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Novelty on the market, novelty in the environment: The invasion of non-native fish jaguar guapote (Perciformes) in northeastern Brazil

Novidade no mercado, novidade no ambiente: invasão do peixe não nativo acará onça no nordeste do Brasil

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Abstract

In Brazil, more than 150 non-native fish species have been introduced either intentionally or unintentionally, mainly due to aquaculture, fishery improvement and ornamental trade. The non-native jaguar guapote *Parachromis managuensis* was recorded in two artificial ponds, four rivers, one stream and two reservoirs, ecosystems belonging to the Una, Ipojuca, Capibaribe and Pajeú River basins, Pernambuco, northeastern Brazil. The sampling period was between October 2006 and July 2015. A total of 376 individuals of *P. managuensis* was captured by seines, casting nets and gillnets. This species may have been introduced in the study sites by accidental release during pond drainage in fish farms, stocking for the purpose of animal protein production or by aquarium dumping. The presence of various ontogenetic life stages in all studied environments is a strong evidence that the species is established. Seven management actions are proposed to prevent further introductions of *P. managuensis* in other environments of the region.

Keywords: exotic, bioinvasion, introduction, aquarism, freshwater fish.

Resumo

No Brasil, mais de 150 espécies de peixes não nativos foram introduzidas intencionalmente ou não, especialmente devido à aquicultura, pesca e aquarismo. A presença do peixe não nativo *Parachromis managuensis*, o acará onça, foi registrada em dois açudes, quatro rios, um córrego e duas barragens distribuídos nas bacias hidrográficas dos rios Una, Ipojuca, Capibaribe e Pajeú, no estado de Pernambuco, nordeste do Brasil. O período de amostragem ocorreu entre outubro/2006 e julho/2015. Um total de 376 indivíduos de *P. managuensis* foi capturado utilizando tarrafas, redes de arrasto e redes de espera. Esse peixe pode ter sido introduzido nos locais estudados por escape acidental durante a drenagem de viveiros de piscicultura, estocagem com a finalidade de produção de proteína animal e através do descarte de aquários. A presença de vários estágios ontogênicos em todos os ambientes estudados representa uma forte evidência de que a espécie está estabelecida. Ações de manejo são propostas para evitar novas introduções de *P. managuensis* em outros ambientes da região.

Palavras-chave: exótica, bioinvasão, introdução, aquarismo, peixes de água doce.

Introduction

Freshwater fish introduction is a major issue for aquatic biodiversity and environmental conservation in continents all over the world, with at least 624 species introduced so far in the six biogeographic realms (Fuller *et al*., 1999; Toussaint *et al*., 2016). In Brazil, since the beginning of the last century, more than 150 non-native species have been introduced from other continents and other regions of the country, either intentionally or unintentionally, mainly due to aquaculture, fishery improvement and ornamental trade (Welcomme, 1988; Alves *et al.*, 2007; Vitule, 2009; Magalhães *et al.*, 2010).

In northeast region, over twenty introduced fish species have been recorded so far, at least eight of them in the state of Pernambuco, including four cichlids: *Astronotus ocellatus* (Agassiz 1831), *Cichla ocellaris* Bloch & Schneider 1801*, Oreochromis niloticus* (Linnaeus 1758) and *Parachromis managuensis* (Günther 1867) (Barbosa *et al.*, 2006; Leão *et al*., 2011). The fish fauna of this state comprises about 492 species (Atlas Digital de Peixes de Pernambuco, 2016), 61 of them being freshwater, including native species such as the cichlids *Cichlasoma orientale* Kullander 1983, *Crenicichla brasiliensis* (Bloch, 1792) and *Crenicichla menezesi* Ploeg 1911, considered endemic to northeastern Brazil (Kullander, 1983).

