



## Occurrence of non-native species in a subtropical coastal River, in Southern Brazil

Ocorrência de espécies não-nativas em um rio costeiro subtropical no Sul do Brasil

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**Abstract: Aim:** This paper aims to concatenate and update the records of non-native species in a subtropical River, in Southern Brazil, warning about their possible impacts in this and other water bodies. **Methods:** Monitoring was carried out in the Guaraguaçu River, the largest River of the Paraná coastal plain, located in the Atlantic Rainforest biome. Fishes were sampled in two periods: from 2002 to 2007 (monthly) and from 2016 to 2018 (semiannually), and the other organisms were collected in isolated samplings. **Results:** The monitoring recorded the presence of six non-native species of animals in this River – four species of fish (*Clarias gariepinus*, *Ictalurus punctatus*, *Oreochromis niloticus* and *Salminus brasiliensis*), one invertebrate (*Macrobrachium rosenbergii*) and one foraminifera (*Ammoglobigerina globigeriniformis*) introduced by escapes from aquaculture, sport fishing and ballast water. These introductions are problematic because they have the potential to impact upon the endangered native species in the River through predation, competition or novel diseases. **Conclusions:** In Guaraguaçu River the increasing number of introductions is worrying because these species have in common a set of traits that turns them into potential invaders. It is of great importance to keep monitoring their populations in order to detect and minimize their negative impacts on native biota, once there is a conservation unit in the region (Guaraguaçu Ecological Station), with the aim to protect the environment in its pristine condition.

**Keywords:** agglutinated foraminiferal species; alien species; estuary; ichthyofauna; prawn.

**Resumo: Objetivo:** Este artigo tem como objetivo reunir e atualizar os registros de espécies não-nativas em um rio subtropical do sul do Brasil, alertando para os impactos que podem exercer neste, e em outros corpos hídricos. **Métodos:** Foi realizado um monitoramento no rio Guaraguaçu, o maior rio da planície costeira do Paraná, localizado no bioma Mata Atlântica. Os peixes foram amostrados em dois períodos: de 2002 a 2007 (mensalmente) e de 2016 a 2018 (semestralmente), e os demais organismos foram coletados em amostragens isoladas. **Resultados:** O monitoramento registrou a presença de seis espécies de animais não-nativos neste rio – quatro espécies de peixe (*Clarias gariepinus*, *Ictalurus punctatus*, *Oreochromis niloticus* e *Salminus brasiliensis*), um invertebrado (*Macrobrachium*



*rosenbergii*) e um foraminífero (*Ammoglobigerina globigeriniformis*), introduzidos principalmente através de escapes de aquicultura, para pesca esportiva ou por água de lastro. Tais introduções são um problema, pois, têm o potencial de impactar negativamente as espécies nativas ameaçadas de extinção neste rio através de predação, competição ou introdução de novas doenças. **Conclusões:** No rio Guaraguaçu o crescente número de introduções é preocupante, pois estas espécies têm em comum um conjunto de características que as tornam potenciais invasoras. Continuar o monitoramento de suas populações é fundamental para detectar e minimizar seus impactos negativos na biota nativa, uma vez que há na região uma unidade de conservação (Estação Ecológica Guaraguaçu), com o objetivo de proteger o ambiente em sua condição prístina.

**Palavras-chave:** foraminífero aglutinante; espécies exóticas; estuário; ictiofauna; camarão.

The introduction of non-native species is one of the major threats to freshwater ecosystems along with overexploitation, water pollution, flow modification and habitat degradation (Dudgeon et al., 2006). A species is considered non-native when it is introduced outside its original geographic range, usually by human action (Lockwood et al., 2007). When it has a self-sustaining population which is reproducing, it may be considered established and, in some cases, become invasive, for instance causing environmental or economic impacts (Blackburn et al., 2011).

