df* = 25, *p* = 6.662e-12), but to the habitat type of the animals (marine or freshwater) (X^2 = 63.222, *df* = 10, *p* = 8.858e-10), and aquarists who own marine fish reported higher expenses (Table 1).

Most participants (40%; n = 364) stated that they cleaned ~~the aquariums~~ and performed partial water changes weekly (36%; n = 330) or biweekly (30%; n = 273). Fish illness was reported by 74% of the participants (n = 675), who mentioned 26 types of diseases, the most cited being: ictio (white spots disease; n = 374), diseases caused by fungi (n = 72), and hole in the head (caused by the protozoan *Hexamita intestinalis*; n = 35). The treatments used ~~by the participants~~ were mainly based on exchanging experiences with other aquarists (40%; n = 419; Table 1). ~~The main treatments mentioned were the~~ use of antibiotic ~~products, use of~~ fungicides, and changes in the ~~physical-~~chemical parameters of the aquarium (e.g., temperature, salinity, luminosity; see supplementary material).

When asked about their attitude when they want to dispose of a fish, the most frequent attitude was donation (44%; n = 559). Other attitudes mentioned were exchanges with other aquarists (30%; n = 382), sale (22%; n = 275), released in the wild (2%; n = 30), exchange or return at the store where they purchased the animal (0.2%; n = 3) and use for feeding (0.1%; n = 2).

Collecting and releasing fish in the wild

About 10% (n = 95) of participants collected fish in the wild, mostly freshwater-only aquarists (77%; n = 73). Among those, most had no formal education (X^2 = 33.0, *df* = 6, *p* = 1.037e-05; 38%), kept more than 500 fish (X^2 = 26.1, df = 5, *p* = 8.267e-05; 42%), and declared that they had no expenses to maintain the hobby (X^2 = 19.4, *df* = 5, *p* = 0.001; 34%; Table 3). The collections were always carried out in habitats close to the aquarists' homes (e.g., rivers, streams, waterfalls, creeks, lagoons/lakes, ponds, dams, estuaries, beaches, rocky shores), using different techniques (i.e., hook and bait, fishing net, sieve, cast net, artisanal traps, manual collection). Fish collections belonging to at least 19 families were reported, mainly Cichlidae (32%) and Poeciliidae (18%).

Considering releases, 10% (n = 88) of participants revealed they had released animals from their ~~aquariums~~ into the wild, most of them freshwater-only aquarists (90%; n = 80). Regarding the profile of aquarists who release fish in the wild, those most likely to perform this practice were males (X^2 = 12.5, *df* = 4, *p* = 0.013; 11%), with less than 20 years (X^2 = 19.7, *df* =

8, $p = 0.011$; 21%), and with an income of more than 10 Brazilian minimum ~~monthly salaries~~ ($X^2 = 22.9$, $df = 10$, $p = 0.011$; 25%; Table 3). ~~According to participants,~~ the releases were made in rivers, streams, waterfalls, creeks, springs, and lakes close to their homes; in artificial lakes and ponds in public parks; in private dams and weirs; and into the sea. Releases of fish belonging to at least 9 families have been reported, mainly Cichlidae (29%) and Loricariidae (22%), and invertebrates of two classes, Gastropoda (*Pomacea* spp.) and Malacostraca (*Macrobrachium carcinus*). Participants who said they had never released any animals (86%; n = 780) expressed their opinions regarding this practice and the most cited words were: "never", "release", "nature", "species", "fish" and "native" (Fig. 3).

Asked about the future of the ornamental fish trade, 66% (n = 599) stated that more fish will be available for commercialization due to cultivation and 34% (n = 307) believe that less fish will be available due to overfishing.

Discussion

Hobby overview

~~Our results demonstrate that~~ the profile of the Brazilian hobbyist is quite homogeneous, being mainly formed by men with education and monthly income above ~~the general~~ average in Brazil (most of the adult population has at most completed elementary school and a monthly income equivalent to little more than two minimum ~~monthly salaries~~; IBGE, 2019). This profile ~~of aquarists~~ with an above-average financial situation reinforces that fishkeeping is a luxury hobby (Rhyne & Tlusty, 2012), although technological development has facilitated maintaining ornamental fish and increased the popularity of the activity (Arbuatti & Lucidi, 2010; Banha et al., 2019). In fact, fishkeeping is a hobby that demands a great financial commitment, since the acquisition of fish and equipment for ~~aquariums~~ can demand a high investment.

