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Fishers' knowledge on the ecology, impacts and benefits of the non-native peacock bass *Cichla kelberi* in a coastal river in southeastern Brazil

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ABSTRACT

Ethnoichthyology has been used to understand how humans perceive environmental changes, including species introductions. In Rio de Janeiro State, Brazil, fishers introduced juveniles of peacock bass *Cichla kelberi* in the Juturnaíba Reservoir in the 1990's. In the last years, this fish started to be caught in the São João River, downstream of the dam. This study aimed to identify whether fishers recognize the potential impact of the peacock bass over the native species, to understand the economic valuation they made to the services provided by this species, and if they include management of the non-native peacock bass in their practices. Semi-structured interviews with artisanal and sport fishers were employed between September and October 2016. A total of twenty-five interviews were carried out, 12 with artisanal and 13 with sport fishers. In general, fishers expressed knowledge about biological and behavioral aspects of the peacock bass, but opinions diverged on its impact over the native ichthyofauna. Differently from the artisanal, most sport fishers do not relate the decline in populations of native species to the occurrence of the peacock bass. Instead, they mention other anthropogenic impacts in the river basin. The later advocate the practice of fish and release in order to maintain a sustainable population of peacock bass in the study area. The ethnoichthyological knowledge gathered from fishers provide novel information of the native ichthyofauna, peacock bass introduction and other anthropogenic impacts, and might constitute a powerful tool to the development of sustainable strategies of the natural resources.

Keywords: Ethnobiology; Artisanal Fishing; Sport Fishing; Introduced Fishes; Juturnaíba Reservoir; São João River.

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SIGNIFICANCE STATEMENT

The assessment of the fishers' knowledge about biological invasion in a coastal dammed river in Southeast Brazil revealed that artisanal fishers are aware of the decline of native species and recognize the increase in non-native species over time. Sport fishers, on the other hand, expressed more details of reproductive biology of the non-native *Cichla kelberi*, their target species. A local sport fisher provides novel information from the first *C. kelberi* introductions in the year 2001. Sport and artisanal fishers acknowledge that by practicing fish and release they contribute to the maintenance of sustainable population of this non-native species. This study reinforces that although differing in the purpose of fisheries, users of the same invaded ecosystems may provide complementary and useful information for the development and management practices of both native and non-native species.

INTRODUCTION

The discipline of Human Ecology addresses the diversity of interactions established by human cultures with the environment and their knowledge about the natural resources, which is accumulated and transferred through the generations (Begossi et al. 2000; Berkes 1999). As part of Human Ecology, the Ethnobiology investigates the local or traditional ecological knowledge in order to understand how human populations perceive, classify and use the natural resources (Begossi and Garavello 1990; Berkes 1999; Porcher et al. 2010). Ethnobiological studies can provide a range of information because they reflect the knowledge of human communities about the classification, biology, ecology and behavior of distinct groups of animals and plants (Camacho Guerreiro et al. 2016; Mourão and Nordi 2002; Pinto et al. 2017).

Artisanal small-scale fisheries require biological knowledge about the explored fishes. The use of fisherfolk knowledge ultimately has improved the use and management of fish as an important source of animal protein along the history of mankind (Fao 2003; Magalhães et al. 2011; Marques 1991). Among the several unfolds of Ethnobiology, the Etnoichthyology focuses on the knowledge, classification and use of fishes as a resource and includes aspects of fish conservation and cultural habits of people (Corneta 2008; Marques 1991; Morrill 1967; Silvano and Begossi 2002). Therefore, the perceptions of fisherfolk about the ecology and behavior of fishes may provide relevant information to guide the conservation and management of ecosystem and environments, including the potential effects of extreme climatic events on fisheries (Camacho Guerreiro et al. 2016; Silvano et al. 2008). In Brazil, the first ethnoicthyological study was published in the early 1990s (Begossi and Garavello, 1990). Since then, several studies have analyzed fisherfolk knowledge about the spatial and temporal distributions, behavior and trophic ecology of target fishes, as well as the cultural practices and traditions (e.g. Begossi et al. 2016; Mourão and Nordi 2002; Pinto et al. 2017; Ramires et al. 2010; Silvano and Valbo-jørgensen 2008). However, few studies have applied the local knowledge of fisherfolk to understand the extension of human impacts in rivers (Hallwass et al. 2013). River damming associated to the formation of reservoirs for water supply or power generation can cause environmental, social and economic impacts (Agostinho et al. 2016; Fearnside 1999; Petrere 1996). Among these impacts, the introduction of non-native species in reservoirs, in addition to facilitating the dispersal and establishment of these species (Johnson et al. 2008), has been associated with severe disturbances that vary from reductions in catches to local extinctions of native species (Latini and Petrere Junior 2004; Pelicice and Agostinho 2009). The changes in the habitat caused by the formation of reservoirs and introduction of non-native species can negatively affect the social condition of fishers, who need to adapt to different fishing strategies and target species, most of them with lower economic value (Hoeinghaus et al. 2009). However, little is known about the fisherfolk perception and reaction to changes in the freshwater environment and in the availability and alteration of fishing resources, including the presence of non-native fishes (Hallwass et al. 2013; Huntington et al. 2017; Silvano and Begossi 2002).

Amazonian fishes popularly known as peacock basses (English) or "tucunarés" (Brazilian Portuguese) (Teleostei: Cichlidae, *Cichla* spp.), have been introduced in several impounded rivers where they succeed in the colonization of reservoirs, experiencing rapid population increases (Espínola et al. 2010; Pelicice and Agostinho 2009). Species of peacock basses were recorded in at least 35% of the 71 Brazilian reservoirs evaluated by Agostinho et al. (2007), being the dominant species of fish in 10% of these. Drastic reductions in the diversity of native fish species have been attributed to the occurrence of peacock bass in systems where they have been introduced (Britton and Orsi 2012; Latini and Petrere Junior 2004; Pelicice et al. 2015; Zaret and Paine 1973). Changes in the composition of the ichthyofauna occurred after the introduction of the peacock bass and other non-native fishes and such changes can affect fishing (Rosa et al., 2014). However, few studies

have been conducted to understand how fishers perceive and interact with non-native species in Brazil (Azevedo-Santos et al. 2010; Silvano and Begossi 2002).

Ethnoichthyology may reveal how traditional people that depend on local scale fisheries interact with environmental changes caused by humans, such as the introduction of non-native fishes (Azevedo-Santos et al. 2010; Carvalho 2002; Moura and Marques 2007; Moura et al. 2008; Pinheiro 2004). Therefore, the present study aimed to investigate how subsistence and recreational fishers (hereafter named respectively as artisanal and sport fisher) perceive and interact with the non-native species of peacock bass *Cichla kelberi*. We also aimed to investigate the perceptions of fishers about the natural resources and the invaded ecosystem in a coastal Neotropical river. In particular, we investigated whether fishers recognize potential impacts of the peacock bass, how they value this non-native species and if they have developed management practices to control or to maintain sustainable population of this fish on the studied system.

