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TRAFFICKING OF ORNAMENTAL FISH IN THE BRAZILIAN AMAZON*

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ABSTRACT

The trafficking of ornamental fish is growing on a yearly basis in the Brazilian Amazon. This represents a serious threat to the biodiversity of the region. The objective of this research was to evaluate the trafficking of ornamental fish in the Brazilian Amazon using data from the seizures by the Federal Police and Brazilian Institute of Environment and Renewable Natural Resources - IBAMA. To assess and quantify this illegal trade, we gathered data relating to the period between January 2003 and January 2020. Information was obtained from IBAMA - Amazon - regional superintendence; National Amazon Research Institute - INPA regarding smuggled species that have been recovered and placed in its fish collection. The results show that in 98 seizures made by IBAMA, a total of 170,849 specimens of at least 73 species of 10 families, and 5 orders were recovered. Most of the illegally trafficked species are from the Loricariidae family (31 species, 8.47%). *Hypancistrus zebra* (Loricariidae), *Potamotrygon jabuti*, *Potamotrygon leopoldi* (Potamotrygonidae), *Osteoglossum bicirrhosum* and *Osteoglossum ferreirai* (Osteoglossidae) are the most targeted by the traffickers, due to their high value. At least 12 species are undescribed new species and were registered and placed in INPA's fish collection. The fish followed different routes to reach the border that Brazil, Colombia, and Peru share. We conclude that in order to fight this illegal trade, tougher laws against smugglers, agreements with neighboring countries to combat trafficking, formal environmental education programs for riverine populations, and further scientific studies of smuggled species are necessary.

Keywords: aquarium species; conservation; smuggling; *Hypancistrus zebra*; monitoring.

TRÁFICO DE PEIXES ORNAMENTAIS NA AMAZÔNIA BRASILEIRA

RESUMO

O tráfico de peixes ornamentais vem crescendo a cada ano na Amazônia brasileira e representa uma grave ameaça à biodiversidade da região. O objetivo desta pesquisa foi avaliar o tráfico de peixes ornamentais na Amazônia brasileira a partir de dados das apreensões da Polícia Federal e do Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA. Para avaliar e quantificar esse comércio ilegal, reunimos dados relacionados ao período entre janeiro de 2003 a janeiro de 2020. As informações foram obtidas de dados fornecidos pelo IBAMA – Amazonas, na superintendência regional; pelo Instituto Nacional de Pesquisas na Amazonia – INPA, onde as espécies contrabandeadas foram tratadas e depositadas em sua coleção de peixes. Os resultados revelam que em 98 apreensões realizadas pelo IBAMA, um total de 170.849 exemplares de pelo menos 73 espécies, de 10 famílias e 5 ordens foram recuperadas. A maioria das espécies comercializadas ilegalmente são da família Loricariidae (31 espécies, 8,47%). *Hypancistrus zebra* (Loricariidae), *Potamotrygon jabuti*, *Potamotrygon leopoldi* (Potamotrygonidae), *Osteoglossum bicirrhosum* e *Osteoglossum ferreirai* (Osteoglossidae) foram as mais cobiçadas pelos traficantes, por terem alto valor comercial. Pelo menos 12 espécies são novas e não descritas, e estão depositadas na coleção de peixes do INPA. Os peixes seguem rotas diferentes até chegarem as fronteiras com Brasil, Colômbia e Peru. Concluímos que, para combater esse comércio ilegal, são necessárias leis mais rígidas contra contrabandistas, acordos com países vizinhos para combater o tráfico, programas formais de educação ambiental para populações ribeirinhas e estudos científicos adicionais de espécies contrabandeadas.

Palavras-chaves: espécies de aquário; conservação; contrabando; *Hypancistrus zebra*; monitoramento.

INTRODUCTION

The global illegal trade of wild animals is a growing illicit economic activity estimated to be worth US$ 20 billion dollars annually (UNODC, 2020). In Brazil, annual estimates have shown a market of US$ 1 billion dollars (Renctas, 2011). This illegal trade and its increasing numbers of illegal hunters and animal traffickers is a threat to biodiversity, especially considering that about 90% of the animals caught by the traffickers die before their final destination (Wyler and Sheikh, 2008; Renctas, 2016; Charity and Ferreira, 2020; UNODC, 2020).

Brazil is one of the most biodiverse countries on the planet. Moderate estimates suggest that more than 15% of the world's biota is found in Brazil (Joly et al., 2019), thus making it one of the richest countries in mammal species (701), bird species (1,979), reptile species (773) and amphibian species (1,080) (ICMBio, 2018). The country also has about 60.6% of the freshwater fish species found in South America (Reis et al., 2016). According to recent records, 4,545 species of freshwater fish are listed nationwide (ICMBio, 2018), of which 2,716 can be found in the Amazon basin (Dagosta and Pinna, 2019). Some of these species are widely distributed in the Amazon and adjacent basins, but others are endemic to only a few small areas of this basin (Reis et al., 2016). It is estimated that more than 62.4% of these fish species (1,696 species) are endemic to the Amazon (Dagosta and Pinna, 2019).

The freshwater ecosystem in the Amazon basin is the most expressive home to freshwater fish biodiversity on the planet, and one in which occurs significant endemism (Dagosta and Pinna, 2019). This fish endemism of small range regional distribution makes ichthyofauna fragile and vulnerable to human impacts such as deforestation, agricultural and livestock production (Kalamandeen et al., 2018), dam construction (Lees et al., 2016), mining (Asner et al., 2013), urbanization (Jacobs et al., 2013) and trafficking of wild animals (Destro et al., 2012; Renctas, 2016). The high commercial values of the animals combined with this great biological diversity makes the Amazon as a constant target of highly organized and well-equipped animal traffickers (Nogueira, 2008; MPE, 2011).

It is estimated that 38 million specimens of birds, mammals and reptiles are smuggled annually from Brazil, though this number does not include fish and invertebrates (Renctas, 2016). For many years, the trafficking of ornamental fish and the "grooming" of fishermen for capture of fish species that will be smuggled have been reported in the Brazilian Amazon (Cavucens, 1996; Nossa, 2007; Anatole et al., 2008; Nogueira, 2008; MPE, 2011), although this has not been the subject of profound analysis. Regarding the fish, there is a lack of information on the damage that the contraband of ornamental fish causes to the ichthyofauna of the Brazilian Amazon and other regions of the country, which makes it difficult to assess the problem and its impact.

As such, the objective of this research was to evaluate the situation of illegal trafficking of ornamental fish in the Brazilian Amazon using the data available regarding the seizures by the Federal Police and IBAMA, in the period between 2003 and 2020, and verify which locations that these animals are be released in after being seized.

MATERIAL AND METHODS

The data on seized ornamental fish species were gathered for period between January 2003 and January 2020. Data included in this study were obtained from three main sources.

The first was the official registry obtained from the regional superintendence of the Brazilian Institute for the Environment and Renewable Natural Resources - IBAMA in the Amazonas state, which includes the donation agreements provided by the Environmental Protection Directorate - DIPRO/IBAMA, which is the department that releases data on seizures and subsequent donations to research institutions in Manaus (UniNilton-Lins University, INPA: Documents IBAMA-CRC 8C90C3BB).

The second source of data was the records of specimens apprehended by IBAMA/Brazilian Federal Police who place the seized fish in the fish collection of the National Institute for Amazonian Research - INPA, with respective voucher numbers and donation terms.

The third and final source was the number of smugglers who were imprisoned. Data were obtained from statements of Federal Police and IBAMA agents. A detailed analysis of the data was carried out to avoid problems of duplicated information.

Data were analyzed and the total number of illegal ornamental fish per species and the number of seizures were verified. The analysis was performed using descriptive statistics, which included total, average and standard deviation (SD), and tables and graphs.

From all three sources, the following information was extracted: date when the fish were seized, location of seizures (municipality or state), species identification (scientific or popular name), quantity per species or lot seized, type of transport used by traffickers (terrestrial, aquatic or air), and the type of recipient used to maintain the specimens. Furthermore, the route traveled by the traffickers, and the final destinations of the fishes, were obtained.