As expected, aesthetics was the main motivation for choosing fishkeeping as a hobby. Fish with striking color patterns and different shapes attract people and make them want to have those fish at home for contemplation and entertainment (Walster et al., 2015). Hobbyists in our study also highlighted as a motivation keeping fish for therapeutic purposes, a trend registered in studies associated with pets of different taxa, which revealed the positive impact pets can have on the quality of life of people who have stress or depression (Brooks et al., 2016, 2018; Enmarker et al., 2012; Hui Gan et al., 2019). These benefits for human well-being constitute another factor that has contributed to popularizing the hobby, attracting people who seek relaxation and reduced stress levels (Magalhães et al., 2017; Stern et al., 2016).

Freshwater fish dominate fishkeeping in Brazil, representing more than half of the species kept by hobbyists who participated in this study. This preference for continental fish was also recorded by Mazza et al. (2015) in a study performed in Italy, and can mainly be attributed to price, as freshwater fish tend to be cheaper than marine fish. Another factor pointed out by these authors which may be decisive for this preference is the ease of maintenance, considering that maintaining ~~aquariums~~ with marine fish requires greater dedication and improved

equipment, in addition to higher financial investment, as we were also able to verify with our results (Borges et al., 2021).

In addition to fish, invertebrates are also exploited by aquarists in Brazil, although to a lesser extent. Despite the use of invertebrates not being as well documented as the use of fish in fishkeeping, it has been recorded by some studies which have highlighted the popularized trade of these animals for this purpose (Alves & Rocha, 2018; Ng et al., 2016; Uderbayev et al., 2017). Without considering corals, it is estimated that about 500 species of invertebrates are used in fishkeeping, including mollusks (gastropods, bivalves, and cephalopods), polychaetes, crustaceans (shrimps, crabs, and lobsters), anemones and echinoderms (starfish, urchins) and sea cucumbers) (Alves & Rocha, 2018; Palmtag, 2017). In addition to the aesthetic factor, invertebrates are sought after by aquarists interested in the services they can provide. Integrating so-called "cleaning teams", the invertebrates work by eliminating parasites from the aquarium, filtering the water, and sifting the substrate (Palmtag, 2017).

Several factors are crucial to ensure the well-being of fish kept as pets, and almost all of them directly depend on the hobbyist's knowledge (Walster, 2015). Herein, we found that aquarists know the needs of the organisms they maintain and adapt aspects such as cleaning and partial water changes to these needs, taking into account the different needs of marine fish and freshwater fish. Some of the main difficulties in keeping ornamental fish are related to water quality maintenance, including parameters such as temperature, pH, salinity, ammonia, nitrate concentration, and dissolved oxygen (Stevens et al., 2017). In addition, inadequate diets, handling, crowding, living with fish species with different needs, and the confinement itself are factors that can cause stress to fish, often culminating in death (Stevens et al., 2017; Walster, 2015).

An imbalance in any of the necessary factors for the well-being of fish in captivity can affect resistance to pathogens, leading to the development of diseases (Cardoso et al., 2019). Most hobbyists reported the occurrence of diseases in their fish for which they mentioned a series of treatments, mostly carried out on their own based on information obtained from other aquarists or on the internet. In fact, the lack of access to a diagnosis performed by professionals, whether due to logistical or financial difficulties, can lead many aquarists to use over-the-counter remedies and home treatments, which can have the opposite effect, causing more suffering to the animals (Walster, 2015). Home treatments for diseases in ornamental fish still raise a concern related to public health. The substances used for these treatments, such as antibiotics, fungicides, and parasiticides, are often added to the aquarium water, and if this untreated water is discarded into the sewage system it can contaminate water that is used by the human population.