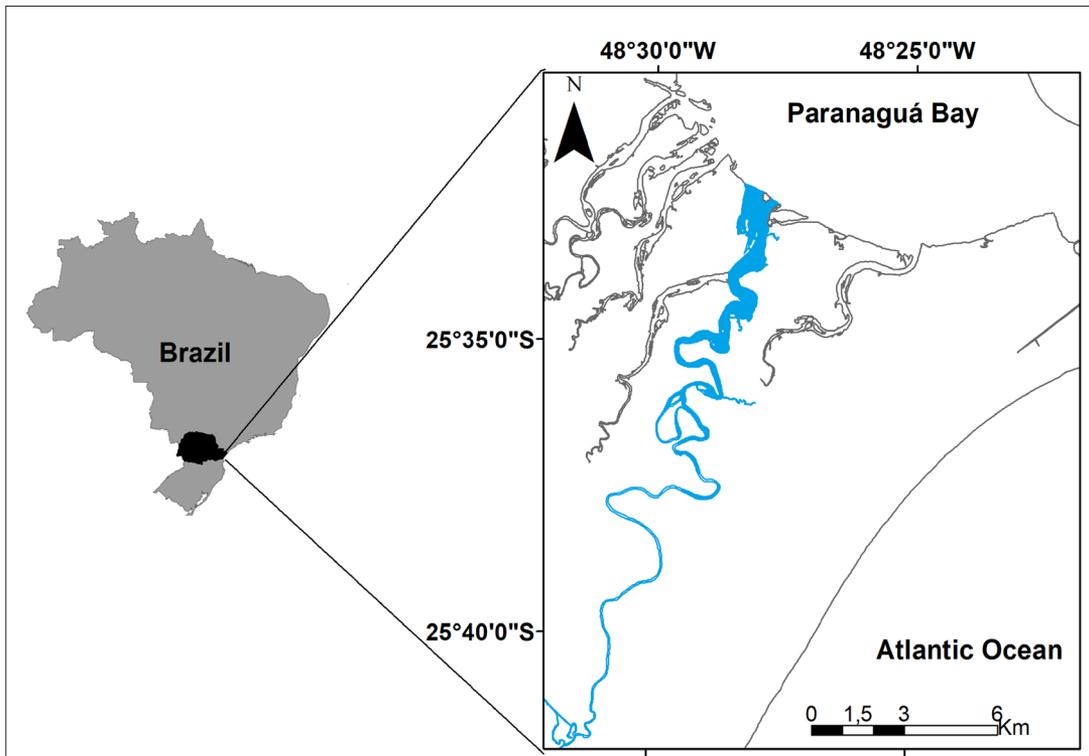
Invasive species are known to cause a great range of negative impacts to biodiversity, in all ecological levels, through new diseases, predation, competition, hybridization and alteration of ecosystems and trophic webs, being one of the leading causes of species extinctions around the world (Clavero & García-Berthou, 2005; Havel et al., 2015). Freshwater ecosystems, particularly, are even more prone to invasions due to the large number of introduction vectors (e.g. aquaculture, hull fouling, aquarium trade, sport fishing, bait release) (Frehse et al., 2016), and because they are already degraded by human alterations (Bezerra et al., 2019). Because of that, it is of great importance to monitor and record the occurrence of new non-native species in the natural environment, to cope with them before they become invasive, implying ecological impacts and economic losses (Simberloff et al., 2013).

The Guaraguaçu River is the largest River of the Paraná coastal plain, located in the Atlantic Forest biome (Figure 1). The climate in the region is humid subtropical and the River presents a wide variety of habitats that goes from mangroves to a unique ecosystem of backwater locally named “caixetal”. It shelters a high level of endemism, with many small-bodied fish species reported in national and regional lists of threatened species (Abilhoa & Duboc, 2004; Machado et al., 2008). A monitoring initiated in 2002 recorded the presence of six non-native species of animals in this River so far, using different

sampling methods (Table 1). Fishes were sampled in two periods: from 2002 to 2007 (monthly) and from 2016 to 2018 (semiannually), and the other organisms were collected in isolated samplings in 2005, 2006 and 2017 (Table 1). This paper aims to concatenate and update these records (e.g. Vitule et al., 2005, 2006, 2014; Pupo & Disaró, 2006; Gazola-Silva et al., 2007; Eichler et al., 2018) addressing the probable threat that these species may pose to the native biota.

The non-native species found in Guaraguaçu River have in common a set of traits (omnivory, wide environmental tolerance range, high propagule pressure and economic interest) that turns them into potential invaders in many environments or conditions (New et al., 2000; Martin et al., 2010; Gutierre et al., 2014; Weyl et al., 2016). More worrying are the introductions of large predators such as *Clarias gariepinus* (Burchell, 1822), *Ictalurus punctatus* (Rafinesque, 1818), and *Salminus brasiliensis* (Cuvier, 1816) because they have the potential to impact upon the endangered native species in the River through elevated predation pressure (Gubiani et al., 2010; Alexander et al., 2014; Faria et al., 2019). The Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) is a highly tolerant species with a short life cycle and omnivorous feeding habits that facilitate its rapid dispersion, being a threat to native species due to competition (Canónico et al., 2005). The introduction of *Macrobrachium rosenbergii* (De Man, 1879), which is host of two viral diseases responsible for high rates of aquaculture mortality, is also a problem (Bonami & Sri Widada, 2011).