The jaguar guapote *P. managuensis* is a large cichlid native to Atlantic Slope drainages in Central America from Ulúa River in Honduras to Matina River in Costa Rica (Bussing, 1987). Males can reach a total length of 65 cm, and females 40 cm (Conkel, 1993). The species prefers lotic habitats with low water current (Page and Burr, 1991; Froese and Pauly, 2016). Adult *P. managuensis* feed on a wide diversity of fish, whereas aquatic invertebrates comprise an important portion of the juvenile diet (Gestring and Shafland, 1997; Figueiredo *et al.*, 2015). *Parachromis managuensis* displays specific courtship behavior and lays 500–5,000 eggs on rocks and other hard substrates during spawning. Parents become quite aggressive and territorial in protecting their eggs. The female protects the eggs, and the male protects the nesting site (Gestring and Shafland, 1997).

Since 2005, *P. managuensis* has become one of the most popular species in fish culture, fish stocking and fishkeeping in Brazil (Barbosa *et al.*, 2006; Barbosa and Soares, 2009; Magalhães and Jacobi, 2010; Barros *et al.,* 2012). It was introduced into some water bodies in Brazilian northeastern region, possibly in the lower São Francisco River located in the states of Bahia, Sergipe and Alagoas, from 2007 to 2008, through the escapees of aquaculture ponds (Barbosa and Soares, 2009).

Despite the already documented introductions in the above mentioned states of northeastern Brazil (Barbosa and Soares, 2009), new introductions of *P. managuensis* exist in the region, notedly in the state of Pernambuco. Thus, the aim of the present study is to describe the stage of the invasion process and possible establishment of this invasive species in new environments of the state, and to suggest management actions in order to prevent further introductions in the region.

Material and methods

Study area

The state of Pernambuco, in northeastern Brazil, has an area of 98,076,001 km^2 and a growing population of more than nine million people living in 185 cities (IBGE, 2016). The state is drained by 13 watersheds, with thousands of streams and reservoirs of different sizes (APAC, 2016).

The study area comprises four river basins included in two important regional biomes, the Brazilian Atlantic Forest, which contains the costal river basins of Capibaribe, Ipojuca and Una, and the Caatinga including the Pajeú River (Table 1). The Brazilian Atlantic Forest extends along most of the Atlantic Ocean coast of Brazil. Of the more than 1,000,000 km^2 of the original forest, only an estimated 7% survived. This biome shows a complex structure, sheltering higher species diversity than the Amazon rainforest. Species richness, the extremely high levels of endemism and the small fraction of the original forest left, led Myers *et al.* (2000) to rank the Brazilian Atlantic Forest among the top biodiversity hotspots in the world. The Caatinga is a unique Brazilian biome that occupies 850,000 km^2, approximately 10% of the Brazilian territory, where the climate is semiarid and consists of heterogeneous arid and semi-arid formations surrounded by more mesic phytogeographic formations. The vegetation is xerophytic, summer-deciduous, morphologically and physiologically drought-adapted, and the rivers are subject to hydrological stress (Prado, 2003).

Sampling

Fishes were collected in October/2006, January/2007, September/2012, May/2014 and July/2015, respectively in the Capibaribe, Ipojuca, Una and Pajeú River basins, state of Pernambuco, northeastern Brazil (Figure 1).

The fishing gear used for capture of the specimens included seines (5-cm mesh), cast nets (2-cm mesh), and gillnets with a mesh size of 2 to 7 cm (all between adjacent knots). The collected specimens were placed in containers with ice scale, according to recommendations proposed by the Use of Fishes in Research Committee – UFR (2004). The specimens of *P. managuensis* were identified, fixed in 10% formalin solution and preserved in 70% ethanol. Standard length (SL, mm) was measured from each individual. Voucher specimens were deposited in the Ichthyo-