Implications of the hobby for conservation

Collecting fish in the wild to meet the demand required by aquarists and the preferences of aquarists raise concerns about the long-term sustainability of this practice (Evers et al., 2019). In addition to the overexploitation of species, destructive fishing practices and the high risk of

biological invasion can transform fishkeeping into a threat to biodiversity (Banha et al., 2019; Evers et al., 2019). Most aquarists in our study believed that a greater number of ornamental fish will be available in the market in the future due to improved cultivation and breeding practices in captivity. In fact, aquaculture has been touted as the solution to the over-exploitation of species for ornamental purposes (Teletchea, 2016). However, it cannot be treated as a panacea, as most of successful cultivation has only been developed for freshwater fish, while the marine ornamental fish trade almost entirely depends on collection in the wild (Máñez et al., 2014; Morcom et al., 2018).

Fish are among the most introduced aquatic animals worldwide (Magalhães & Jacobi, 2013) and the ease of acquiring exotic species through pet shops and the internet enhances the ability of aquarists to trigger introductions (Azevedo-Santos et al., 2015). The action of invasive species is ~~considered~~ the second leading cause of extinction worldwide (Wilcove et al., 1998). These species act by drastically modifying the ecosystems in which they settle, causing the decline of native species and resulting in biodiversity loss (Mantellato et al., 2018). There are introduction records of more than 150 non-native fish species in the last two centuries in Brazil, many of which were introduced through fishkeeping (Azevedo-Santos et al., 2015; França et al., 2017).

Hobbyists discarding their fish in the wild is mainly motivated by the growth of the animals, a demonstration of aggression, or the time and money demand that the hobby requires (Azevedo-Santos et al., 2015; Magalhães & Jacobi, 2013). For example, some of the fish genera kept by the aquarists interviewed, such as *Channa* Scopoli 1777, *Pangasianodon* Chevey 1931, *Clarias* Scopoli 1777 and *Osphronemus* Lacepède 1801, can reach large sizes and exhibit predatory behavior, representing a high risk of biological invasion (Magalhães & Jacobi, 2013) and are commercialized for ornamental purposes with restrictions in Brazil (MPA, 2012). Other examples of aquarium introductions include the jaguar cichlid (*Parachromis managuensis*) in northeastern Brazil (França et al., 2017) and the lionfish (*Pterois volitans*) along the east coast of North America (Whitfield et al., 2002), with the latter being considered one of the worst marine invasive species.

Invertebrates are also of concern when it comes to biological invasion. The invertebrates most used by aquarists participating in the study were snails of the genus *Pomacea*, which had their importation prohibited in the European Union because they ~~are considered organisms with~~ a high threat of invasion (Ng et al., 2016). Herein, we recorded the release of these animals into the wild. In addition to snails, we also recorded the use of some species that were previously introduced in Brazil and other countries through fishkeeping. For example, the Red swamp crayfish (*Procambarus clarkii*) has established itself worldwide after being extensively translocated by the ornamental trade (Torres and Álvarez, 2012) and is considered one of the 100 worst invaders in Europe (Gherardi, 2007). The establishment of this species has already been demonstrated in Brazil (Loureiro et al., 2015) and it has been hypothesized that the introduction occurred through fishkeeping (Magalhães et al., 2005), although studies on its impacts have not

yet been conducted in Brazilian ecosystems. Another example is the case of the Thiarid snail (*Melanoides tuberculatus*), which was first recorded in Brazil in 1967 and currently has extensive distribution throughout the country (Barros et al., 2019). It was primarily introduced and dispersed through the plant and animal trade (Vaz et al., 1986), with the high abundance of this snail having caused damage to the native benthic community of Brazil (Pointier, 1993).

In addition to the intentional introduction, fishkeeping also acts as a dispersion route for potentially invasive species that can be accidentally transported along with fish, such as invertebrates, aquatic plants, and microorganisms (Assis et al., 2014; Banha et al., 2019; Patoka et al., 2015). Potentially zoonotic pathogens that pose risks to the pet industry and humans can also be spread through improper disposal of water used in aquariums (Cardoso et al., 2019; Pate et al., 2019).