MATERIAL AND METHODS

The Juturnaíba Reservoir is located ca. 40 km upstream the São João River mouth, State of Rio de Janeiro, southeastern Brazil (22º 33' S and 42º 18'W) (Figure 1). The reservoir was built in the 1980s, it occupies an area of 43 km^2, provides water to the populous Região dos Lagos and serves as a recreational and sport fishing area. The São João River originates at 800 m of altitude and runs about 120 km west, until flowing into the Atlantic Ocean in a mangrove-dominated estuary in the district of Barra de São João, in the municipality of Casimiro de Abreu.

Anglers introduced *C. kelberi* in this reservoir during the 1990s (Catelani et al. 2020). About five years ago, this fish became frequent in the catches downstream of the reservoir in the last stretch of the São João River, which includes an estuarine area. This portion of the river was already highly modified by human intervention, due to flow regulation and previous channelization of the meandering course, which occurred between 1950 and 1985.

We conducted semi-structured interviews with fishers, and they included closed and open questions. The advantages of this approach is to gather quick and objective interviews and the confidence that important research questions have been addressed (Silvano et al. 2008). Two types of questionnaires were employed: one targeted to local artisanal fishers and other to sport fishers. The same person (P. A. Catelani), performed the interviews, which were carried out between September and October 2016 in three locations (Figure 1), in order to include fishers from Juturnaíba Reservoir and the downstream last stretch of the São João River.

The questionnaires covered (i) general aspects of the fishing activity, (ii) the socio-cultural profile of fishers, (iii) their knowledge about the biology of the peacock bass, (iv) composition and economical valuation of the native and non-native fish fauna, and (v) their awareness about changes in the abundance and composition of fish fauna by anthropogenic interventions (Table 1). The popular and scientific names of the species cited by the fishers during the interview are presented in supplementary material (Additional file 1).

The snowball sampling technique (sensu Biernacki and Waldorf 1981) was employed after the first interview. Interviews lasted an average 20 minutes and were carried out in several places of each locality, according to the availability of each interviewee. All interviews were recorded with prior consent of the informants, and the research was previously approved by the Ethics Committee of the Federal University of Rio de Janeiro - campus Macaé, Brazil (CAAE: 58514816.9.0000.5699).

RESULTS AND DISCUSSION

Fishers profile

A total of 25 interviews were carried out with 12 traditional and 13 sport fishers. Three traditional fishers were women (Table 2), the remaining nine were men. On average, artisanal fishers were 48 ± 10 years old. Seven of them conducted their fishing activities only in the Juturnaíba Reservoir and the other five only in the last stretch of the São João River. Most fishers had incomplete elementary education and none had higher education. Almost all fishers were married (91.7%) and all of them had children. Although 75% of the fishers confirmed that their parents were fishers, only 33% of their children currently practice this activity (Table 2).

Among sport fishers, only men were interviewed. Four practice fishing only in the Juturnaíba Reservoir, four only in the last stretch of the São João River, and five in both locations (Table 2). The fishermen visit the places for leisure and are from six cities of the State of Rio de Janeiro, three cities of the State of Minas Gerais State and one of Sate of São Paulo. The average age of sport fishermen was lower than that of artisanal fishers (40 ± 13 years old), as well as the proportion of married (46%) and those who have children (54%). On average, the interviewed sport fishers have been fishing in the São João River for 12 years (± 10.8). In Juturnaíba Reservoir, most sport fishers hire guide and boat services, which include fuel and live baits. The main bait used is the tetra (*Astyanax*

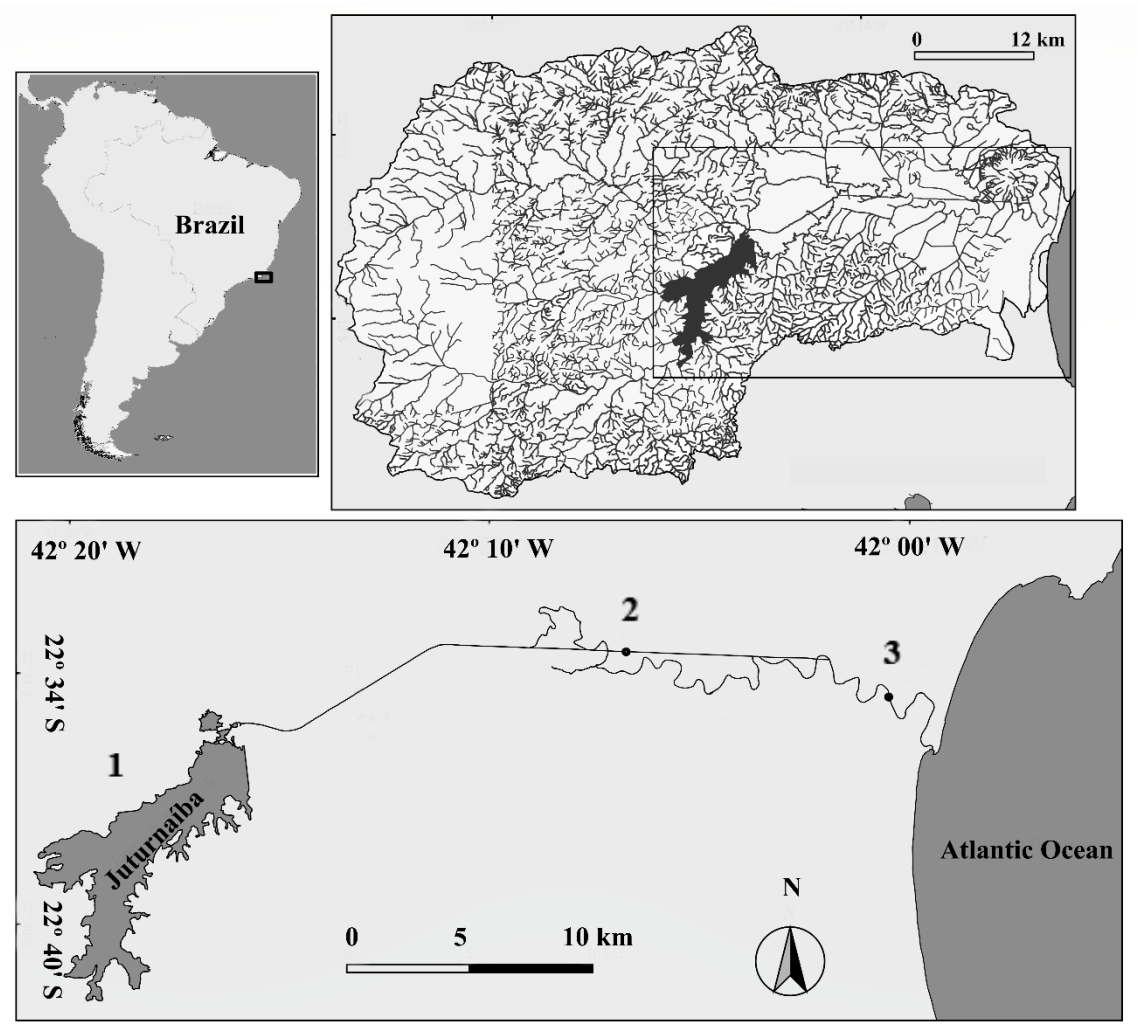

Figure 1. Location of the São João River Basin, State of Rio de Janeiro, Brazil and sampling localities (1-3). (1): Juturnaíba Reservoir, Silva Jardim municipality; (2): São João River downstream of the dam, Casimiro de Abreu municipality; (3): mouth of the São João River, district of Barra de São João, Casimiro de Abreu municipality.

spp.), which was cited by five fishers. The baits are previously caught by the guides with gill nets and stored in tanks. According to these fishermen, unused baits are returned to these tanks.