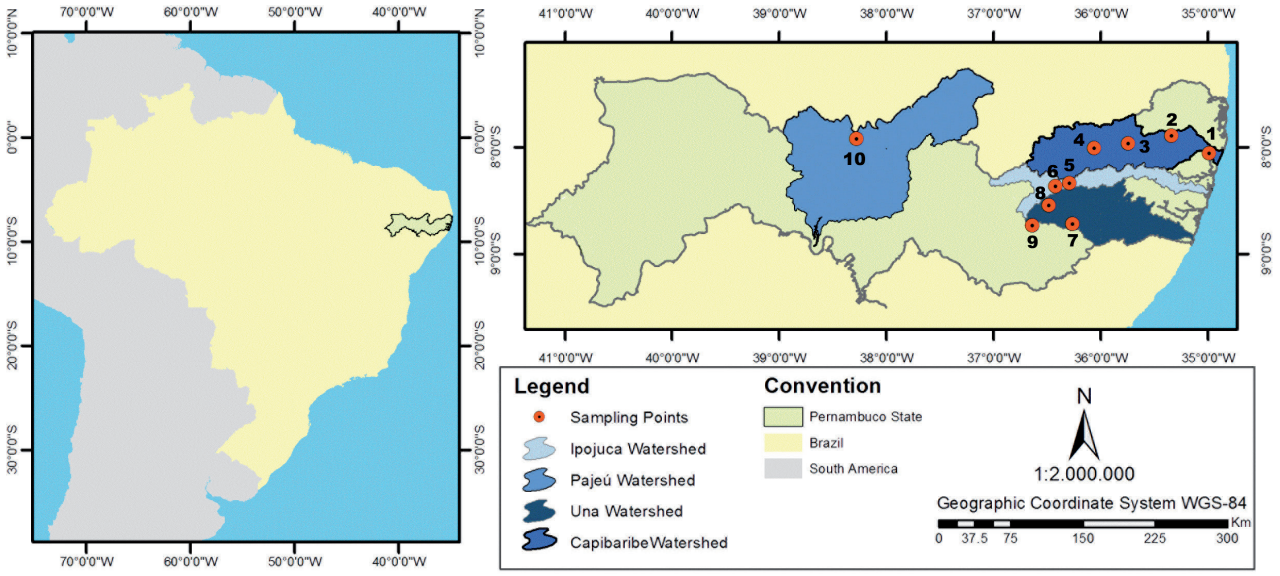

Figure 1. Sites of capture of non-native jaguar guapote *Parachromis managuensis* in four watersheds within the state of Pernambuco, Brazil.

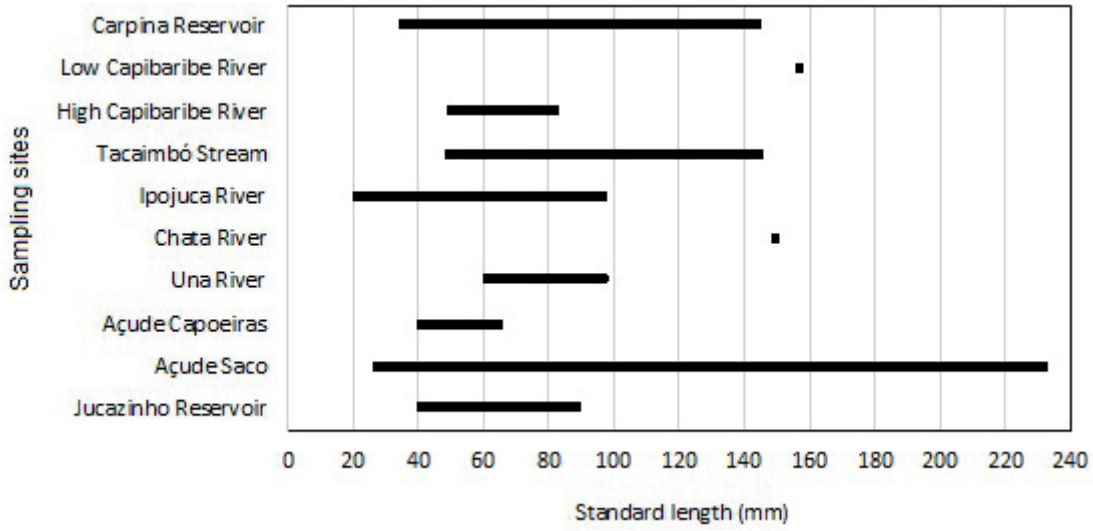

Figure 2. Standard length range of specimens of non-native jaguar guapote *Parachromis managuensis* sampled in the state of Pernambuco, northeastern Brazil, in the period between October 2006 and July 2015.

logical Collection of the Federal Rural University of Pernambuco (UFRPE), Brazil.