Brazil is a signatory country of the United Nations Convention on Biological Diversity, , through which it commits to making efforts to prevent and control possible introductions in aiming to protect against the threat that invasions can pose to biodiversity (França et al., 2017). The regulation of fish importation for ornamental purposes in the country is based on lists of permitted species, with emphasis on species that are strictly prohibited due to high invasion risk. However, lack of disclosure of legal restrictions and precarious inspection ~~are factors that~~ prevent the full functioning of the legislation, in addition to the fact that there are aquarists willing to violate the law to maintain prohibited species (Banha et al., 2019; Marchio, 2018; Patoka et al., 2018).

Management and conservation opportunities

Our results showed that most aquarists participating in the study are aware of the risks related to the release of non-native fish into the wild, reinforcing the idea that education and information campaigns are the main key to modifying behaviors that can trigger biological invasions. As fishkeeping offers an opportunity to bring the population closer to scientific concepts by directly observing organisms and their ecological processes, the educational potential of the hobby is an opportunity that can be used to communicate conservation, seeking to sensitize hobbyists on the problem of biological invasions and involve them in conservation initiatives (Azevedo-Santos et al., 2015; Evers et al., 2019; Marchio, 2018).

Some strategies for disseminating this information are to distribute informative material in aquarium stores, discuss this subject in the specialized media (i.e., aquarium magazines and websites), and disseminate it on social networks through channels of the environmental agencies themselves (Azevedo-Santos et al., 2015). The attitude of sellers is also a key point to inhibit improper disposal of ornamental fish through responsible sales. Consumers should receive all technical information about the species they intend to acquire, especially regarding behavior and maximum size (Azevedo-Santos et al., 2015). In addition to investing in environmental education, creating collection centers to receive unwanted animals offers an alternative to discarding fish in nature (Banha et al., 2019).

Conclusions

Our results reveal the main trends in fishkeeping in Brazil, such as the choice of hobby mainly being motivated by aesthetic and behavioral factors of the animals, the preference for freshwater species and non-native species, and the fact that most aquarists are males with above-average education and financial situation. Furthermore, our findings support the premise that fishkeeping has the potential to trigger biological invasions, especially considering that most species used in the hobby are exotic and many are known to be potential invaders. These results reinforce that performing fishkeeping as a sustainable hobby, which does not represent a threat to biodiversity, requires the joint action of aquarists, traders, and environmental agencies. Considering that there is already legislation in the country that prohibits the use of certain species for fishkeeping, efforts must now be directed toward environmental education practices and improved inspections and monitoring.

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Table 1(on next page)

Answers from Brazilian aquarists interviewed to questions related to hobby maintenance.

Table 1. Answers from Brazilian aquarists interviewed to questions related to hobby maintenance.

Question	Type of fish kept			
	Freshwater (%, n)	Marine (%, n)	Both types (%, n)	General (%, n)
How many fish do you currently have?				
Less than 5 fish	10% (77)	24% (11)	9% (7)	10% (95)
Between 5 and 10 fish	19% (147)	46% (21)	19% (16)	20% (184)
Between 10 and 20 fish	26% (202)	19% (9)	16% (14)	25% (225)
Between 20 and 50 fish	39% (303)	11% (5)	50% (42)	39% (350)
Between 50 and 100 fish	1.5% (13)	0	1% (1)	1.5% (14)
Between 100 and 500 fish	1.3% (10)	0	3% (2)	1.3% (12)
Between 500 and 1000 fish	1.1% (9)	0	0	1% (9)
More than a thousand	1.1% (9)	0	1% (1)	1% (10)
How much do you spend monthly on the hobby?				
Don't spend anything	0.5% (4)	0	0	0.5% (4)
Less than US$ 20	53% (437)	24% (11)	32% (27)	52% (475)
Between US$200 and US$ 100	38% (293)	63% (29)	51% (43)	40% (365)
Between US$100 and US$ 200	4% (34)	8.7% (4)	6% (5)	5% (43)
Between US$200 and US$ 400	3.5% (3)	0	0.5% (4)	1% (7)
More than US$ 400	3.5% (3)	2% (2)	3.5% (3)	1% (8)
Do not know	2% (2)	0	2% (2)	0.5% (4)
What is the cleaning frequency?				
Daily	0.4% (3)	2% (1)	1% (1)	1% (5)
More than once a week	10% (77)	22% (10)	19% (16)	11% (103)
Weekly	40% (313)	41% (19)	38% (32)	40% (364)
Biweekly	28% (216)	17% (8)	30% (25)	27% (249)
Monthly	18% (141)	15% (7)	11% (9)	17% (157)
Quarterly	1% (7)	0	0	1% (7)
Semiannual	1% (7)	0	0	1% (7)
As required	0.6% (5)	0	1% (1)	1% (6)
Other answers	1% (7)	2% (1)	0	1% (8)
What is the frequency of partial water changes?				
Weekly	38% (296)	13% (6)	33% (28)	36% (330)
More than once a week	5% (38)	0	4% (3)	4.5% (41)
Biweekly	30% (230)	30% (14)	34% (29)	30% (273)
Monthly	16% (125)	33% (15)	20% (17)	17% (157)
Bimonthly	5% (42)	19% (9)	6% (5)	6% (56)
When necessary	1% (8)	2% (1)	1% (1)	1% (10)
Just replenish the water	3% (22)	0	0	2.5% (22)
Other answers	2% (15)	2% (1)	1% (1)	2% (17)
Have any of your fish ever gotten sick?				
No	26% (205)	28% (13)	15% (13)	25% (231)
Yes	73% (571)	72% (33)	84% (71)	75% (675)
Where did you seek treatment?				