The compiled list follows the taxonomic classification used by Betancur et al. (2017), with orders organized into systematic/phylogenetic classification, as families, genera, and species in alphabetical order. An update of the scientific taxonomic nomenclature and geographic distribution of the species was carried out using the California Academy of Fishes - CAS Eschmeyer Catalogue of Fish (Eschmeyer et al., 2021) as well as with help from INPA specialists.

The conservation status of the species follows the global classification of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Red Book of Threatened Brazilian Fauna (ICMBio, 2018).

The organization of the data by location (municipalities and states) where illegal catches and seizures of ornamental fish specimens occurred was performed using ArcGis, version 9.3® (ESRI, 2006).

The acronyms presented in the text, L or LDA (for species of Loricariidae) and C or CW (for Callichthyidae species), represent how these species of fish are known internationally (Schraml

and Schäfer, 2004). Taxa considered new species were classified by specialists (fish researchers and taxonomists at the National Institute for Amazonian Research - INPA).

RESULTS

Species and quantities seized

Between January 2003 and January 2020, Brazilian institutions seized around 170,849 specimens of ornamental fish, mostly from the Amazon basin. These included at least 73 species and/or morphotypes of 10 families and five orders (Table 1). The results show that specimens of the order Osteoglossiformes were the most frequent in the seized activity (42.06% of the specimens), followed by Siluriformes (33.83%) and Characiformes (8.52%). The most representative fish seized were from the order of Osteoglossiformes, with the high record of *Osteoglossum bicirrhosum* (25%) and *O. ferreirai* (17%). Among the order Siluriformes, the specie *Hypancistrus zebra* (5.12%) where the most relevant in number, followed by *Corydoras* sp. (Callichthyidae), and *Ancistrus* sp. (Loricariidae) as the highest number of specimens, totaling 40,000 or 23.4% in a single seizure in 2013. For the Characiformes, the specie *Paracheirodon axelrodi* (5.21) was the most apprehended species (Table 1).

Table 1. List of ornamental fish species seized by IBAMA in 98 seizures between January 2003 and January 2020. The numbers indicate the total of specimens seized during operations mainly in the states of the Amazonas and Pará, in addition to the natural distribution of species, conservation status and voucher specimens.

Order/Family/Specie	Popular name	No. seized	%	Distribution[1]	Conservation status[2]	Voucher specimens[2]
MYLIOBATIFORMES						
Potamotrygonidae						
Potamotrygon henlei + *Potamotrygon* spp.	stingray	129	0.08	Toc River (Endemic)	**A, C** - *P. henlei*	**B**
Potamotrygon jabuti	stingray	386	0.23	Tap River (Endemic)	**A, E**	**B**
Potamotrygon leopoldi	stingray	231	0.14	Xing River (Endemic)	**A, C**	**B**
Potamotrygon orbignyi	stingray	5	<0.01	Amaz /Ori / Gui basins	**A, C**	**B**
Potamotrygon wallacei	stingray	10	0.01	Neg River (Endemic)	**A, C**	**B**
OSTEOGLOSSIFORMES						
Osteoglossidae						
Osteoglossum bicirrhosum	white arowana	42,700	24.99	Amaz / Rup / Oia basins	**C**	**B**
Osteoglossum ferreirai	black arowana	29,162	17.07	Neg River (Endemic)	**C**	INPA-ICT 059358
CHARACIFORMES						
Characidae						
Hemigrammus bleheri	rummy-nose tetra	3,320	1.94	Neg and Met Rivers	**D**	INPA-ICT 059367
Paracheirodon axelrodi	cardinal tetra	8,906	5.21	Neg / Ori Rivers	**D**	INPA-ICT 059366
Hyphessobrycon socolofi	tetra	100	0.06	Neg River	**D**	INPA-059365
Lots: (*Paracheirodon* /*H. bleheri* / *Hyphessobrycon*/*Bunocephalus* / *Corydoras*	piabas	2,200	1.29	Neg River	**D**	INPA-ICT 059364
Lebiasinidae						

[1] **Distribution codes**: Amaz = Amazon, Bran = Branco, Esseq = Essequibo, Guap = Guaporé, Gui = Guiana, Jav = Javari, Mam = Mamoré, Met = Meta, Neg = Negro, Oia = Oiapoque, Ori = Orinoco, Par = Paraná, Pry = Paraguay, Pur = Purus, Rup = Rupununi, Tap = Tapajós, Toc = Tocantins, Uau = Uaupés, Ury = Uruguay, Xing = Xingu; Countries: BRA = Brazil and BOL = Bolivia; States: RJ = Rio de Janeiro, SC = Santa Catarina; L = Lower, M = Middle, Cent = Central. [2] **Conservation status and Voucher specimens' codes: A** = Threatened species (CITES, 2017 - appendix III); **B** = Released in natural environment; **C** = Quota regime - exploration in conservation areas (CEMAAM, 2017); **D** = Legally commercialized (IBAMA, 2012); **E** = Commercial species (prohibited as ornamental).

Table 1. Continued...

Order/Family/Specie	Popular name	No. seized	%	Distribution[1]	Conservation status[2]	Voucher specimens[2]
Copella nattereri	spotted tetra	10	0.01	Amaz / Ori Rivers	**D**	
Nannostomus trifasciatus	pencil fish	11	0.01	Amaz / Ori Rivers	**D**	
Crenuchidae						
Crenuchus spilurus	sailfin characin	20	0.01	Amaz / Ori / Gui Rivers	**D**	INPA-ICT 059363
Serrasalmidae						
Pygopristis denticulata	silver piranha	5	<0.01	Amaz / Ori / Gui Rivers	**D**	INPA-ICT 059370
SILURIFORMES						
Callichthyidae						
Corydoras adolfoi	corydora	769	0.45	Neg River	**D**	
Corydoras sp. C21	C21	100	0.06	Xing River	Recognized as possible new species	INPA-ICT 059382
Corydoras aff. *blochi* "tapajós"	corydora	2	<0.01	Tap River	Recognized as possible new species	INPA-ICT 059384
Corydoras bifasciatus	two-stripe corydora	181	0.11	L Amaz River	Currently unstudied	INPA-ICT 05938
Corydoras caudimaculatus	corydora	142	0.08	Guap River	**D**	
Corydoras gossei	corydora	77	0.05	Mam River	**D**	
Corydoras griseus	corydora	544	0.32	Amaz basin	**D**	
Corydoras sterbai	corydora	279	0.16	Cent BRA and BOL	**D**	
Corydoras schwartzi	corydora	1,107	0.65	Pur River	**D**	
Corydoras sp. "jamanxim"	CW 004	7	<0.01	Tap River	Currently unstudied	INPA-ICT 059383
Dianema urostriatum	flagtail catfish	30	0.02	Amaz basin	**D**	INPA-ICT 059369
Scleromystax barbatus	banded corydoras	93	0.05	RJ/SC	**D**	
Lots: (*Corydoras* sp.; including *Ancistrus* sp.)	Corydoras/ plecos	40,000	23.41	Jav River	Currently unstudied	
Loricariidae						
Acanthicus adonis	pleco			Toc River	Currently unstudied	notified only
Ancistrus dolichopterus	L 045	4	<0.01	Neg River	**D**	
Ancistrus hoplogenys	L 183 seda	25	0.01	Amaz / Esseq basins	**D**	INPA-ICT 059381
Ancistrus ranunculus	L 034	22	0.01	Xing / Toc Rivers	**D**	
Aphanotorulus sp. "xingu"	pleco	2	<0.01			

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Table 1. Continued...