Considering artisanal fisher people, although most of them have fishing as their main activity, 50% perform other activities to supplement their incomes. Only one person interviewed does not have artisanal fishing as a main occupation (he is a civil worker). Most of them (83%) have one or more family members involved in fishing activities (Table 3).

Sport fishers presented higher educational level (Table 2) and reported 10 different professions (Table 4), two of them directly related to the sport fishing activity. One interviewed owns a company that manufactures artificial baits and the other works as shop assistant in a shop specialized in fishing products.

Fishing activity

Among the five fishing gears mentioned by the artisanal fishers, gillnet was the most used, whereas line and hook with artificial or live baits were mainly used by sport fishers (Figure 2).

In general, artisanal fishers target more species than sport fishers (Figure 3). In the reservoir, the main target species of artisanal fishers were the trahira *Hoplias* aff. *malabaricus* and the peacock bass (Figure 3A), which have higher market value (between US$ 3.15 and US$ 4.80/kilogram). Other fishes reported cost, on average US$ 1.60/kilogram, as the pearl cichlid *Geophagus brasiliensis*, the armored catfish *Loricariichthys castaneus*, and the singing catfish *Trachelyopterus striatulus*. In the downstream section, fishers mentioned the same freshwater species reported in Juturnaíba, in addition to some marine

Table 1. Topics and questions addressed in the questionnaires used in interviews conducted in the Juturnaíba Reservoir and downstream last stretch of the São João River, between September 28 and 08 October 2016.

Topics covered	Questions evaluated
Socio-cultural profile of fishers	Sex, age, origin, education, marital status, number of children, parents are or not fishers, children are or not fishers
General aspects of the fishing activity	Frequency and importance of fishing, other activities developed, How many family members involved in fishing, fishing area, time spent fishing, fishing methods and target species
Knowledge about the biology of the peacock bass	Origin, reproductive activity, behaviour, abundance, items consumed and predators of the peacock bass
Interaction with the peacock bass	Importance and management of the peacock bass as a resource, economical valuation of the native and non-native fish fauna
Changes caused by the peacock bass	Changes in tourism and economy, fishes before and after the introduction of the peacock bass
Changes by anthropogenic interventions	Occurrence of other non-native species, impacts perceived by interviewee

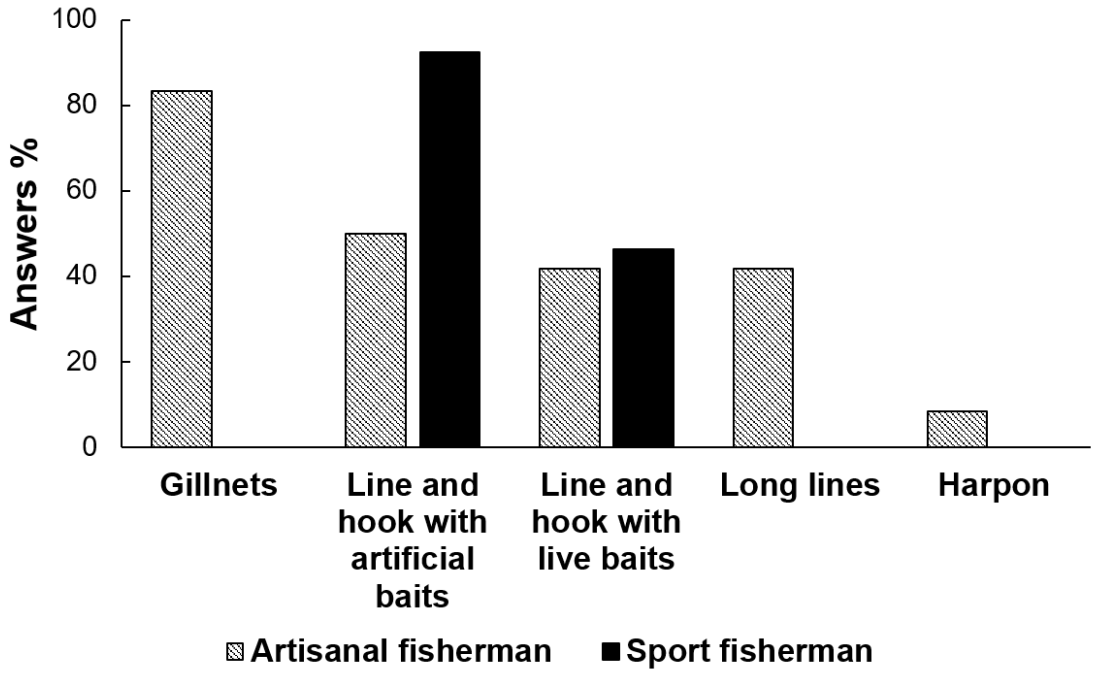

Figure 2. Fishing methods used by artisanal ($N = 12$) and sport ($N = 13$) fishers interviewed in the Juturnaíba Reservoir and in the downstream section of the São João River, between September 28 and 08 October 2016.

fishes (Figure 3B). One of these species are the sea basses *Centropomus* spp., which attain the highest market value (between US$ 6.40 and US$ 8.00/kilogram). The non-native redbreast tilapia *Oreochromis niloticus* was also frequently cited by the artisanal fishers. Sea catfishes were also reported, probably captured when these fishes enter the river to spawn.

The main target species of the sport fishing in the reservoir was the peacock bass, whereas the sea basses *Centropomus* spp., followed by the peacock bass, were the main species targeted in the stretch downstream of the dam (Figure 3). Even though both species are the most valued by the fishers, their preference of fishing in those areas relies mainly on the occurrence of

the peacock bass in the region.