With others aquarists	40% (349)	42% (23)	38% (47)	40% (419)
On the Internet	38% (329)	33% (18)	34% (42)	37% (389)
With professionals	21% (182)	24% (13)	27% (34)	22% (229)

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Table 2(on next page)

Ornamental fish species kept by Brazilian aquarists with some degree of threat according to the IUCN classification.

Table 2. Ornamental fish species kept by Brazilian aquarists with some degree of threat according to the IUCN classification.

Species	Family	25+ cited	Native	Brazilian legislation
Neart threatened				
Altolamprologus calvus (Poll, 1978)	Cichlidae		No	Allowed
Aulonocara nyassae Regan, 1922	Cichlidae		No	Allowed
Corydoras panda Nijssen & Isbrücker, 1971	Callichthyidae		Yes	Allowed
Chiloscyllium punctatum Müller & Henle, 1838	Hemiscylliidae		No	Allowed
Chindongo elongatus (Fryer, 1956)	Cichlidae		No	Allowed
Chitala chitala (Hamilton, 1822)	Notopteridae		No	Forbidden
Chitala blanci (d'Aubenton, 1965)	Notopteridae		No	Allowed
Danio kyathit Fang, 1998	Cyprinidae		No	Allowed
Erpetoichthys calabaricus Smith, 1865	Polypteridae		No	Forbidden
Trichopodus leerii (Bleeker, 1852)	Osphronemidae		No	Allowed
Vulnerable				
Aulonocara hansbaenschi Meyer, Riehl & Zetzsche, 1987	Cichlidae		No	Allowed
Aulonocara steveni Meyer, Riehl & Zetzsche, 1987	Cichlidae		No	Forbidden
Balantiocheilos melanopterus (Bleeker, 1850)	Cyprinidae		No	Allowed
Cyprinus carpio Linnaeus, 1758	Cyprinidae	Yes	No	Allowed
Cyrtocara moorii Boulenger, 1902	Cichlidae		No	Allowed
Datnioides undecimradiatus (Roberts & Kottelat, 1994)	Datnioididae		No	Forbidden
Haplochromis aeneocolor Greenwood, 1973	Cichlidae		No	Forbidden
Haplochromis obliquidens (Hilgendorf, 1888)	Cichlidae		No	Allowed
Notholebias minimus (Myers, 1942)	Rivulidae		Yes	Forbidden
Paratilapia polleni Bleeker, 1868	Cichlidae		No	Forbidden
Pethia nigrofasciata (Günther, 1868)	Cyprinidae		No	Forbidden
Pseudotropheus demasoni (Konings, 1994)	Cichlidae		No	Allowed
Puntius titteya Deraniyagala, 1929	Cyprinidae		No	Forbidden
Tropheus duboisi Marlier, 1959	Cichlidae		No	Allowed
Endangered				
Champsochromis spilorhynchus (Regan, 1922)	Cichlidae		No	Forbidden
Glossolepis incisus Weber, 1907	Melanotaeniidae		No	Allowed
Melanotaenia boesemani Allen & Cross, 1980	Melanotaeniidae		No	Allowed
Pangasianodon hypophthalmus (Sauvage, 1878)	Pangasiidae	Yes	No	Forbidden
Placidochromis phenochilus (Trewavas, 1935)	Cichlidae		No	Allowed
Pterapogon kauderni Koumans, 1933	Apogonidae	Yes	No	Allowed
Puntius arulius (Jerdon, 1849)	Cyprinidae		No	Allowed
Sahyadria denisonii (Day, 1865)	Cyprinidae		No	Allowed
Critically endangered				
Aulonocara baenschi Meyer & Riehl, 1985	Cichlidae		No	Allowed
Aulonocara maylandi Trewavas, 1984	Cichlidae		No	Allowed