Order/Family/Specie	Popular name	No. seized	%	Distribution[1]	Conservation status[2]	Voucher specimens[2]
Baryancistrus niveatus	L 026	223	0.13	Toc River	Critically endangered (ICMBIO, 2018)	
Baryancistrus xanthellus	L 081	1	<0.01	Xing River		INPA-059393
Baryancistrus sp.	pleco	170	0.10			
Hypancistrus debilittera	L 129	4	<0.01	Ori River	Currently unstudied	
Hypancistrus zebra	imperial pleco	8,751	5.12	L/M Xing River	Critically endangered	INPA-ICT 059355; 059372
Hypancistrus sp. (L-333)	pleco L-333	214	0.13	L/M Xing River	Recognized as possible new species	INPA-ICT 059389
Hypancistrus sp. "zebra marrom"	L-174	11	0.01	L/M Xing River	Recognized as possible new species	INPA-ICT 059375
Hypancistrus sp.	pleco	241	0.14		Possible new species	INPA-059390
Leporacanthicus joselimai	L 263	54	0.03	Tap basin	**D**	
Megalancistrus parananus	L 113	2	0.00	Pry / Ury	Off the endangered list (IBAMA)	
Spectracanthic punctatissimus	LDA 14	59	0.03	Xing and Toc Rivers	**D**	
Panaqolus tankei	L-398	465	0.27	Xing River	Recently described new species	INPA-ICT 059387
Panaque armbrusteri	L-027	42	0.02	Tap River basin	**D**	INPA-ICT 059353
Panaque sp.	panaque	110	0.06			
Peckoltia braueri	peckoltia L-135			Neg / Bran River	**D**	
Peckoltia sabaji	L 075	166	0.10	Ori River		
Peckoltia vittata	L 015	182	0.11	L/M Amaz River	**D**	
Peckoltia sp.	peckoltia	36	0.02			
Pseudancistrus sp. "xingu"	pleco	2	<0.01		Recognized as possible new species	Endemic to Xingu River
Pseudacanthicus pirarara	L 025	38	0.02	L/M Xing River	Recently described	INPA- 05935
Pseudacanthicus sp. "tapajós"	L-097	48	0.03		Recognized as possible new species	INPA-ICT 059356

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Table 1. Continued...

Order/Family/Specie	Popular name	No. seized	%	Distribution[1]	Conservation status[2]	Voucher specimens[2]
Scobinancistrus aureatus	L 014	104	0.06	Xing River	Vulnerable (MMA, 2018)	INPA- 05939
Scobinancistrus pariolispos	L 048	22	0.01	Toc/Tap River basins	Vulnerable (MMA, 2018)	INPA-ICT 059357
Scobinancistrus sp. "tubarão"	L 082 - tubarão pleco	31	0.02		Recognized as possible new species	INPA-ICT 059376; 059394
Scobinancistrus sp. / *Peckoltia* sp.	Pleco	422	0.25		Currently unstudied	
Spectracanthicus punctatissimus	L 315	1	<0.01	Xing River basin	Off the list (IBAMA)	
Lots: (*Parancistrus* sp. / *Peckoltia* cf. *vittate* / *Scobinancistrus* sp. / *Baryancistrus* sp.	plecos	3,022	1.77	L/M Amaz River	Currently unstudied	
Pimelodidae						
Phractocephalus hemioliopterus	redtail catfish			Amaz/Ori	**E**	notified only
Pseudoplatystoma tigrinum	tiger sorubim			Amaz basin	**E**	notified only
Pseudoplatystoma punctifer	tiger catfish			Amaz basin	**E**	notified only
CICHLIFORMES						
Cichlidae						
Aequidens pallidus	doublespot acara	10	0.01	Amaz basin	**D**	INPA-ICT 059362
Apistogramma agassizii	dwarf cichlids	10	0.01	Amaz basin	**D**	INPA-ICT 059359
Apistogramma gephyra	dwarf cichlids	10	0.01	L Neg River	**D**	
Apistogramma hippolytae	dwarf cichlids	10	0.01	Neg River		INPA-ICT 059361
Apistogramma mendezi	cichlids	1	<0.01	Neg River	**D**	
Apistogramma meinkeni	dwarf cichlids	10	0.01	Uau River	**D**	
Apistogramma sp.	dwarf cichlids	181	0.11	Tap River		INPA-ICT 059386
Dicrossus filamentosus	xadrez	389	0.23	M Neg River	**D**	INPA-ICT 059360
Symphysodon discus	discus	1	<0.01	Neg River	**D**	
Others species unidentified					Currently unstudied	
Ornamental fish	varieties	25,227	14.77	Xing/Tap Rivers	Currently unstudied	
Total		**170,849**	**100**			

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In total, 98 seizures were recorded in separate IBAMA/Federal Police operations, a number that has been growing exponentially in recent years (Figure 1A). Most of the seizures in 2014 were due to more rigorous inspections, mainly at the airport in Manaus. However, many seizures also occurred in 2015 (Figure 1A). On average, 10,678 specimens are seized per year, although this number may vary greatly from year to year (Figure 1B). For example, in 2013, there was a significant quantity of seized specimens that are related to the operations of the IBAMA/Federal Police on the northern border with Colombia and Peru, during which a significant volume of *Corydoras* sp. and *Ancistrus* sp. were seized (Table 1, Figure 1B).

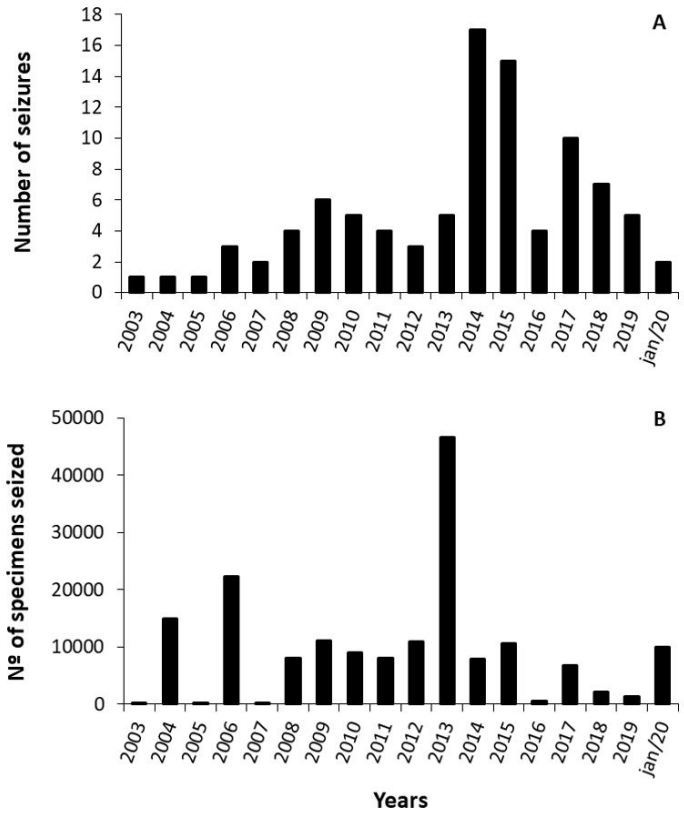

Figure 1. Number of seizures (A) and quantity of fish seized (B) by IBAMA/Brazilian Federal Police from January 2003 to January 2020.

Main fish species seized

The most frequently seized species was the *H. zebra*, which was present in 44.6% of the seizures, followed by *Potamotrygon jabuti* (23.5%), *P. leopoldi* (19.4%) and *O. ferrerai* (13.3%).

In three different operations, foreigners were also arrested transporting ornamental fish, and among the species seized in these three operations were *Acanthicus adonis*, *Peckoltia braueri* and *Apistogramma gephyra*. On the list of smuggled species, we found 37 that are normally allowed for export as ornamental fish by the Normative Instruction that was in force at the time (No. 001 January, 2012; IBAMA, 2012), however, they were either seized together with other species prohibited for export, or their owners had no legal authorization for their transportation and commercialization. Among these species, we find all the species of the order Characiformes, as well as some species of the order Siluriformes (Callichthyidae family), *Corydoras adolfoi*, *C. gossei*, *C. griseus*, *C. sterbai*, *C. schwartzi*, *Scleromystax barbatus* and *Dianema urostriatum*; and the Loricariidae family, *Ancistrus hoplogenys*, *A. dolichopterus*, *A. ranunculus*, *Baryancistrus niveatus*, *Hypancistrus* sp. (L-333), *Leporacanthicus joselimai*, *Pseudacanthicus punctatissimus*, *Panaqolus tankei* (L-398), *Panaque armbrusteri*, *Peckoltia brauri*, *P. vittata, Pseudacanthicus* sp. and all the Cichliformes (Cichlidae) species. Other lots were identified only by popular name or by quantity seized and these accounted for 15.9% of the specimens (Table 1).