Interaction with the peacock bass

In general, fishers had a considerable knowledge about the biology of the peacock bass, especially the artisanal ones that work in the reservoir and target this species as the main resource. The recognition that the peacock bass is not-native in the São João River was consensual, except for a young sport fisherman, who answered that this fish always occurred there. Among artisanal fishers, the most common response was that the peacock bass escaped from fish breeding tanks. According to most sport fishes, the peacock bass comes from the Amazon basin (Figure 4). When asked about the time of introduction, artisanal fishers responded that the peacock bass was introduced on average 16 years ago (± 4.2), and most of them (83.3%) started fishing before its introduction. Only one sport fisherman that was involved in the release of the peacock bass in Juturnaíba provides the more accurate answer and stated that the introduction occurred 15 years ago. According to him, at the time of the first fish release, each sport fisher willing the peacock bass introduction contributed with US$ 15.00 for the purchase of 5,000 specimens from the State of Mato Grosso, which were released into the reservoir.

Responses were unanimous regarding the food habit, informing that the peacock bass feeds on a wide range of aquatic animals, such as young fish, including conspecifics, and shrimp (Figure 5A). Some fishers emphasized that the peacock bass is a "heavy predator". In general, sport fishers detailed the preys, citing the tetras, the sea bass and the peacock bass, as well as shrimp and aquatic insects.

Table 2. Profile of the 12 artisanal and 13 sport fishers interviewed in the Juturnaíba Reservoir and downstream last stretch of the São João River, between September 28 and 08 October 2016.

	Artisanal fishers(N= 12)	**Sport fishers(N= 13)**
Sex (%)		
Male	75.0	100.0
Female	25.0	0.0
Age (year)		
Minimum	33.0	23.0
Mean	48.2	40.1
Maximum	69.0	62.0
Education (%)		
None	25.0	0.0
Incomplete fundamental	58.3	7.7
Complete fundamental	0	7.7
Incomplete high school	0	7.7
Complete high school	16.7	38.5
Incomplete higher education	0	7.7
Complete higher education	0	30.8
Place of origin (%)		
Rio de Janeiro State	91.7	69.2
Minas Gerais State	0	23.1
Espírito Santo State	8.3	0.0
São Paulo State	0	7.7
Marital status (%)		
Single	8.3	54.0
Married	91.7	46.0
Children (%)		
No	0.0	46.0
Yes	100	54.0
Parents are also fishers(%)		
No	25.0	23.1
Yes	75.0	76.9
Children are also fishers(%)		
No	66.7	28.6
Yes	33.3	71.4

Table 3. Characteristics of the 12 artisanal fishers interviewed in the Juturnaíba Reservoir and downstream last stretch of the São João River, between September 28 and 08 October 2016.

Characteristics	Artisanal fishers(N= 12)
Fishing as main activity (%)	
No	8.3
Yes	91.7
Other activities (%)	
Guide	25.0
Cooker	16.7
Housewifely	8.3
Civil worker	8.3
None	41.7
Frequency of fishing (%)	
Daily	50.0
Weekly	50.0
Family members involved in fishing (%)	
0	16.7
1	33.3
2	16.7
3	25.0
4	8.3
Years fishing in the region	
Minimum	4.0
Mean	27.4
Maximum	48.0

Table 4: Characteristics of the 13 sport fishers interviewed in the Juturnaíba Reservoir and downstream last stretch of the São João River, between September 28 and 08 October 2016.

Characteristics	Sport fishers (N= 13)
Activities developed (%)	
Engineer	23.0
Bricklayer	23.0
Businessman (Artificial baits)	7.7
Shop assistant (fishing products)	7.7
Economist	7.7
Communication technician	7.7
Graphic designer	7.7
Firefighter	7.7
Civil servant	7.7
Frequency of fishing (%)	
Daily	15.4
Weekly	30.8
Fortnightly	7.7
Monthly	23.0
Bimonthly	7.7
Annually	15.4
Years fishing in the region	
Minimum	1.0
Mean	12.4
Maximum	43.0

In relation to the predators of the peacock bass, some fishers were not able to cite anyone. The main predator mentioned was the african catfish *Clarias gariepinus*, which is also introduced in the São João

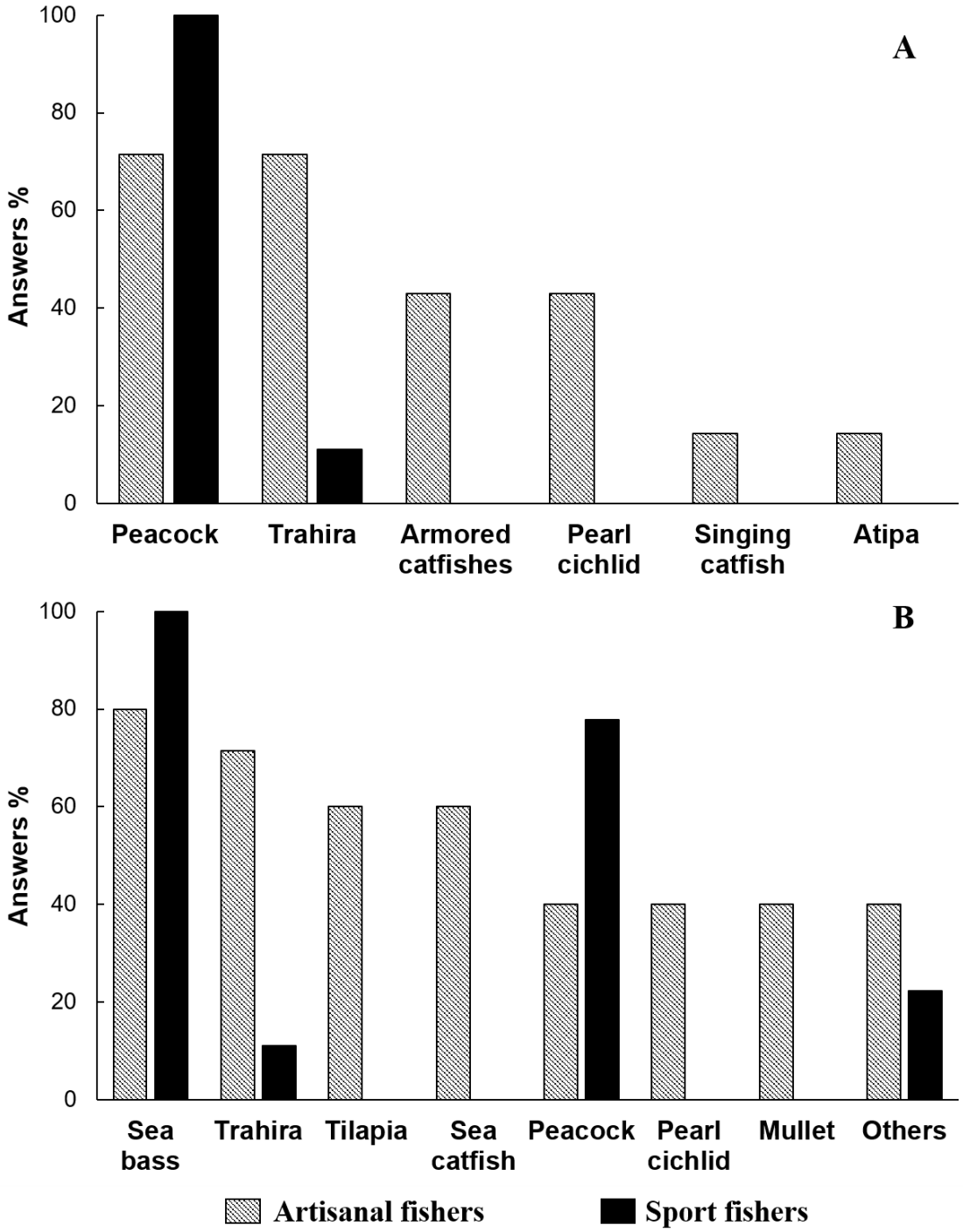

Figure 3. Target species reported by the 12 artisanal and 13 sportfishers interviewed in the Juturnaíba Reservoir and downstream last stretch of the São João River, between September 28 and 08 October 2016.