Chindongo saulosi (Konings, 1990)	Cichlidae	No	Forbidden
Epalzeorhynchos bicolor (Smith, 1931)	Cyprinidae	No	Allowed
Haplochromis latifasciatus Regan, 1929	Cichlidae	No	Forbidden
Melanochromis chipokae Johnson, 1975	Cichlidae	No	Allowed
Pseudotropheus cyaneorhabdos (Bowers & Stauffer, 1997)	Cichlidae	No	Forbidden

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Table 3(on next page)

Chi-square tests of socioeconomic characteristics from Brazilian aquarists to determine the relationship with the capture and release of ornamental fish in the wild (significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Table 3. Chi-square tests of socioeconomic characteristics from Brazilian aquarists to determine the relationship with the capture and release of ornamental fish in the wild (significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Independent variables	Capture in the wild			Release in the wild		
	Yes (%)	No (%)	X^2	Yes (%)	No (%)	X^2
Gender			8.10*			12.50*
Female	4	96		0	96	
Male	11	89		11	85	
Não declared	50	50		0	100	
Age group			6.20			19.70*
Less than 20 years	18	82		21	75	
Between 20 and 30 years	11	89		11	84	
Between 30 and 40 years	10	90		8	89	
Between 40 and 50 years	8	92		4	90	
More than 50 years	11	89		6	84	
Monthly income			11.80*			22.90*
Less than US$ 266	18	82		20	80	
Between US$ 266 - US$ 530	16	84		12	81	
Between US$ 530 - US$ 800	10	90		8	87	
Between US$ 800 - US$ 1060	8	92		8	88	
Between US$ 1060 - US$ 2660	8	92		8	90	
More than US$2660	25	75		25	75	
Not declared	9	91		13	76	
Education level			33***			18.67
No formal education	38	62		25	75	
Elementary school	21	79		20	75	
High school	9	91		9	86	
Incomplete higher education	11	89		8	89	
Complete higher education	6	94		9	85	
Postgraduate studies	10	90		8	90	
Hobby experience			11.60*			18
Less than one year	7	93		6	90	
Between 1 and 5 years	8	92		7	90	
Between 5 and 10 years	9	91		10	86	
Over tem years	8	92		9	86	
Since childhood	15	85		15	80	
Number of fish			26.10***			9.90
Less than 10 fish	7	93		11	84	
10-20 fish	8	92		8	88	
20-50 fish	13	87		9	88	
50-100 fish	20	80		7	86	
100-500 fish	8	92		8	84	
More than 500 fish	42	58		26	69	
Monthly spend			19.40**			8.41
Don’t spend nothing	34	66		33	67	
Less than US$ 20	9	91		9	87	
Between US$200 - US$ 100	10	90		10	85	
Between US$100 - US$ 200	26	74		14	84	

Between US$200 - US$ 400	14	86	14	86
More than US$ 400	0	100	12	88

4

Figure 1

Socioeconomic characteristics of research participants (n = 906 aquarists) and their distribution in Brazilian states