Six species, such as *Phractocephalus hemioliopterus*, *Pseudoplatystoma tigrinum*, *Pseudoplatystoma punctifer*, all of them catfish of large size and sold by commercial fisheries, as well as *Apistogramma gephyra*, *Acanthicus adonis* and *Peckoltia braueri* (small species), were only mentioned in the seizures, without the number of specimens (Table 1).

At least 12 species are new and have been deposited in the fish collection at INPA. Among these species are *Aphanotorulus* sp. "xingu", *Baryancistrus* sp., *Hypancistrus* sp. (L-333), *Hypancistrus* sp. "zebra marron pleco" (L 174), *Hypancistrus* sp., *Peckoltia* sp., *Pseudancistrus* sp. "xingu", *Pseudacanthicus* sp. "tapajós" (L-097), *Scobinancistrus* sp. "tubarão", *Apistogramma* sp., *Corydoras* sp. "jamanxim" (CW 004) and *Corydoras* sp. (C21) (Table 1).

In addition to the aforementioned four species, other genera of the Loricariidae family were apprehended, and included *Acanthicus, Ancistrus, Aphanotorulus, Baryancistrus, Hypancistrus, Leporacanthicus, Megalancistrus, Panaqolus, Panaque, Peckoltia, Parancistrus, Pseudancistrus, Pseudacanthicus, Scobinancistrus* and *Spectracanticus* (Table 1). Among all these species, 33 of them have material deposited in the fish collection of the National Institute for Amazonian Research (INPA) (Table 1, Figure 2).

At least 60.0% of the seized lots contained mainly arowana or dragon fish (*Osteoglossum* spp.), stingrays *(Potamotrygon* spp.) and species of plecos (Loricariidae), and these fish were released back into their natural environment by the relevant environmental agency, and others were donated to research institutions (INPA, Universidade Nilton Lins – UniNilton-Lins, Universidade Federal do Amazonas – UFAM and Centro de Instruções de Guerra na Selva - CIGS). However, in the present research we do not have the exact percentage of fish that were donated to each of these research institutions. Some of the species of stingrays commonly seized in police operations can be seen in Figure 3.

Types of recipients used to transport ornamental fish

Traffickers generally use transparent plastic bags with some water and partially pressurized oxygen, and these are hermetically sealed and transported in ways that are unsuitable for animal welfare. As an example, specimens of *H. zebra* seized in bags

Figure 2. Species of ornamental fish seized by IBAMA and Brazilian Federal Police that have been deposited in the INPA fish collection. (A) *Hypancistrus zebra*; (B) *Hypancistrus* sp. "zebra marron pleco"; (C) *Pseudacanthicus* sp. "Tapajós" (L097); (D-E) *Hypancistrus* sp. or L-333, (F) *Scobinancistrus* sp. "tubarão"; (G) *Scobinancistrus aureatus*; (H) *Pseudacanthicus pirarara* (recently described); (I) *Corydoras* sp. "Jamanxim" CW 004; and (J) *Apistogramma* sp. live specimen in a laboratory at INPA (bar = 1 cm).

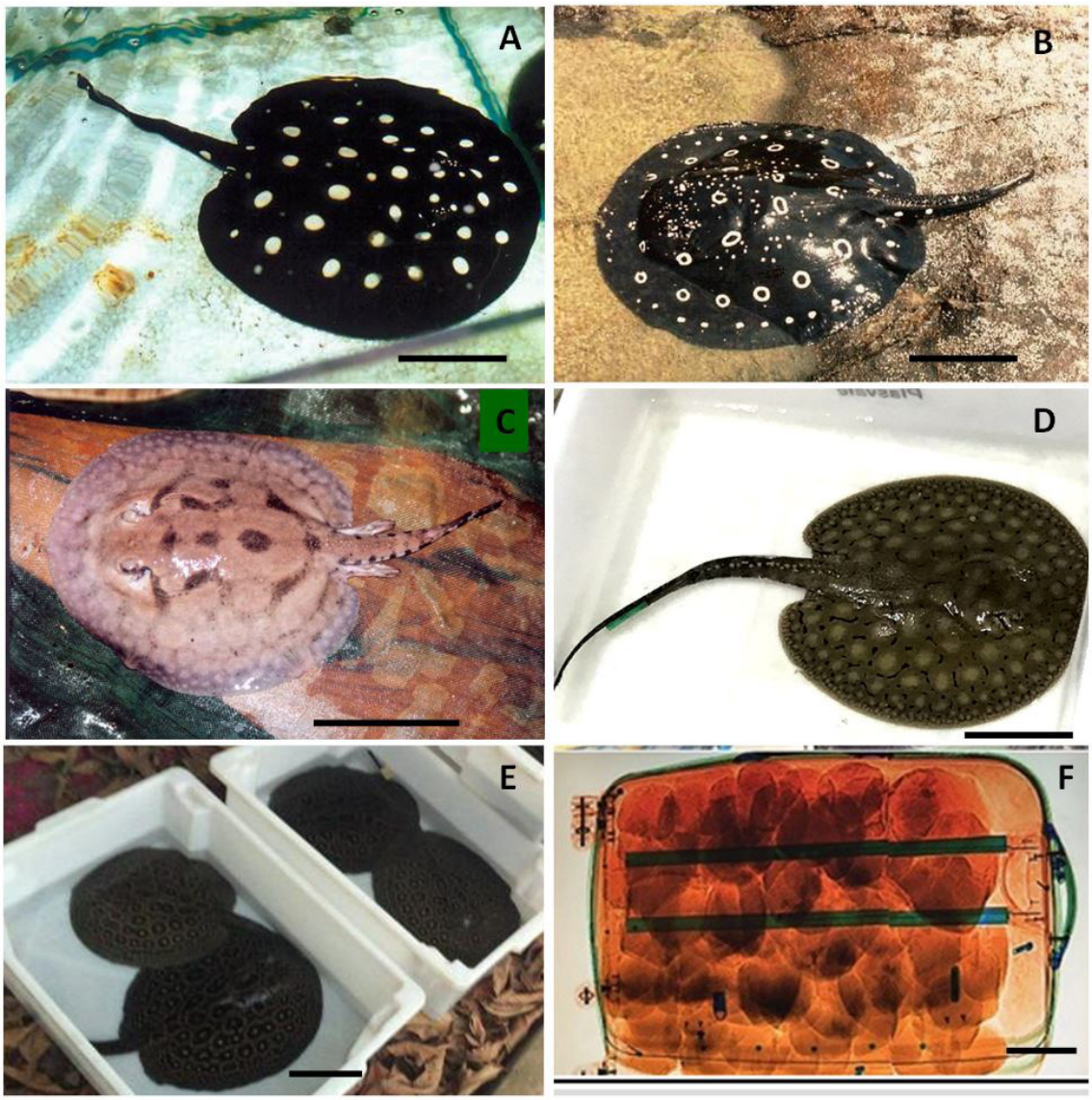

Figure 3. Stingray species (*Potamotrygon* spp.) usually encountered during seizures: (A and B) *Potamotrygon leopoldi* variation standard color, (C) *Potamotrygon wallacei*, (D) *P. orbignyi* (E) *Potamotrygon jabuti* and (F) x-ray of suitcase at Santarém Airport, with *P. jabuti*. (Credits: B-C Project Piaba; E-F Civil Police of the State of Pará, Santarém) (bar = 10 cm).

at Manaus airport are often packed in 500 mL (capacity) plastic bags and, depending on the size of the animals (2-4 cm standard length), between 3 to 5 specimens are packed in each plastic bag. In the plastic bags, the smugglers put a minimal amount of water (approximately 50-60 mL) and the rest of the bag is filled with pressurized oxygen and tied with a rubber band.

Most of the specimens do not survive this type of conditioning, since both the minimal amount of water and the excess oxygen in the environment can harm the animals (Zuanon, J.A.S, personal communication[a]). At the time of the seizures, most of the specimens are usually already close to death (between 10 to 50% die depending on the amount of time they are in the container, generally 2 to 3 days, for example (Zuanon, J.A.S., personal communication[a]). Most of the animals do not survive the long trips to their final destination in the importing countries.