River, followed by the trahira (Figure 5B). One artisanal fisherman who uses harpoon as fishing gear provided an interesting response. According to him, the African catfish must be the only species that prey on the peacock bass, as juveniles, but without much success, due to the parental care exhibited by peacock bass, which remain near the nest protecting their offspring.

All fishers informed that peacock basses form aggregations. However, when asked at which portion of the water column the peacock bass is most commonly found, responses varied and were often related to the water temperature or to the employed fishing method. According to artisanal fishers, the peacock

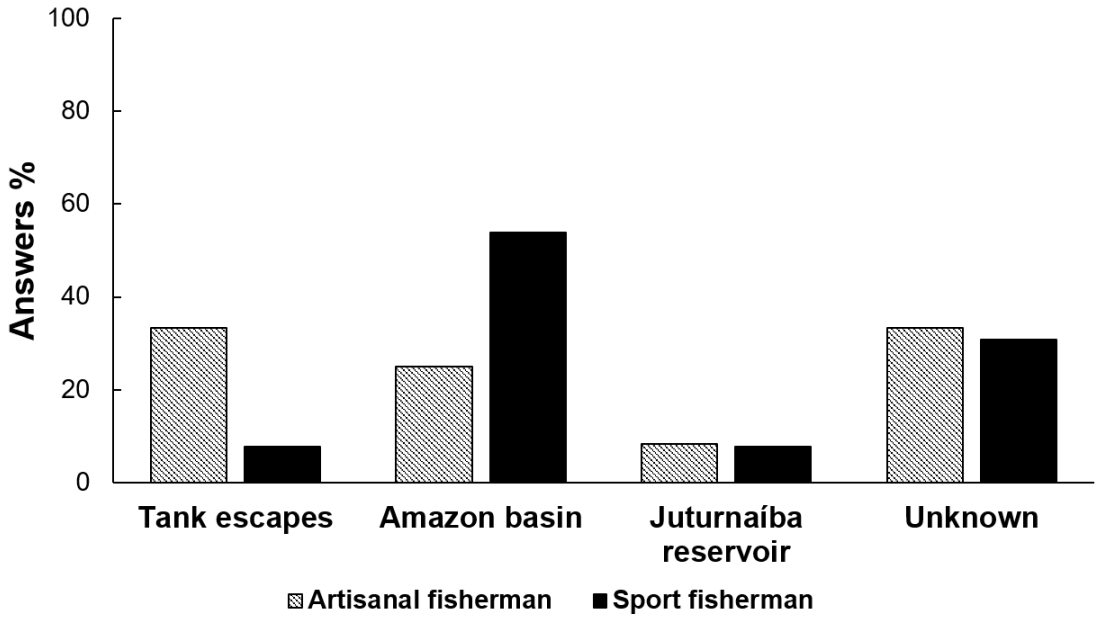

Figure 4. Origin of the peacock bass according to the 12 artisanal and 13 sport fishers interviewed in the Juturnaíba Reservoir and downstream last stretch of the São João River, between September 28 and 08 October 2016.

bass is abundant throughout the year, but with higher catches during the summer, because of greater activity of this fish in higher water temperatures. Respective to abundance, 50% of artisanal fishers and 61.6% of sport fishers of Juturnaíba Reservoir reported that there are usually more juveniles than adults. Along the last stretch of the São João River downstream to the dam, sport fishers' perception differs, since half believe there are more juveniles than adults and the other half said that there are more adults than juveniles.

The reproductive period of the peacock bass was a less known aspect, especially among the artisanal fishers. Nearly half of them did not know when the reproductive period occurs and some said they had not seen peacock bass with eggs. Some fishers answered that the peacock bass reproduces two to three times a year, but they were unsure about the respective months. Summer, followed by spring, was the season most cited by the interviewed fishers (Figure 6).

Environmental changes associated with peacock bass introduction

Artisanal fishers, mainly those that live near Juturnaíba Reservoir, were more specific on their answers concerning alterations due to peacock bass introduction. Only three sport fishermen fished on the site before the introduction of the peacock bass. When questioned about the tourism directed to peacock bass, artisanal fishers recognized a change in the motivation toward this activity. They reported that before the introduction of the peacock bass, local tourism was targeted to tetras, which attracted a great amount of people that arrived even in chartered buses. At that time, fishing took place on the banks of the reservoir without the need for boats, and people were able to catch a large number of tetras. According to these fishers, the current tourism focused on sport fishing is worse to the local economy than the previous tourism directed to tetras. This lower importance of tourism directed to the peacock bass was associated with low catches of this fish near the shoreline. As the fishing of peacock bass requires boats and guide services, such activity is consequently more expensive for practitioners. Even though it is more expensive and less crowded than tourism targeted to the tetra, peacock sport fishing motivates a large group of participants who agree with the practice of catch and release, aiming at maintaining the regional stock of peacock bass.

Another fact emphasized by most interviewed people irrespective to the site and modality was the change in the composition of the fish fauna after the introduction of the peacock bass and the drastic decrease in the population size of some species, mainly tetras and the toothless characin, due to predation by the peacock bass (Figure 7). The artisanal fishers of Juturnaíba Reservoir agreed that the toothless