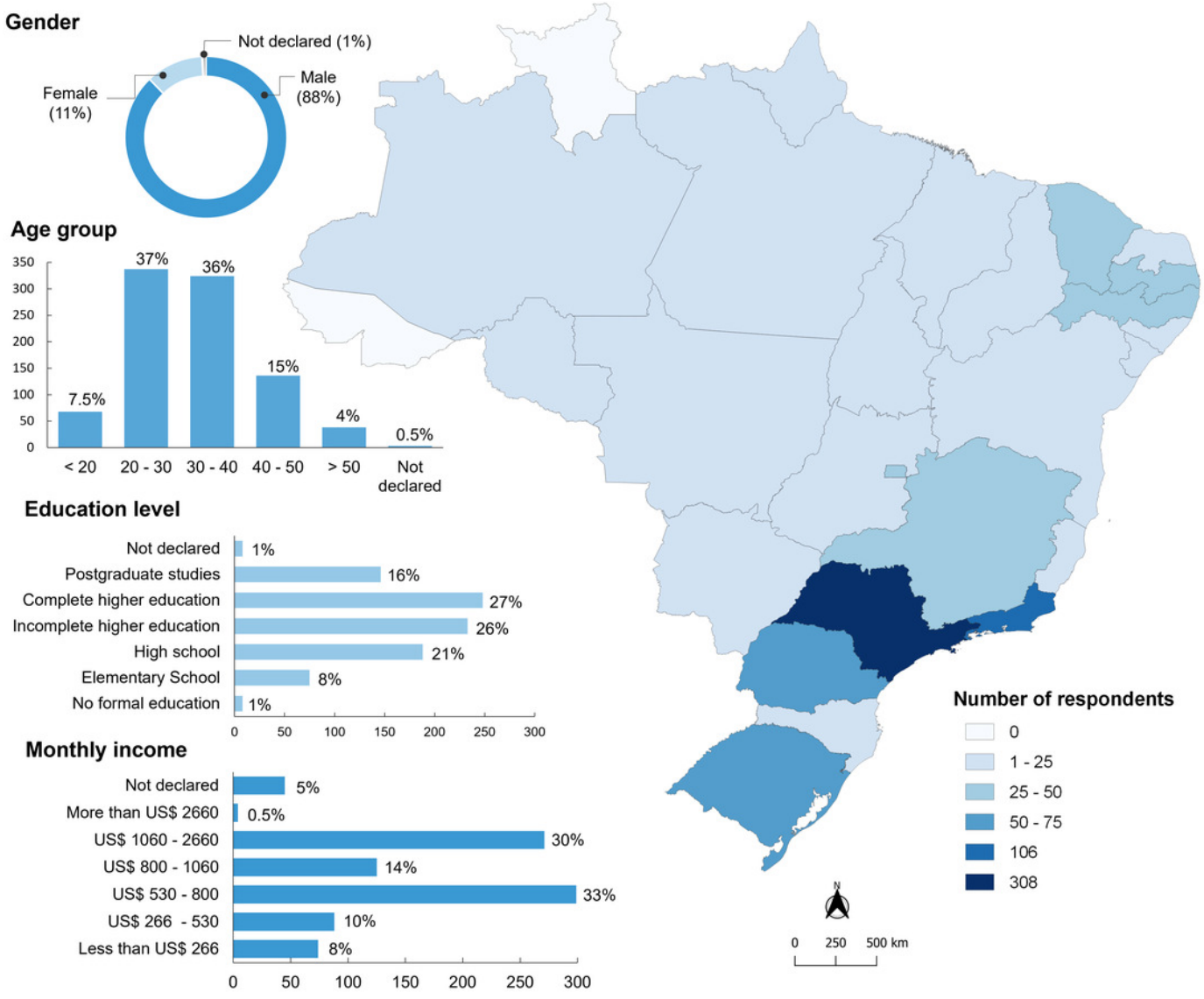
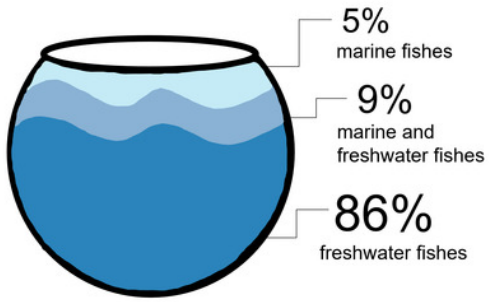