A species considered an invading foraminifer was the most abundant at Guaraguaçu River in 2005 when it was registered for the first time in Paraná waters, dominating 6 of 23 sampling points, mostly around the mouth and at the lower portion of the River (Figure 2). According to McGann & Sloan (1999) the agglutinated foraminifer *Trochammina hadai* Uchio, 1962 first appeared as an invasive species from Japan in estuarine bottom sediments



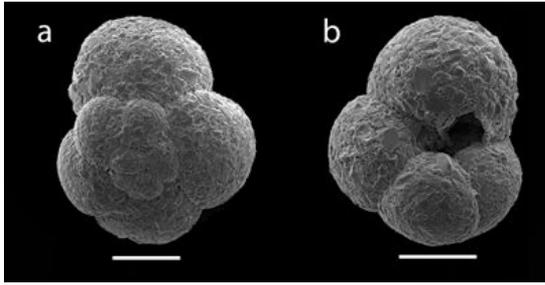
**Figure 1.** Map of the study area, the Guaraguçu river in the coastal plain, Paraná State, southern Brazil.

**Table 1.** Records of non-native species at Guaraguçu river in the last 18 years.

Species	Native range	Year of record and sampling method	Possible vector of introduction	Reference
<i>Clarias gariepinus</i> (Burchell, 1822)	Most of Africa and some parts of Asia (Israel, Syria and south of Turkey)	2002 and 2004, gill net, longline and fishing rods	Escapes from aquaculture	Vitule et al. (2006)
<i>Ictalurus punctatus</i> (Rafinesque, 1818)	North America: Central drainages of the United States to southern Canada and northern Mexico	2004, 2005 and 2017, gill net, longline and fishing rods	Escapes from aquaculture	Vitule et al. (2005)
<i>Oreochromis niloticus</i> (Linnaeus, 1758)	Africa	2004 to 2007, and 2017, gill net and cast net	Escapes from aquaculture	This study
<i>Salminus brasiliensis</i> (Cuvier, 1816)	Southern South America in the Paraná, Paraguay and Uruguay rivers, the Laguna dos Patos drainage, and the Chaparé and Mamoré rivers (Amazon Basin)	2006, gill net	Deliberate introduction for sport fishing	Vitule et al. (2014)
<i>Macrobrachium rosenbergii</i> (De Man, 1879)	Southeast Asia	Carapace in 2006; full specimens in 2017, trap	Escapes from aquaculture	Gazola-Silva et al. (2007)
<i>Ammoglobigerina globigeriniformis</i> (Parker & Jones, 1865)	North Atlantic, Antarctic, Arctic, Mediterranean, Red Sea, Indian Ocean, Abrolhos Bank, Greenland, South Atlantic from ~55 to ~4000 m depth	Shells with protoplasm in 2005; vanVeen Grab	Ballast water from transoceanic tankers and bulk carrier	Pupo & Disaró (2006), Eichler et al. (2018)

of San Francisco Bay (California, USA) in 1995. It was registered in 1983 in the same area but, at that time, it comprised a mere 1.5% of the fauna (McGann, 2014). Eichler et al. (2018) registered *T. hadai* as an invasive species at Ubatuba (São

Paulo, Brazil) and these authors mentioned its presence at Paranaguá Bay in 2005 based on written information and photos made available by Disaró (personal communication) and Pupo & Disaró (2006).



**Figure 2.** *Ammoglobigerina globigeriniformis* (Parker & Jones, 1865). (a) Dorsal view; (b) ventral view. Scale bar: 100  $\mu$ m.

This species was assigned to *Ammoglobigerina globigeriniformis* (Parker & Jones, 1865) by Pupo and Disaró but, despite the controversial question about its taxonomic identity and origin, the species mentioned by McGann & Sloan (1999), McGann (2014), Eichler et al. (2018) and Pupo & Disaró (2006) is, indeed, the same. The mechanism by which it was introduced into the estuarine system is unknown, but it might be related to the release of ballast water, sedimentary residues attached on anchor or cables of transoceanic tankers or bulk carriers at the Paranaguá Port, which is approximately 9 km from the mouth of the River. Anthropogenic interference may have cooperated with this surprising distribution in an area of the Brazilian coast where this species had never occurred before. Further studies are needed to verify whether this species has established populations that may threaten native species, or if it was just an episodic occurrence.

Aquatic invasions are sometimes hard to detect at early stages, so the effort must be continuous. In Guaraguaçu River the increase of introduction events is worrying because one non-native species can facilitate the establishment of another, elevating their number in the long term, or resulting in trophic cascades and additive or synergistic negative effects on the native community (Ricciardi & MacIsaac, 2010; Braga et al., 2019). Besides that, the invasion by a few non-native cosmopolite species and the possibly extinction of endemic species caused by them, can lead to biotic homogenization (Rahel, 2002; Ricciardi & MacIsaac, 2010). The occurrence of these non-native species is also a problem because there is a conservation unit in the region (Guaraguaçu Ecological Station), with the aim to protect the environment in its pristine condition. In order to reach that aim, the presence of non-native species is not acceptable and measures to keep them away are needed. Finally, the varied number of taxa and the constant emergence of new

records of occurrence in this basin is an evidence of the intense propagule and colonization pressure in the region.

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