Results

A total of 376 individuals of *P. managuensis* were captured during the 5-year collection period: 14 specimens in Una River basin, 74 in Ipojuca River basin, 232 in Capibaribe River basin, and 56 specimens in Pajeú River basin. The jaguar guapote was present in several habitats such as streams, rivers, small earthen ponds (locally called *açudes*) and large concrete dammed reservoirs. Of all the specimens captured in the present work, Carpina reservoir (226 individuals) and Ipojuca River (59 individuals) were the localities with the highest abundances and participation in our collections (60.1% and 15.7%, respectively).

Standard lengths varied among the studied habitats, as evidenced by the capture of alevins (20-50 mm), juveniles (60-97 mm) and adults (145-235 mm) of *P. managuensis* (Figure 2, Table 1).

Table 1. General data about the non-native jaguar guapote *Parachromis managuensis* introduced in the state of Pernambuco, northeastern Brazil.

River basin	Biomes	Sampling Points	Site/Municipality	Geographic coordinates (lat. - long.)	Year	N.	%	SL (mm) Min.-Max.	Ontogenetic stages
Una	Atlantic Forest	9	Açude Capoeiras/ Capoeiras	-8.7312S / -36.6354W	2006-2007	5	1.33	40 – 64	alevins, juveniles, adults
	Caatinga	8	Una River/Capoeiras	-8.5443S /-36.4826W	2006-2007	8	2.13	60 – 97	
		7	Chata River/Capoeiras	-8.7177S / -36.2629W	2006-2007	1	0.26	150	
Ipojuca	Atlantic Forest	6	Ipojuca River/Belo Jardim	-8.3671S/-36.4229W	2006 2007	59	15.7	20 – 97	alevins, juveniles, adults
	Caatinga	5	Tacaimbó Stream/ Tacaimbó	-8.3360S / -36.2918W	2006-2007	15	3.99	47 – 145	
Capibaribe	Caatinga	4	Upper Capibaribe River/Toritama	-8.0129S / -36.0623W	2006-2007	5	1.33	50 – 82	alevins, juveniles, adults
	Atlantic Forest	1	Lower Capibaribe River/Recife	-8.0601S / -34.9847W	2014	1	0.26	157	
		2	Carpina Reservoir/ Lagoa do Carro	-7.8946S / -35.3385W	2015	226	60.1	34 – 145	
		3	Jucazinho Reservoir/ Surubim	-7.9657S / -35.7426W	2006-2007	25	6.65	40 – 90	
Pajeú	Caatinga	10	Açude Saco/Serra Talhada	-7.9254S / -38.2777W	2012	31	8.24	26 - 235	alevins, juveniles, adults

Discussion

In Brazil, fish species introductions have been increasingly reported in the literature in recent years (Orsi and Agostinho, 1999; Alves *et al.,* 2007; Magalhães, 2010; Azevedo-Santos *et al.,* 2015), although the actual number of non-native species is supposed to be underestimated (Vitule, 2009; Magalhães and Jacobi, 2010; Azevedo-Santos *et al.,* 2015). Therefore, it is worth emphasizing the importance of reporting the presence of any non-native species in natural, semi-natural or artificial environments in any region of the country. The presence of *P. managuensis* detected in several environments of Una, Ipojuca, Capibaribe, and Pajeú river basins in the state of Pernambuco, reported herein, can be due to three factors: (1) accidental release during pond drainage, (2) stocking in reservoirs and (3) aquarium dumping.