Some species of the Loricariidae family, such as the genus *Pseudacanthicus* and *Scobinancistrus*, are individually packaged in small plastic bottles (Figure 4), in which the traffickers drill a few holes so that the water from the plastic bag flows freely into the bottle. Such a system is to prevent the spines and odontodes of the fish making holes in the plastic bags in which the specimens are packed. These transport conditions certainly cause serious discomfort to the animals, since they are maintained in very small containers. Some of the individuals donated by IBAMA/Federal Police to local research institutions (INPA and universities) are generally animals that are already very debilitated and have suffered greatly during transportation (Figure 4).

[a] Jansen Alfredo Sampaio Zuanon, Biodiversity Coordination - INPA, Oct. 15, 2019.

Figure 4. (A) Seizure of a suitcase belonging to ornamental fish traffickers at Manaus International airport; (B) identification of specimens at INPA, showing the type of improper recipient that are generally used by traffickers, and (C) a large number of specimens do not survive transport (Photos: Akemi Shibuya/INPA).

A portion of the seized ornamental fish are forwarded and donated to research institutions (Instituto Nacional de Pesquisas da Amazônia - INPA, Universidade Federal do Amazonas - UFAM, Universidade Nilton Lins - UniNilton-Lins, Universidade Federal do Oeste do Pará - UFOPA, Universidade Federal do Pará - UFPA, and public aquariums such as the Jungle Warfare Instruction Center - CIGS). At INPA, for example, there are 6,029 specimens of illegal fish catalogued, 1,150 of which are listed in the zoological collection. However, for other institutions we do not have an exact number of what has been donated.

Routes of the traffic and traffickers

Seizures were made in six cities (Belém, Altamira, Santarém, Itaituba, São Félix do Xingu and Goianésia do Pará) located in the state of Pará, and eight cities (Manaus, Tabatinga, Novo Airão, São Paulo de Olivença, Benjamin Constant, Tonantins, Santo Antônio do Içá and Codajás) in the state of Amazonas.

The main species targeted by ornamental fish traffickers in the Amazon followed different routes, which depend on the organization of the traffickers according to the final destination of the smuggled species. Manaus was the city with the highest number of seizures (42 seizures; 42.9%), followed by Altamira (10; 10.2%), Tabatinga and Santarém (9; 9.2%, each) and Belém (8; 8.2%). Another nine cities registered 20 seizures (Table 2). The greater representativeness of the city of Manaus, Santarém and Belém in relation to the number of seizures is due to the fact that these cities have a more rigorous level of inspection, with X-ray machines at international airports, which identify the individuals smuggling fish. In addition, seizures were also carried out on rivers such as the Xingu, Javari, and Amazonas and in the Mairea Sustainable Development Reserve (Table 2).

Airplanes are the most commonly used form of transport used by traffickers, due to the rapid displacement between cities, and which possibly avoids excessive fish mortality. However, fluvial transport is also significant; mainly in cities such as Tabatinga, Benjamim Constant, Santo Antônio do Içа and Tonantins that are close to the northern border with Colombia and Peru, all these cities are linked by rivers (Table 2).

Seizures have also been carried out on terrestrial transport, which occurs through the AM 070 highway (Novo Airão-Manacapuru, in the Amazonas state), PA 279 highway (São Felix do Xingu) and BR 010 highway (Belém-Brasília) in the Pará state. Other terrestrial seizures were carried out in the cities of Santarém, Manaus and Novo Airão (Table 2).

The period of the year in which most seizures occurred was the rainy season (57 seizures), however, in the dry season, there was also a moderate number of seizures (41) (Table 2). Air transport is mostly used for smuggling of Loricariidae (~ 31 species) and stingrays (6 species), which occurs in both the dry and the rainy seasons; 46% were seized in the rainy season and 54% in the dry season. For the stingrays, 59% were seized in the rainy season and 41% in the dry season. In fluvial transport, the greatest seizures of *Osteoglossum* spp. (arowana - two species), occurred mainly in Tabatinga and surrounding cities. For arowana, 93% were seized in the rainy season and 7% at the end of the dry season. In terrestrial transport, species of *Potamotrygon* spp. (3 species) were seized in cities in the Pará state, and were bound for Belém (capital of the state).

Analyses of all the information mentioned by the Federal inspection agents (Federal Police/IBAMA) reveal that the trafficking routes can follow different paths. On fluvial routes, for example, agents found lots of *H. zebra, Potamotrygon* and other species of Loricariidae from the Xingu and Tapajós Rivers (all with high value) being transported from Altamira and/or Itaituba (Pará state) to Santarém and then transported on commercial flights to Manaus, to reach Letícia (Colombia) and Santa Rosa (Peru)

Table 2. Number of seizures carried out in the main cities of the Amazon that traffickers use as trafficking routes, in addition to locations outside the municipalities, transport route and season for the period between January 2003 and January 2020.

Cities	Number of Seizures	%	Transportation facilities			Season	
			Air	Fluvial	Terrestrial	Rainy	Dry
Manaus	42	42.9	40	1	1	22	20
Tabatinga	9	9.2	4	5		7	2
Novo Airão	3	3.1		2	1	3	
Santo Antônio do Içá	1	1.0		1		1	
São Paulo de Olivença	4	4.1	4			3	1
Benjamin Constant	1	1.0		1		1	
Tonantins	1	1.0		1		1	
Codajás	1	1.0		1		1	
Belém	8	8.2	7		1	4	4
Santarém	9	9.2	5	3	1	3	6
Altamira	10	10.2	8	2		5	5
Itaituba	2	2.0	2			2	
São Félix do Xingu	2	2.0			2		2
Goianésia do Pará	1	1.0	1			1	
Other locations (Mamirauá reserve, Xingu River, Javari River, Amazon River)	4	4.1		4		3	1
Total	**98**		**71**	**21**	**6**	**57**	**41**

(Figure 5). From Altamira and Itaituba to Belém, traffickers used different routes, by air, terrestrial and even fluvial means, in order to leave the country on international flights from Belém. The illegal species were exported using the name of legally exported species (Figure 5).

Traffickers also rent small private airplanes to transport illegal species directly from Altamira or Itaituba (Pará state) to small cities in the Amazonas state, located near the border with Colombia and Peru. These cities, such as São Paulo de Olivença, Benjamin Constant, Santo Antônio do Içá, and Tonantins have small airports

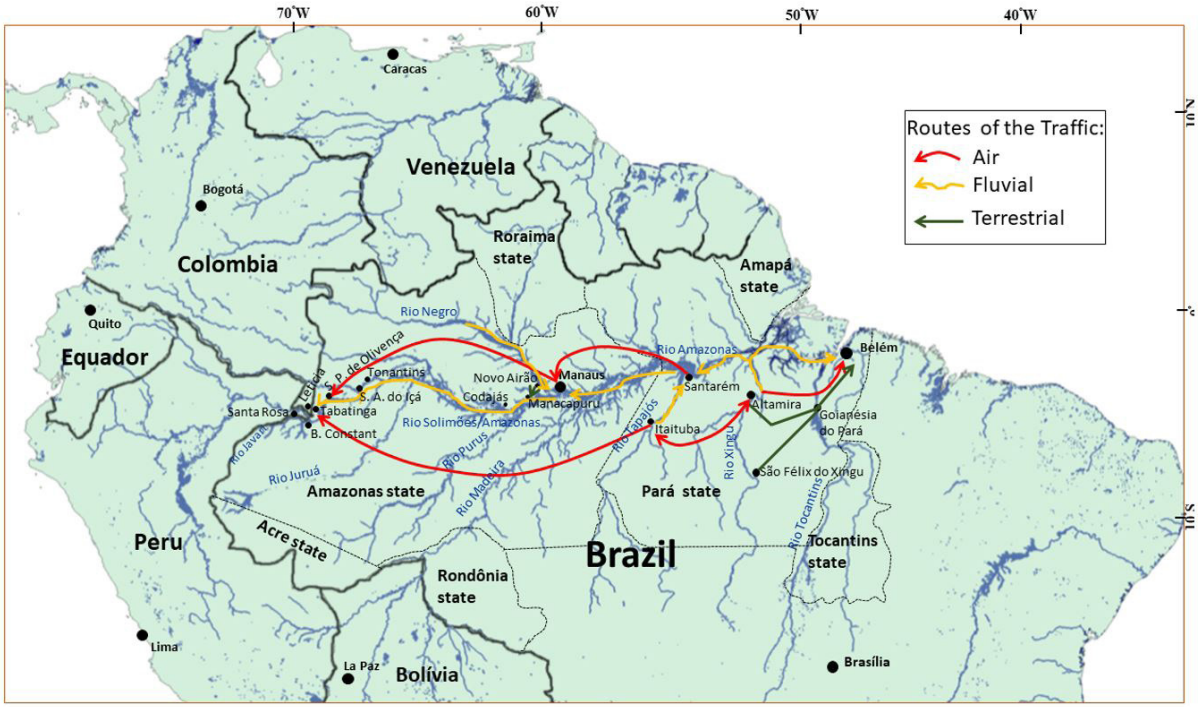

Figure 5. Partial map of Brazil and adjacent countries showing the main cities used as ornamental fish trafficking routes, and the cities in which the traffickers are most active.