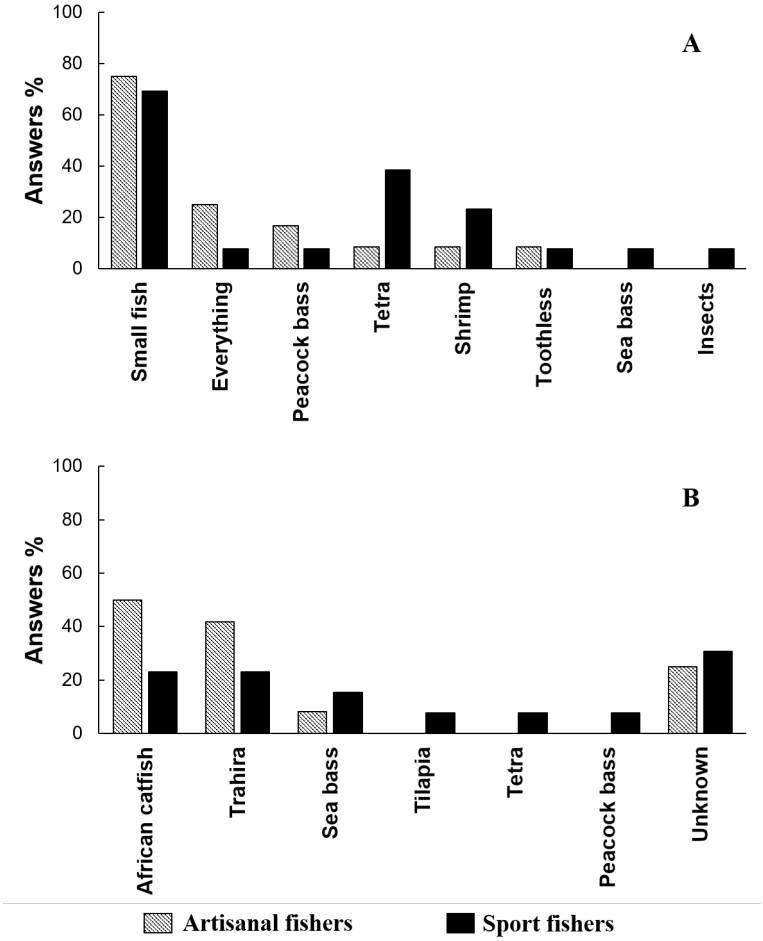

Figure 5: Items consumed by the peacock bass fishers (A) and predators of the peacock bass (B) according to the 12 artisanal and 13 sport fishers interviewed in the interviewed in the Juturnaíba Reservoir and downstream last stretch of the São João River, between September 28 and 08 October 2016.

characin sustained the fishing activity before the introduction of the peacock bass, which were commercialized including in other nearby cities. The sport fisherman who participated in the release of peacock bass in Juturnaíba Reservoir regretted that he has contributed to the introduction of the species in the region. He is aware of the gradual reduction of the abundance of the toothless and the tetras, in addition to the establishment of the peacock bass and the control it exerts on other species the in the section of the river downstream the dam.

Fishers' responses indicated that peacock bass is currently important in Juturnaíba Reservoir, and since its introduction the species is getting more abundant than the native ones that are also fished in the region (Figure 7A). The artisanal fishers of the São João River, on the other hand, do not seem to perceive an increase on the abundance of the peacock bass, probably because this fish occurs in stretches farther away from the mouth, where, in general, the artisanal fishing occurs (Figure 7B). As few sport fishers acted before the introduction of the peacock bass, the answers of Juturnaíba Reservoir and São João River were grouped (Figure 7C). According to these fishers, most of the species that are also targeted in their fishing practices and that were previously found in the São João River basin are disappearing. Another consensus among the interviewed people was the relative stability of the population of the trahira throughout the time, even after the introduction of peacock bass (Figure 7).

The decrease in the abundance of other species of fishes was also mentioned, among them the leporinus and the tiete tetra. However, the fishers attribute the reduction of these species to the construction of the dam, which prevented their ascendant movements to the upstream stretch of the São João River to spawn. Only two of the artisanal fishers evaluated the impoundment of the river as positive, claiming that the water level was higher compared to the former lagoon

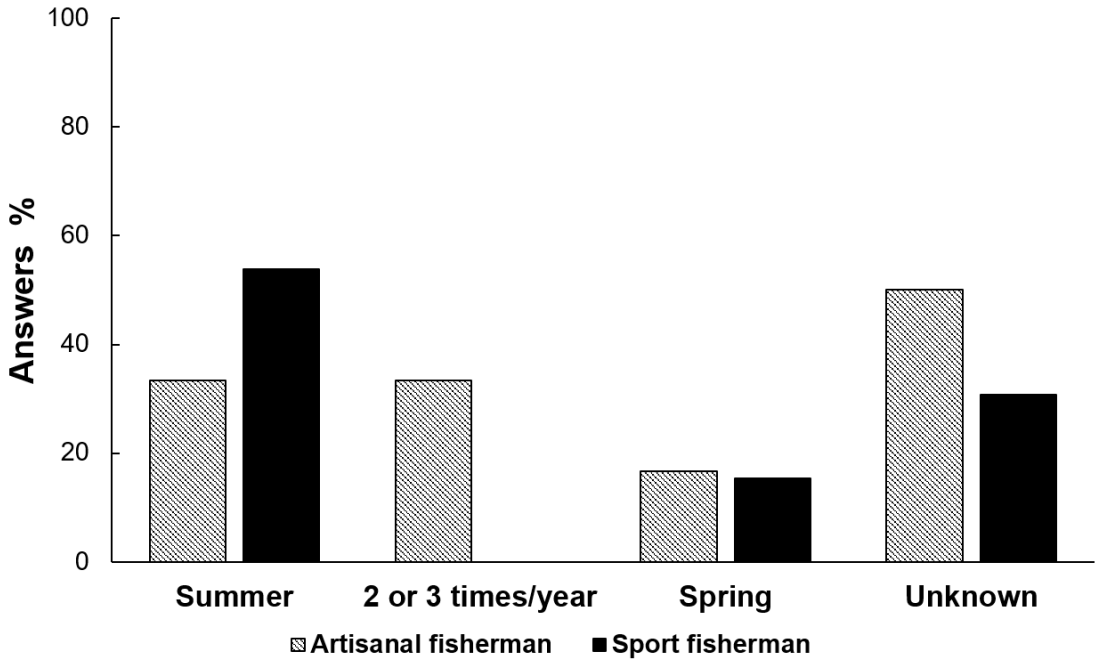

Figure 6. Reproductive activity of peacock bass according to the 12 artisanal and 13 sport fishers interviewed in the Juturnaíba Reservoir and downstream last stretch of the São João River, between September 28 and 08 October 2016.

and that the amount of fish increased, since, according to them, they became trapped in the reservoir.

For the artisanal fishers of the São João River, two other non-native species became more frequent in fishing, the redbreast tilapia and the african catfish *C. gariepinus* (Figure 7B). In addition to changes in the abundance of some species after introduction of the peacock bass, fishers were also asked about the occurrence of other species introduced. Among the 13 cited species, the african catfish, the cachama *Colossoma macropomum* and the cichlid oscar, *Astronotus ocellatus* and the redbreast tilapia were the most cited (Table 5). Six other non-native species were also recorded in scientific samplings (Catelani et al. 2020).