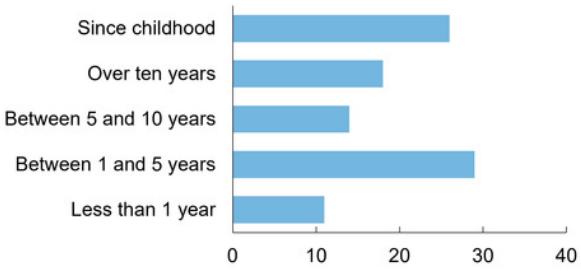
Figure 2

Answers from aquarists interviewed to questions about their relationship with the hobby.

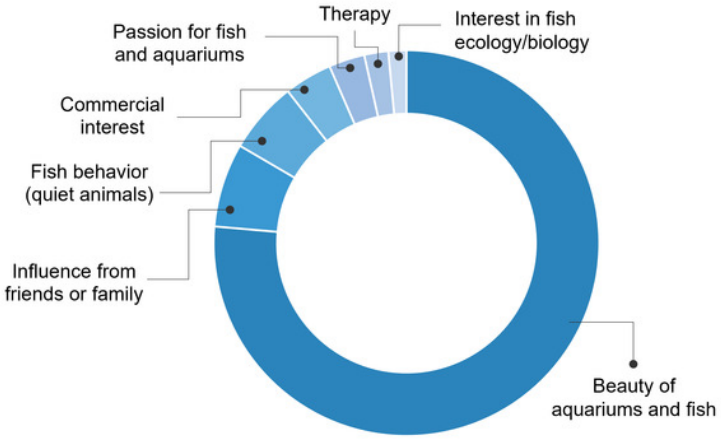
Do you have marine or freshwater fish?



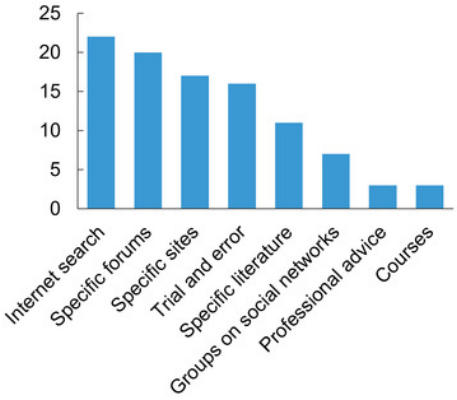
How long have you been practicing fishkeeping?



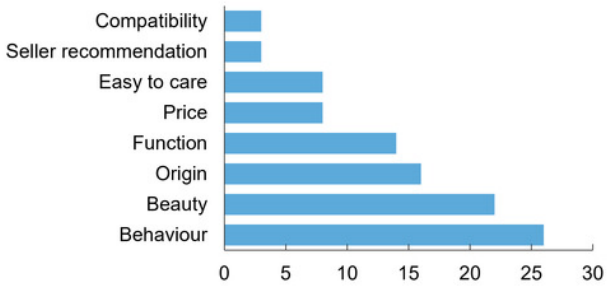
What motivated you to choose fish as pets?



Where did you get experience in fishkeeping?



What do you value most when choosing a new fish?



Where do you get your fish?

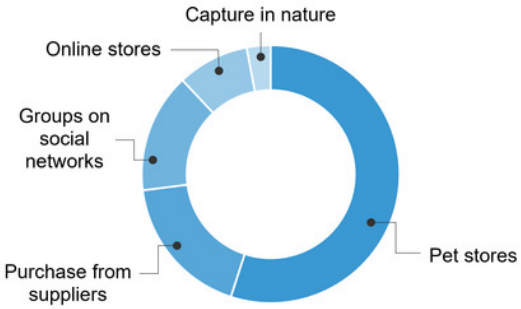


Figure 3

Wordcloud elaborated from aquarists' responses who are against the practice of releasing ornamental fish in the wild (n = 780 responses). Larger words indicate higher frequencies of occurrence.