with little control. From these locations, the ornamental fish are transported in small boats to the cities of Letícia (Colombia) and Santa Rosa (Peru), and from there they follow international routes. In one example, police captured a shipment in Santarém with 40 stingrays *P. jabuti* and 400 plecos *Scobinancistrus* sp./*Peckoltia* sp. and in São Paulo de Olivença a shipment with 40 stingrays *P. jabuti* and 300 *Scobinancistrus* sp./*Peckoltia* sp. and this cargo was evaluated at U$S 30,000.00 and U$S 16,000.00, respectively.

The smuggling route for black arowana specimens (*O. ferreirai*) generally follows fluvial routes, leaving the Negro River through the city of Novo Airão (AM-070 highway), often going by terrestrial route to the city of Manacapuru in the Amazonas state and leaving from there for the northern border with Colombia and Peru (Figure 5). The white arowana (*O. bicirhossum*) are usually caught in the floodplains of the mid and upper Solimões/Amazon River (in the Extractive Reserves of Mamirauá and Auatí-Paraná) and transported via fluvial routes directly to the cities of Tabatinga, and then to Leticia, Colombia (Figure 5). The operations carried out by the government agencies in the period of this survey (2003-2020) culminated in the arrest of 95 traffickers, many of them couriers who are contracted by the traffickers.

DISCUSSION

Fisheries of ornamental fish in the Brazilian Amazon

Ornamental fish have been commercialized in the Brazilian Amazon since the 1950s (Chao et al., 2001). The exploitation of these fish as pets is an important aspect of the extractive economy of mainly the Amazonas and Pará states (Prang, 2001; Prang, 2007; Anjos et al., 2009; Carvalho-Junior et al., 2009). Work carried out for decades by the Piaba Project in the middle Negro River reveals that ornamental fish can be a sustainable resource if they are taken from rivers in the region without causing damage to the environment. As a result, these fisheries can bring income to fishers and benefit the entire production chain (Chao et al., 2001).

However, there exists a parallel illegal market that is always looking for new varieties (new species that may have great potential for export). International importers, with little or no legislation in their countries, are constantly seeking species with potential to generate more sales, which encourages illegal fishers from some remote regions like the Amazon to catch species that are endangered or vulnerable (Cavucens, 1996; Rapp Py-Daniel and Zuanon, 2005; Prang, 2007; Anatole et al., 2008).

The black market for ornamental fish has existed in Brazil for many years (Renctas, 2011), and is quite intense in the northern region (Cavucens, 1996). Cavucens (1996) reported that indigenous peoples of the Javari River located on the northern border (Brazil-Peru) were enticed by smugglers at that time to catch ornamental fish, and many ornamental fishers are also involved in this practice (Nossa, 2007).

Nevertheless, the dimension of this activity in the Amazon basin is very difficult to measure, since the seizures made by the government agencies presented in this paper represent only a small fraction of what is illegally exported. Thus, it is not possible to estimate the quantity of ornamental fish that have been smuggled through the border with Colombia and Peru via the Amazonas state.

Data on wildlife trafficking in and from the Brazilian Amazon is notoriously scarce and whatever data do exist are scattered across the multiple law enforcement agencies (federal and state) responsible for combatting illegal trade in wildlife in the region (Charity and Ferreira, 2020); therefore, the available data regarding ornamental fish are not consolidated in a single database. We observed that high demand for illegally fished ornamental fish species comes from aquarists, mainly from developed countries (e.g., the United States and Japan; Pedersen, 2016) or emergent countries as China (Sousa et al., 2021), and Taiwan (Tribuzy-Neto et al., 2020).

We have found that, in the list of smuggled species, at least 12 species are new species and were deposited in the fish collection at INPA. Another 37 species, which are normally permitted by law for export as ornamental fish (IBAMA, 2012), were seized together with consignments of species that are prohibited for export, or their owners had no legal authorization for the transportation and commercialization of any type of animals.

In addition to seizures involving Brazilian ornamental fish traffickers, there are also seizures involving foreigners who come to visit the country on tourist visas and try to return to their home countries with ornamental fish hidden in their luggage. According to our research, among the species seized in the possession of these foreigners were *Acanthicus adonis*, *Peckoltia braueri* and *Apistogramma gephyra*.

Taking into consideration the total number of seizures, the recorded numbers of *Hypancistrus zebra, Potamotrygon jabuti, P. leopoldi, Osteoglossum ferrerai* and other species, especially those that are new to science, demand inhibitory action that promotes their conservation, since these are endemic species and frequently encountered in seizures. The high rate of seizures of these four species is because these species are either prohibited for commercialization or have quota regimes and, therefore, command high prices on the black market.

The traffickers' favorite species

The Imperial pleco (*H. zebra* - L046), endemic to the middle Xingu River (Pará state), was legally exported until 2004 (Bourscheit, 2019; Tapullima, 2019; Sousa et al., 2021), when was commercialized about 22,240 specimens (Anjos et al., 2009). However, due to evidence of depletion of natural stocks, and local endemism, its export was prohibited by the Normative Instruction Nº. 5 of May 21st, 2004 (MMA, 2004). Nevertheless, demand has continued high due to its beauty (Anatole et al., 2008) and because demand for a given species may increase when it is included in the Red List (Demeau et al., 2019; Sousa et al., 2021); as a result, this species has been suffering a drastic reduction in its natural population.

Previous estimates in 2008 show that about 500 specimens per week were illegally transported from the city of Altamira (Anatole et al., 2008), which represents 26,000 specimens annually. Since 2004, rampant fisheries have caused a fall in the population density of the species (Rapp Py-Daniel, L.H., personal

communication[b]). Although, more recent studies conservatively estimate that ~100,000 specimens are trafficked out of Brazil annually, of which half or more die in transport, and only a small fraction is seized by law enforcement in Brazil or internationally (Sousa et al., 2021).

In addition to illegal fisheries, the Imperial pleco and other species of Loricariidae still suffer from other equally serious environmental problems that occur in the region, such as deforestation, mining, and the construction of the Belo Monte hydroelectric dam, which is located on the Xingu River, precisely in the habitat of the Imperial pleco and other endemic species (Camargo et al., 2012; Sousa et al., 2021). The *H. zebra* and *B. niveatus* are on the list of critically endangered species (CITES, 2017), as well as the Red List of Endangered Brazilian Species (ICMBio, 2018). Other species of Loricariidae (many of them new species) suffer the same type of situation that occurs with *H. zebra*. The interest of the international trade in illegal ornamental fish has increased exponentially in recent years (Pedersen, 2016), and there is a greater demand for these species, as evidenced by the present research through the increase in seizures observed in recent years in the Brazilian Amazon.