Two interviews in Juturnaíba presented conflicting information, although provided by artisanal fishers who have lived in the region for more than 30 years and depend economically from fishing activity. According to one of them, who did not change his methods of fishing even after the introduction of the peacock bass (basically gillnet and long line), the reduction in the abundance of some species, mainly the tetras and the leporinus is due to the predation exerted by the peacock bass. For the other one who started to offer guide services after the introduction of the peacock bass and whose incomes depend mainly on this activity, the abundance of the tetras actually did not fall. According to him, this apparent reduction of the tetras results from changes on the circadian rhythm of this species which was formerly diurnal and switched to nocturnal habits. Concerning the reduction in the abundance of the toothless, this fisherman believes it preceded the introduction of the peacock bass and is due to the wastewater treatment for public supply, that is released into the reservoir. While the guide has his economic activity directly related to the peacock bass, the other fisherman associated the reduction of the diversity and the fish stock to the peacock bass and complained that it damages the material a lot and has low catchability, since it is able to detect the net and escape, by moving away.

Even though not all fishermen perceive impacts associated with the introduction of the peacock bass, the practices of catch and release are unanimous. According to them, this practice helps to maintain populations of peacock, the fishing activity and strengthens tourism activity. In the Juturnaíba Reservoir, it is easy to verify the presence of signs encouraging the catch and release practice.

DISCUSSION

The people interviewed demonstrated awareness and biological knowledge about the non-native peacock bass in the study area. Artisanal fishers demonstrated a more detailed and a deeper comprehension of their environment, including (i) the anthropic changes experienced since the impoundment and alteration of

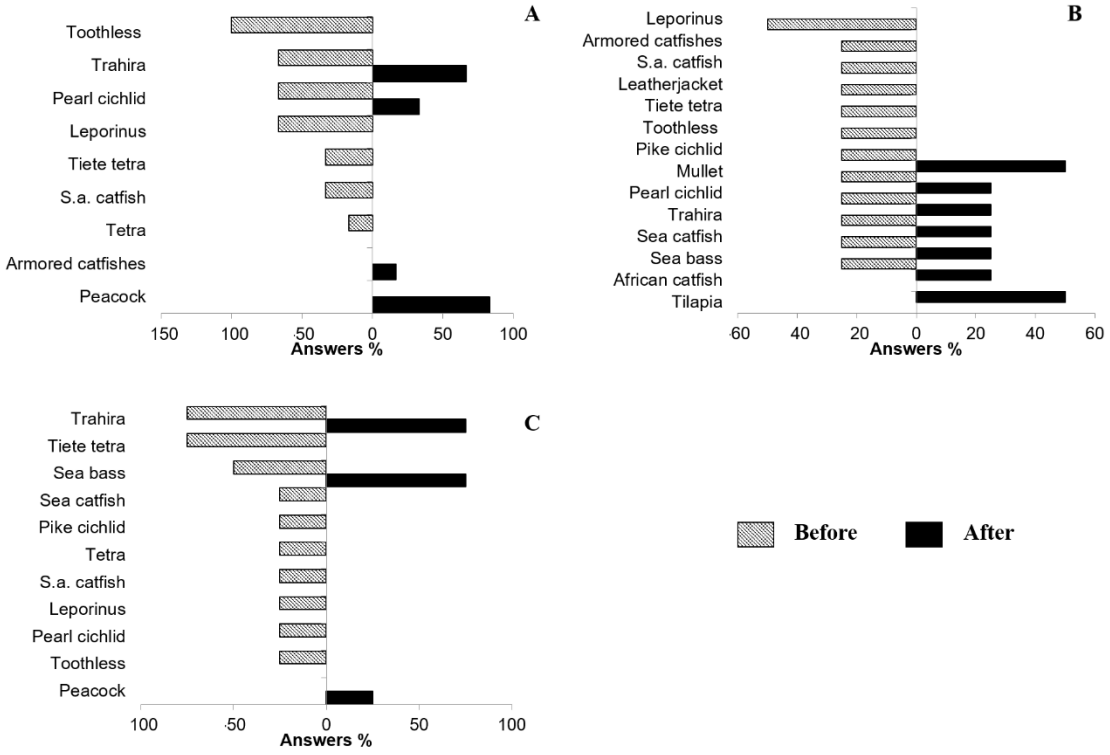

Figure 7. Species cited in the interviews carried out between September 28 and 08 October 2016 with artisanal fishers before and after the introduction of the peacock bass, in the Juturnaíba Reservoir (A); with artisanal fishers before and after the introduction of the peacock bass, in the São João River (B); with sport fishers before and after the introduction of the peacock bass, in the Juturnaíba Reservoir and in the São João River (C).

Table 5. Non-native species in the Juturnaíba Reservoir and downstream last stretch of the São João River which were cited by 12 artisanal and 13 sport fishers interviewed between September 28 and October 8, 2016.The "X" on the last column, indicates species recorded in experimental catches carried out by the authors or records of scientific literature.

Popular name	Scientific name	% Citation by artisanal and sport fishers ($N = 25$)	Recorded in scientific catches
African catfish	*Clarias gariepinus*	40	X
Cachama	*Colossoma macropomum*	24	X
Oscar	*Astronotus ocellatus*	24	X
Redbreast tilapia	*Oreochromis niloticus*	20	X
Spotted sorubim	*Pseudoplatystoma* spp.	20	
Spotted silver dollar	*Metynnis lippincottianus*	8	X
Atipa	*Hoplosternum littorale*	8	X
Arapaima	*Arapaima gigas*	4	
Dorado	*Salminus brasiliensis*	4	
Tiete tetra	*Brycon* spp.	4	
Common carp	*Cyprinus carpio*	4	
Grass carp	*Ctenopharyngodon idella*	4	

the river course throughout channelization, (ii) the decrease of native species and (iii) the introduction of that non-native ones. In fact, the effectiveness of artisanal fishing depends on this type of knowledge (Clauzet et al. 2007; Marques 1991), therefore the more precise responses of artisanal fishers reflect their cultural transmission, daily fishing practice and dependence on the resources in the study area.

In general, the biological knowledge about the peacock bass was similar between artisanal and sport fishers, with exception of the reproductive aspects of the species. Answers were more similar when regarding the consumed feeding items of the peacock bass. The uncertainty in the questions about the reproductive period may be related to the partitioned spawning, characteristic of many species of Cichlidae, including the peacock bass (Gomiero et al. 2009). The seasonal variation in the gonadal volume of the peacock bass is less remarkable than of those single-spawning species (i.e. migratory fishes) (Vazzoler 1996), and particularity this characteristic may hamper the perception of fishers about the spawning periods of this fish. Indeed, other studies have also shown that artisanal fishers have some difficulty in recognizing fish spawning periods elsewhere (Silvano and Begossi 2002; Begossi and Silvano 2008; Silvano et al. 2006; Silvano and Begossi 2010). However, some fishers detailed other reproductive characteristics of peacock bass, such as the deposition of eggs on the substrate, the parental care of both sexes and the establishment and defense of a territory where eggs are laid. In fact, these characteristics are well known to peacock basses that have been reported by other fishers in ethnobiological studies (Moura and Marques 2007). Even though their difficulty of recognizing the spawning period of the peacock bass, the interviewed fishers still provided sound information on the reproductive behavior of this non-native fish.