In Brazil, the introduction of non-native fish species has been mainly attributed to aquaculture (Agostinho *et al*., 2007; Ortega *et al*., 2015). When capturing the individuals for harvest in production ponds, it is common to drain the ponds and their contents via direct discharge into the nearest water body without any treatment or biosafety measures. Thus, specimens of the cultivated species, which are not harvested, are easily discharged and spread to nearby water bodies (Orsi and Agostinho, 1999). Accidental release of *P. managuensis* during pond drainage may have occurred in fish farms, discharging water directly into adjacent water bodies such as the Tacaimbó Stream and Una, Chata, Ipojuca and Upper Capibaribe rivers.

Stocking fish in reservoirs for the purpose of animal protein production has long been a common practice intended to minimize the scarcity of food, mainly in northeastern Brazil (Gurgel and Oliveira, 1987; Leão *et al*., 2011). These activities were performed using non-native cichlids, such as the Nile tilapia *Oreochromis niloticus*, longfin tilapia *O. macrochir* (Boulenger, 1912), Mozambique tilapia *O. mossambicus* (Peters, 1851), redbreast tilapia *Tilapia rendalli* (= *Coptodon rendalli*) (Boulenger, 1897), oscar *Astronotus ocellatus* and peacock basses *Cichla ocellaris*, *C. monoculus* Agassiz, 1831 and *C. temensis* Humbolt, 1821, acting as an important mean of species introductions (Gurgel and Oliveira, 1987; Barbosa and Ponzi Jr., 2006; Leão *et al.,* 2011). Stocking of *P. managuensis* for the purpose of animal protein production may have occurred specially in Capoeira, Saco, Carpina and Jucazinho reservoirs.

Aquarium trade or fishkeeping is supposed to be responsible for the release of jaguar guapote into public waters through aquarium dumping (e.g., Lower Capibaribe River). Due to its large size, the jaguar guapote has possibly been released into the Lower Capibaribe River by amateur aquarists since ornamental fishes with exaggerated growth in aquaria have costly maintenance, causing the rejection of their owners and the consequent aquarium dumping into the new environments, as emphasized by Magalhães and Jacobi (2013).

Potentially invasive species like *P. managuensis* typically present the ability to develop in a wide range of lotic and lentic environments analyzed in the present study (i.e. streams, rivers and reservoirs) due to particular survival strategies, such as live in hypoxic waters, tolerate high water temperatures, and perform bi-parental care of eggs, larvae, alevins and juveniles. Moreover, the species is a highly predatory fish with enlarged pseudocanines, allowing it to grasp and hold on to the prey. Such strategies represent evolutional successes of essential importance for the maintenance of future generations. These characteristics are corroborated by Welcomme (1988), who considered that hardiness; parental care and predaceous nature are determining factors for the survival of several cichlid species introduced into new habitats.

Juveniles of *P. managuensis* were the most abundant individuals in relation to other ontogenetic stages in all samples collected, especially in the Carpina Reservoir, Capibaribe River basin, thus suggesting constant renewal of the population in this ecosystem. A similar situation was observed in the Pampulha Reservoir, state of Minas Gerais (Weber, 2013), and in the Sampaloc Lake, province of Laguna, Philippines (Briones *et al.,* 2016), where young jaguar guapote were the most abundant ontogenetic stage in collections.

The differences in standard length observed in jaguar guapote suggest reproductive activity, further evidenced by the presence of alevins, juveniles and adults (i.e. recruitment and establishment). This has also been confirmed by Agasen *et al.* (2006) and Rosana *et al.* (2006), who found juvenile and adult *P. managuensis* introduced in the Taal Lake, Philippines.