In addition to the zebra pleco, all species of Brazilian freshwater stingrays (*Potamotrygon* spp.) are also listed in Appendix III (CITES, 2017) and their status is considered threatened. Nevertheless, some species of stingrays in the Amazon are still legally exported from the Amazonas and Pará States every year, through a quota regime, IBAMA - Decree Nº. 36/03 of 25th June, 2003 (IBAMA, 2003) and IBAMA Normative Instruction No. 19, of 19th November, 2013 (IBAMA, 2013). Up to 1,000 specimens of the stingray *P. henlei* (endemic to the Tocantins River) can be caught and commercialized per year, and 5,000 *P. leopoldi* (endemic to the Xingu River) specimens per year according to the current annual quota regime (Ramos, 2017). *Potamotrygon motoro* and *P. orbignyi* have a wide distribution in the Amazon basin, and about 5,200 and 1,000 specimens can be captured, respectively. For *P. wallacei* and *P. schroederi* (in the Negro River), the quotas are 6,000 and 1,000 specimens per year, respectively (Ramos, 2017).

Regarding the quota regime, the smugglers exercise influence with corrupt government agents, and many politicians, and demonstrate great influence in the Ministry of Fisheries and Aquaculture regarding the quotas allocated for stingrays in the Brazilian Amazon, as demonstrated in the operation "Enredados", which investigated a criminal organization based in Brasília (Federal District) and had ramifications in the Pará and Rio Grande do Norte states. So far, there have been no studies regarding the impact of catch quotas on the populations of stingrays, since they are species with low fertility and high longevity (Queiroz et al., 2013) and therefore have low resistance to overfishing.

The black arowana (*O. ferrerai*) (endemic to the Negro River) and the white arowana (*O. bicirrhosum*) (widely distributed in the Amazon) had their commercialization as ornamental fish prohibited by IBAMA Ordinance No. 62-N of June 10th, 2002 (IBAMA, 1992). However, in 2017, the Amazonas state government permitted commercialization of larvae and juveniles under a quota regime inside sustainable development reserves (CEMAAM, 2017).

The Amazonas state supplies ornamental fish, such as the black arowana (*O. ferrerai*) and the white arowana (*O. bicirrhosum*), for the trafficking through the northern border with Colombia and Peru. Colombia exported more than 1,060,000 juveniles *Osteoglossum* in 2004, while Peru exported more than 1,257,000 juveniles of this species in 2003 (Moreau and Coomes, 2007). We do not know, however, what percentage of *Osteogrossum* comes from the trade of ornamental fish in Brazil, since most of the seizures of juveniles of the two species were carried out mainly near the aforementioned border.

We also do not know the quantity of fish that are produced legally in captivity or captured in nature illegally. However, the fishers of the lower and middle Xingu River (Pará state) are paid between US$ 1.89 and US$ 4.72 per specimen of imperial pleco (L-046) (Anatole et al., 2008; Rapp Py-Daniel, L.H., personal communication[b]). Although, Sousa et al. (2021) states that "the price paid to them is nearly as low (US$ 7.00 nominal, US$ 11.00 inflation corrected) per specimen as the minimum amount (US$ 5.00 nominal, US$ 7.00 corrected for inflation) they received prior to 2004".

The highest price in the early 1990's for a specimen of *H. zebra* was US$ 500.00 (Sousa et al., 2021), but presented a decreasing in this price in the years ahead. A wholesale sales record from the United States from 1993 lists a sale price of US$ 12.00/fish (US$ 21.00, corrected for inflation). The inclusion of the zebra pleco in the CITES (2017) - Appendix III led to a new increase in demand and increased in the price of trafficked fish from a wholesale price from US$ 45.00 (US$ 48.00, corrected for inflation) to an average US$ 90.00-120.00 (US$ 95.00–127.00, corrected for inflation) per individual (Sousa et al., 2021). Although, in the market, the imperial pleco was also sold to customers for US$ 600.00 in Japan (Pedersen, 2016).

The stingray *P. jabuti* fetches far higher values and these can be as much as US$ 3,844.00 per specimen. The black arowana (also known as the "dragon fish") can fetch values of between US$ 450.00 to US$ 600.00 per individual, due to high demand in Asian countries. These exorbitant values generate the flow of capital that finances the trafficking of ornamental fish in the Amazon basin. Meanwhile, the market is always looking for news species, and usually these new species come from the Amazon, due to the region's expressive diversity of fish species.

Mistreatment of animals and donations

The investigation known as Operation Poseidon (Federal Police and institutions environments) proved the existence of mistreatment of animals by the group of the traffickers, since the fish were transported in suitcases with little oxygen and space. Under these conditions, many of the animals died during transport.

The transport containers are inadequate due to the insufficient packaging of the specimens, and many fish arrive debilitated due to this poor condition. According to the manual of good practices of management and well-being of Amazonian ornamental fish of the Secretariat of Fisheries and Aquaculture (Araújo, 2013),

[b] Lúcia Helena Rapp Py-Daniel, INPA researcher, Dec. 19, 2019

for the well-being of ornamental fish, there is a need for good quality water and oxygen and an adequate number of specimens in containers, which can avoid the excess stress, injuries and abrasions in fish, which increase the mortality rate during transport (Araújo, 2013).

A significant proportion of the ornamental fish seized alive are sent to research institutions of the region (National Institute for Amazonian Research - INPA, Federal University of Amazonas - UFAM, Centro Universitário UniNilton-Lins, Federal University of West Pará - UFOPA and Federal University of Para - UFPA). The UFPA Altamira campus, for example, hosts the exhibition "Discovering the fish of the Xingu River", and its main objective is to educate the population about the river and its fish, with emphasis on the preservation of species, and reproduction of endangered species such as the *Hypancistrus zebra* (Sousa et al., 2021). The National Center Research for Conservation of Freshwater Fishes (Chico Mendes Institute), has the National Center for Research and Conservation of Amazonian Biodiversity - CEPAM, in Manaus, which highlights the monitoring of Amazonian aquatic biodiversity through the assessment of the risk of extinction of Amazonian continental fish species, the performance in national action plans for the recovery of endangered species in the biome, participation in research projects, and the implementation of environmental education.

Current environmental laws

Until March 2020, only 725 species of ornamental fish (~ 500 species from the Amazon) could be legally caught and sold as ornamental fish (IBAMA, 2012). However, recently published legislation (Decree SAP/MAPA No 17, of January 26th, 2021 (MAPA, 2021) permits a large part of the species to be used for ornamental purposes, except those on the list of endangered species in Brazil (ICMBio, 2018), and the species that are on the CITES list (CITES, 2017). In addition, six species of stingrays (all on the CITES list) are allowed to be caught under quota regimes in the Amazonas and Pará states (IBAMA, 2013), as well as two species of *Osteoglossum* (larvae and juveniles) from sustainable areas managed in the Amazonas state (CEMAAM, 2017).

Brazilian laws have been standardized with the laws of its neighboring countries (Colombia and Peru) and indicate which species can or cannot be exported (IBAMA, 2012). Although Brazilian environmental laws were created to protect biodiversity, the resources of public inspection agencies are not sufficient to the point that they are able to cover all areas and regions, particularly in regard to the number of specialized professionals needed to supervise the species on the list. Since the number of agents is low, this weakens their supervisory power.

Although, a new decree MAPA/SAP, No 17, from January 26, 2021 (MAPA, 2021) establishes new rules, with greater flexibility in the list, putting only native species that are on the national list of endangered species (ICMBio, 2018) and in the appendices of the Trade in Species of Wild Flora and Fauna in Danger of Extinction - CITES; in context international (CITES, 2017), this decree allow a greater number of species with export potential, but not improve the number of the agents to supervise this new rule in the environmental agencies.

One of the challenges in combating the smuggling of ornamental fish is the existence of loopholes that allow traffickers to operate with impunity. The environmental crime laws (trafficking of animals) in Brazil are considered lenient. A clear example are the fines applied to traffickers, which are rarely paid. In the period between 2005 and 2010, IBAMA issued more than US$ 119,02 million in fines to animal traffickers throughout the country, but less than 2% of these fines were paid (Bennett, 2013). This is also a similar situation in regard to the penalties under Brazilian law for ornamental fish trafficking, since as the traffickers rarely end up in prison, and once they can pay their fines or post bail, they are free, and this causes traffickers to feel immune to the laws. However, in the present study, we do not have the exact number of how many occurrences of these type were recorded in Brazil.