Fishers of both modalities stated that the peacock bass is a predatory species, which feeds on juvenile fish, including conspecifics, as well as shrimp and aquatic insects. The responses given agree to those gathered in similar studies elsewhere. In the Furnas reservoir, fishers emphasized the predatory ability of the peacock bass (Azevedo-Santos et al. 2010). Among the several aspects and particularities of the peacock bass biology, its voracious behavior seems the main feature used by fishers to associate the possible impacts that the species may cause in an invaded environment. Ethnobiological studies (Azevedo-Santos et al. 2010; Moura and Marques 2007) confirmed the decrease in population and even extirpation of some native species that became prey of the introduced peacock bass in lentic systems (i.e., lakes and reservoirs). The response of a fisherman of Furnas reservoir (Paraíba do Sul River, State of Rio de Janeiro) agrees with the fishers' perception about the peacock's food habit in this study; according to him, the peacock bass is at the top of the food chain of the reservoir, where its natural predator is absent (Azevedo-Santos et al. 2010).

The fishers' perception about the biology of the peacock bass was also compatible with the scientific literature. The reproductive aspects, such as parental care and territorialism (Gomiero and Braga 2004; Winemiller 2001; Winemiller et al. 1997), as well as information about the food habit and the decline in prey populations (Latini and Petrere Junior 2004; Pelicice and Agostinho 2009; Pelicice et al. 2015) were reported for the species in the studied area. Such congruencies emphasize the quality of fishers' knowledge about the species, especially those that use it as a resource.

Besides the detected awareness of the impact of peacock bass predation over fish species, most sport fishers consider the introduction of peacock bass as positive, being favorable to the maintenance of populations in the São João River. This seemingly contradiction is partially based on the importance of the peacock bass as a fishing resource in the environments where it is introduced (Azevedo-Santos et al. 2010; Moura and Marques 2007). For the maintenance of the peacock bass in Juturnaíba Reservoir, most of the sport fishers encourage the practice of catch and release, even if this practice is considered an environmental crime according to Law 9605 of 1998, which prohibits the release of non-native species throughout the national territory (Brasil 1998). Artisanal fishers who maintained fishing methods and targeted species even after the introduction of the peacock bass, claimed a decrease in the abundance of their fishing resources and associated such decrease mainly to the predation by this non-native species. However, those artisanal fishers who adapted their activities including guide services for sport fishers in the fishing of the peacock bass find positive the introduction of the peacock bass, even being aware of its negative impact on the native fauna. Thus, a positive socio-economic impact was verified by the presence of peacock bass in the region, as much for its value in the commerce as for the tourism of the sport fishing.

The guides associate changes in the diversity of some fish species with other anthropogenic factors, such as the dispose of sewage and waste from potable water treatment, as well as the channeling and damming of the river. In Extremoz lagoon, Northeastern Brazil, fishers associate the loss of fish diversity mostly to two major anthropogenic changes: the construction of bridges between the Doce River and the lagoon and the introduction of the peacock bass (Rosa et al. 2014). Due to these changes in Juturnaíba Reservoir, economically important species have become scarce in fishers' catches, such as the tetra and the toothless. As observed in this study, fishers in Neotropical rivers generally recognize the construction of dams as the main factor for the decrease of fish species (Hallwass et al. 2013; Hoeinghaus et al. 2009), especially the migratory ones, which is the case of the leporinus. Furthermore, in addition to the loss of native ichthyofauna associated with the

peacock bass or impoundment, fishers reported the occurrence of an alarming number of the non-native species. Of a total of 25 species cited by fishers in this study, 13 are non-native in the São João River basin. The most cited species was the African catfish, also known to cause many impacts where it is introduced (Weyl et al. 2016).

CONCLUSION

In summary, the ichthyological knowledge gathered with the sport and artisanal fishers of Juturnaíba Reservoir and São João River provide novel information related to the peacock introduction and other anthropogenic impacts. The content of the responses provided by fishers agree with the information reported in other ethnobiological and ichthyological studies. By assessing the fishers' knowledge about fish biology, anthropogenic environmental modifications, and their interaction with the peacock bass, this study highlights that the fisheries management policies should necessarily include non-native fishing resources. Even when causing environmental impacts, non-native species may become more economically important than native species, especially for the sport fishing and tourism associated with this activity.

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DATA AVAILABILITY

The data used to support the findings of this research is available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the idea: PAC, ACP, FMP, RAMS
Data analysis: PAC, ACP, FMP, RAMS
Wrote the first draft of the manuscript: PAC
Wrote the Final versions of the manuscript: PAC, ACP, FMP, RAMS
Supervision: ACP, FMP, RAMS

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Additional Files

Add File 1. Popular and scientific names of the species cited along the manuscript.

Popular name (Portuguese)	**Popular name (English)**	***Scientific name***
Bagre-africano	African catfish	*Clarias gariepinus* (Burchell 1822)
Pirarucu	Arapaima	*Arapaima gigas* (Schinz, 1822)
Cascudo-viola	Armored catfishes	*Loricariichthys castaneus* (Castelnau 1855)
Camboatá	Atipa	*Hoplosternum littorale* (Hancock, 1828)
Tambaqui	Cachama	*Colossoma macropomum* (Cuvier, 1816)
Palombeta	Castin leatherjacket	*Oligoplites* spp.
Carpa	Common carp	*Cyprinus carpio* Linnaeus, 1758
Dourado	Dorado	*Salminus brasiliensis* (Cuvier, 1816)
Carpa-capim	Grass carp	*Ctenopharyngodon idella* (Valenciennes, 1844)
Piau	Leporinus	*Leporinus copelandii* Steindachner, 1875
Tainha	Mullet	*Mugil curema* spp.
Apaiari	Oscar	*Astronotus ocellatus*
Tucunaré	Peacock bass	*Cichla kelberi* Kullander & Ferreira 2006
Acará	Pearl cichlid	*Geophagus brasiliensis* (Quoy & Gaimard 1824)
Jacundá	Pike cichlid	*Crenicichla lacustris* (Castelnau 1855)
Tilápia	Redbreast tilapia	*Oreochromis niloticus* (Linnaeus, 1758)
Robalo	Sea bass	*Centropomus parallelus* Poey 1860
Cumbaca	Singing catfish	*Trachelyopterus striatulus* (Steindachner, 1877)
Pacu	Spotted silver dollar	*Metynnis lippincottianus* (Cope, 1870)
Pintado	Spotted sorubim	*Pseudoplatystoma* spp.
Piaba	Tetra	*Astyanax* spp.
Piabanha	Tiete tetra	*Brycon* spp.
Sairú	Toothless characins	*Cyphocharax gilbert* (Quoy & Gaimard, 1824)
Bagre-branco	White sea catfish	*Genidens barbus* (Lacepède 1803)
Traíra	Trahira	*Hoplias malabaricus* (Bloch 1794)