According to Lockwood *et al.* (2007), an invasion process occurs in five stages: (1) transportation from the place of origin; (2) arrival in the new environment; (3) establishment, when an immigrant population is maintained by reproduction and recruiting (presence of young individuals); (4) dispersal, when a population expands its geographic range; and (5) low to high impact, when the receiving biota is affected by the invader. In the present study, it was confirmed that *P. managuensis* is at least in the stage 3, appearing to be well adapted in the Atlantic Forest and Caatinga water bodies, habitats with similar conditions to those of its place of origin, the tropical regions of Central America (Froese and Pauly, 2016). Accordingly, the establishment of this cichlid fish in these river basins is of concern, because once established, it tends to disperse naturally and colonize new areas (Agasen *et al.,* 2006). These new areas in the state of Pernambuco may be mangrove inlets of Una, Ipojuca and Capibaribe River estuaries, areas rich in native fishes (Atlas Digital de Peixes de Pernambuco, 2016). In addition, cichlids have a high degree of euryhalinity and are capable to survive in mesohaline conditions for long periods and could potentially use the brackish waters of estuaries as vectors for the dispersal to other environments (Gutierre *et al.,* 2014). The jaguar guapote can also spread to tributaries of the Una, Ipojuca, Capibaribe and Pajeú Rivers, which have endemic freshwater species such as the cichlids black acará *Cichlasoma orientale* and the pike cichlids *Crenicichla brasiliensis* and *C. menezesi* (Rosa *et al.,* 2005; Silva Filho *et al.,* 2011), hence reaching the second, third, fourth and fifth stages of the process of biological invasion in these sites. The fifth stage already occurs in Gurjão Reservoir located in the Una River basin, where *P. managuensis* predates and competes for food with the native pearl cichlid *Geophagus brasiliensis* (Quoy and Gaimard 1824) (Figueiredo *et al.,* 2015).

Non-native aquatic species constitute a serious threat to biodiversity, especially in megadiverse tropical countries like Brazil (Nuñez and Pauchard, 2010). The Convention on Biological Diversity, signed by Brazil, establishes in its article eight that each country that is party to the Convention has to make efforts to prevent the introduction, and if possible, control the populations of non-native species (Alho *et al.,* 2011). Given the apparent establishment of *P. managuensis* in waters of the state of Pernambuco, and the real risk of spread and adverse ecological impacts as already occurs in Gurjão Reservoir, some management recommendations are suggested to avoid further introductions:

(1) Installation and maintenance of screens with a small enough mesh to prevent the escape of fishes in the production ponds;
(2) Installation and maintenance of gravel filtration on pond discharge structures;
(3) Awareness campaigns with people who work directly in fish farms and pet stores, informing that the release of non-native fish species is an environmental crime with a penalty of detention (from three months to one year) and fine, in accordance with Article 31 of the National Law on Environmental Crimes;
(4) Periodic inspection of fish farms by the Brazilian Environmental Police in order to prevent unintentional release based on the National Law of Wildlife Protection;
(5) If unintentional release persist, effectively enforcement of National Environmental Policy, that enacts the Polluter Pays Principle because biological pollutants in the form of introductions of non-native fish species may be as serious an impact to aquatic ecosystems as are chemical additives;
(6) Stocking programs should focus in native species such as the Brazilian bocachico *Prochilodus brevis* Steindachner 1875, saguiru *Steindachnerina notonota* (Miranda Ribeiro, 1937) and trahira *Hoplias malabaricus* (Bloch, 1794);
(7) A program for returning unwanted fishes to pet stores can be effective in order to stop new aquarium-fish introductions into Lower Capibaribe River; and

display warning informing about the negative effects of aquarium dumping in all fish plastic bags provided by pet stores.

Finally, northeastern Brazil has a negative history of introduced cichlids, such as peacock bass *C. ocellaris* and Nile tilapia *O. niloticus*, which have often become invasive, being implicated in the local extinction in Lagoa Redonda of native pacu *Metynnis cf. roosevelti* Eigenmann 1915 and zooplankton communities (Molina *et al.,* 1996; Attayde *et al.,* 2007). Thus, all above recommendations may prove useful to maintain the integrity of native fish fauna of the Brazilian Atlantic Forest and Caatinga in the Una, Ipojuca, Capibaribe and Pajeú river basins. Additionally, these recommendations may be relevant to popularize the environmental laws (e.g., National Law on Environmental Crimes, National Law of Wildlife Protection, Polluter Pays Principle) and show a strategy to combat non-native species introductions, approaches still timidly disseminated in all Brazilian society.

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