The current environmental legislation, Law Nº. 9605 of February 12th, 1998, in Article 29, recommends imprisonment of six months to a year for anyone who captures and transports specimens of wild animals without permission (Brasil, 1998), but Article 7 of the same law states that the criminal will only be detained if sentenced to more than four years imprisonment, which does not happen even if the highest penalty is applied (Brasil, 1998). Decree Nº. 6514/2008, which deals with the trafficking of animals (in Article 35), permits the imposition of fines of between U$ 132.25 (US$ 1.00 = R$ 5.29 on January 17th of 2021) to US$ 18,892.52 (Brasil, 2008), the latter being the situation that most occurs for most ornamental fish smugglers arrested in the Amazon.

The lack of international agreements between Brazil and neighboring countries (related to inspection policy against traffic in ornamental fish), such as Colombia and Peru, on the northern border, needs to be urgently elaborated, mainly because the ornamental fish from Brazil when arrive in neighboring countries (Colombia and Peru), they are treated as species from those countries (Nogueira, 2008; MPE, 2011). In 2010 and 2011 alone, the city of Leticia, Colombia, which is adjacent to the city of Tabatinga, Brazil, exported about 2,119,151 and 2,442,718 specimens of ornamental fish, respectively (Colombia, 2011). We do not know, however, what percentage of this trade comes from trafficking of ornamental fish from the Brazilian territory.

Routes used by traffickers

The most worrisome routes are those that originate in Altamira and Itaituba in the Pará State and take fish by illegal flights on small airplanes or commercial flights with a stopover in Manaus (intermediate destination) to cities in the Amazonas state near the border. Later, they depart for the city of Tabatinga and, finally, arrive in Letícia, Colombia, from where fish are exported to the rest of the world as "legal" fish. Other worrisome routes are those that involve the Negro River (trafficking of black arowana) and those of the regions near the Mamirauá extractivist reserve and the region of Auatí-Paraná (trafficking of white arowana), both reserves located in the Central Amazon region.

Air transport is most used means of transport by traffickers due to the great distance between fishing grounds and cities.

The last seizure at Manaus International airport consisted of zebra pleco (*H. zebra*) and was the biggest of 2017, with a record of 672 specimens of seven different species, mostly *H. zebra*, as well as two new species of plecos (Zuanon, J.A.S. personal communication[1]). The fish are generally detected at the Manaus International airport using X-ray equipment, but such equipment is non-existent at the airports in Altamira and Itaituba.

A major inspection by the Federal Police and IBAMA at the airport of Manaus during the World Cup in Brazil (2014) revealed an increase in seizures in the years 2014 and 2015. This is probably linked to more severe inspections during this period. Numbers of seizures were very different between 2016 and 2019 and showed a fall. Another possibility is that the ornamental fish traffickers are looking for new routes due to more rigorous inspection in the airports. IBAMA and the Brazilian Federal Police carry out operations to arrest traffickers and make seizures of fish simultaneously in different cities of the states Amazonas and Pará (in conjunction with local police), as mentioned in Operations Agate VII, Safer River, Poseidon. These operations serve to inhibit traffic on routes maintained by traffickers.

Air transport was also mainly used for smuggling Loricariidae and stingrays, while in river transport, large volumes of *Osteoglossum* (arowana) were seized. The seizures of larvae and juveniles of *O. bicirrhossum* and *O. ferreirai* were carried out almost exclusively in the Amazonian rainy season, which is certainly related to the reproductive period of the two species that occurs from January to June (Soares et al., 2007; Rabello-Neto and Chao 2008). Seizures of Loricariidae (including *H. zebra*) occurred in both periods, though seizures were greater in the dry season (July to November), indicating a greater fishery of Loricariidae in the dry season. During this period, the Xingu and Tapajós River (location of greatest seizures of Loricariidae) are relatively shallower, and thus facilitate the capture of small Loricariidae that occur in the rapids and in the main channel of the river (Camargo et al., 2012). The fishers capture the fish by diving in the shallow environments (1.0 to 1.5 m), and with the use of air compressors at greater depths (up to 15 m) (Camargo et al., 2012). Sousa et al. (2021) also noted the absence of zebras mainly from July to November at sites where they were seen prior to the construction of the Belo Monte dam, and the presence or absence of *H. zebra* was noted in each dive recorded on video.

The state of Amazonas is part of the main international route for the illegal trade in ornamental fish, which also crosses the northern border with Colombia and Peru. Thus, there is an urgent need to monitor the routes of the ornamental fish trade more intensively in the Amazon and improve the operational instruments of inspection. The lack of scientific research monitoring of these ornamental fish populations must also be urgently redressed in order to ensure mitigation of the impacts. Inspections at airports using X-ray machines are certainly quite efficient in inhibiting the smuggling of ornamental fish, such as those carried in Manaus, Belém and Santarém and this type of system should also be installed in the smaller airports, such as Altamira and Itaituba, in order to increase the efficiency of inspections. In addition, the wild animal screening centers (CETAS-IBAMA) should be better structured (Viana and Zocche, 2013) to guarantee greater survival of the specimens seized, until their reintroduction into their natural habitats.

Environmental and conservation devices

Despite increased seizures of illegally fished species in the Amazon, trafficking of ornamental fish increased in 2014, although, it decreased from 2015 to 2019. The lack of knowledge and information of inspection authorities regarding the identification of seized ornamental fish and the lack of logistics for the proper storage and maintenance of seized animals, as well as the difficulty in returning the animals to their original habitats after the seizures is always a problem and must be resolved. However, some of the seized fish are released in Amazonian environments by the environmental agency (IBAMA and ICMBio) that has knowledge of the real distribution of the species. In addition, other seizures of fish are donated to research Institutions, though these are fish generally in a debilitated state, which results in some mortality due to the critical condition of the specimens received. Nonetheless, sometimes this results in the specimen recovery due to the excellent fish care of these researchers, and enables, in some cases, the use of breeding fish in research within the scope of their conservation (Caldas and Godoy, 2019; Caldas et al., 2021).

The trafficking of ornamental fish can bring serious problems to the biodiversity of the Amazon, and this should be combatted since many species are new and are smuggled without scientific knowledge. The zebra pleco (*H. zebra*), for example, suffers a series of threats due to the excessive number of specimens caught by illegal fishers, which, as a result, can drastically decrease the existing populations in the region of the lower and middle Xingu River - an area in which the species is endemic (Camargo et al., 2012; Sousa et al., 2021).

Impacts that occur in the natural environments of these endemic species also need to be urgently monitored. The alluvial gold mining, which occurs in the habitats of the zebra pleco and many species of Loricariidae, mainly on the Xingu and Tapajós Rivers, destroys a part of the environment that these species inhabit, and this is certainly a threat to the species' survival due to loss of habitat (Camargo et al., 2012; Beltrão et al., 2016).

The construction of the Belo Monte hydroelectric dam can be considered another threat, since this dam interrupts and modifies the ecology of long stretches of the Xingu River, making the environment inappropriate for the permanence of the zebra pleco and other species of Loricariidae that depend on the lotic environment of the rapids and the periphyton for their survival (Lees et al., 2016).

The Belo Monte dam complex in the Volta Grande sector of the river, which became operational in November 2015, represents the most significant threat to the Loricariidae habitat (Bratman, 2015; Sousa et al., 2021). Furthermore, licenses for an open pit mine on the largest unexplored gold deposit in Brazil, along the southern sector of the dewatered section of the Volta Grande, are also underway (Tófoli et al., 2017; Sousa et al., 2021). The zebra pleco's entire known range falls within the impact zone (reservoirs and the dewatered section) of the operational Belo Monte dam, and the planned Belo Sun mining project (if final permits are approved) (Sousa et al., 2021).

CONCLUSIONS

It is possible to conclude that the trafficking of ornamental fish in the Amazon is a real threat to the region's biodiversity. There is an urgent need to repress this trafficking. Measures, such as the development of international cooperation agreements with neighboring countries, the implementation of environmental education programs for riverine populations that promote conscientious fishing with the aim of conservation of threatened species, increasing in the number of inspections and inspected places, the implementation of x-ray machines at airports in smaller cities, in order to mitigate smuggling in the natural habitat of the animals, would reduce reverse logistics costs for live fish and reduce fish mortality in transport, as well as contribute substantially to the conservation of biodiversity in the Brazilian Amazon.

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