




Non-marine invasive gastropods on Ilha Grande (Angra dos Reis, Rio de Janeiro, Brazil): distribution and implications for conservation

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Abstract: Invasive species are one of the main causes of biodiversity loss and the knowledge of their distribution is essential for conservation efforts. The present study inventoried the land and freshwater invasive molluscs of 25 villages of Ilha Grande (Rio de Janeiro, Brazil), an island with Atlantic Rainforest remnants. Three invasive species are found: *Melanooides tuberculata* (Müller, 1774), *Physa acuta* Draparnaud, 1805, both on two localities; and *Achatina fulica* Bowdich, 1822, on 16 localities. Most records were done on the island continental side, in anthropic areas, probably due to ease of access. One record was inside a conservation area, that calls concern about the spread of those species on the island and possible effects.

Keywords: *Achatina fulica*, *Melanooides tuberculata*, *Physa acuta*, non-native species, Gastropoda.

Moluscos continentais invasores na Ilha Grande (Angra dos Reis, Rio de Janeiro, Brasil): distribuição e implicação para a conservação

Resumo: As espécies invasoras são uma das maiores causas de perda de biodiversidade e o conhecimento acerca da sua distribuição é essencial para os esforços de conservação. O presente estudo inventariou os moluscos continentais invasores em 25 vilas da Ilha Grande (Rio de Janeiro, Brasil), uma ilha com remanescentes de Mata Atlântica. Três espécies invasoras foram encontradas: *Melanooides tuberculata* (Müller, 1774), *Physa acuta* Draparnaud, 1805, ambas em duas localidades; e *Achatina fulica* Bowdich, 1822, em 16 localidades. A maior parte dos registros foi no lado continental da ilha, provavelmente devido a facilidade de acesso. Um dos registros foi dentro de uma área de conservação, o que chama a atenção para a dispersão destas espécies na ilha, e seus possíveis efeitos.

Palavras-chave: *Achatina fulica*, *Melanooides tuberculata*, *Physa acuta*, espécies não-nativas, Gastropoda.

Introduction

The impact of non-native species on ecosystems is well discussed (e.g. Lockwood et al. 2005, Pimentel et al. 2005, Boltovskoy 2017, Cowie et al. 2017), especially on an insular system (Cowie 1998, Clavero & García-Berthou 2005, Pyšek et al. 2017). Some of these species, as *Achatina fulica* Bowdich, 1822, and *Melanoides tuberculata* (Müller, 1774), are dispersed worldwide, offering a combination of environmental, economic, and health concerns (Graeff-Teixeira 2007, Santos et al. 2012).

The African giant snail was introduced in Brazil around 1980 for commercial purposes and nowadays is widespread (Thiengo et al. 2007, Colley & Fischer 2009). This species is hermaphrodite, and a single specimen can initiate a new population, as autofecundation is possible (Thiengo et al. 2007, Fischer & Colley 2005). *Achatina fulica* can cause not only environmental problems, like the competition with native species, as *Megalobulimus* spp. (Gutiérrez-Gregoric et al. 2011), but also questions related to public health (Thiengo et al. 2007, Graeff-Teixeira 2007). *Achatina fulica* is the intermediate host for nematodes of medical and veterinary importance like *Angiostrongylus costaricensis* (Morera & Céspedes, 1971), *Angiostrongylus cantonensis* (Chen, 1935), *Aelurostrongylus abstrusus* (Railliet, 1898), *Rhabditis* sp. and *Strongyluris* sp. (Vicente et al. 1993, Thiengo et al. 2008, 2010, Oliveira et al. 2010).

The Afro-Asiatic freshwater snail *M. tuberculata* was introduced in Brazil around 1967, in Santos, São Paulo state, probably by aquarium trade (Vaz et al. 1986). Nowadays it is widespread in Brazil (Fernandez et al. 2003, Santos et al. 2012, Miyahira et al. 2020). *Melanoides tuberculata* is parthenogenetic and resistant to desiccation (Facon et al. 2004; Weir & Salice 2012), two features that probably helped this species to disperse so widely. This species is the intermediate host of several trematodes, including *Centrocestus formosanus* (Nishigori, 1924) and *Philophthalmus gralli* Mathis & Leger, 1910 (Pinto & Melo 2011, Ximenes et al. 2017). There are no autochthonous human cases of these parasites described to Brazil, although it was already recorded in oriental immigrants, living in São Paulo city, infected with *Clonorchis sinensis* (Cobbold, 1875) (Leite et al. 1989).

Physa acuta is an invasive freshwater gastropod worldwide distributed (Paraense & Pointier 2003, Taylor 2003). The first record on Brazil was in 1966, under the name *Physa (Physella) cubensis* Pfeiffer, 1839 (Leme 1966), but nowadays it is widespread especially in southeastern Brazil (Santos et al. 2012) and some records in the states of Bahia and Goiás (Santos et al. 2016). This species is hermaphrodite and recognized for some environmental impacts (Taylor 2003, Zukowski & Walker 2009).

Ilha Grande is one of the largest insular remains of the Atlantic Rainforest in Brazil, and place of four conservation areas: Ilha Grande State Park, Praia do Sul Biological Reserve, Adventureiro Marine State Park, and Tamoios Ambiental Protection Area. The first two include almost all terrestrial surface of the island, except for most villages, that are included in Tamoios Ambiental Protection Area.

Those three invasive species were already recorded for Ilha Grande: *Achatina fulica* was first mentioned in 2002 (Santos et al. 2002), *M. tuberculata* in 2005 (Santos et al. 2007), and *P. acuta* in 2009 (Miyahira et al. 2010) to the main village of Ilha Grande, Vila do Abraão. However, the distribution of these species on the island is unknown. The main goal of this study was to present the distribution of these species on Ilha Grande, as also some observations on conservation issues, as the first step for future managing, conservation, and educational plans.

Material and Methods

Ilha Grande (23° 05', 23° 15' S and 44° 06', 44° 23' W), is an island located on the southern coast of the Rio de Janeiro state, southeast Brazil, far from 150 km from the city of Rio de Janeiro, in the municipality of Angra dos Reis. The island is covered with important remnants of Atlantic Forest especially on highlands (Callado et al. 2009), but near the coast, the habitats are modified by deforestation, non-native plants, domestic animals, and domestic sewage (Santos et al. 2007). The island can be divided into two sides, one facing the mainland (Continental or North side), with the most villages; and the other facing the open ocean (Oceanic or South side) with fewer villages and more difficult access by boats or trails.

Twenty-five localities were surveyed for invasive snails, were included the villages and nearby areas (anthropic and perianthropic). The localities were reached by trails or boats. Each locality was visited at least twice, and the search for the snails was done by three people at all kinds of suitable habitats. For *A. fulica* we did a visual inspection on walls, plants, under vegetation debris, and garbage for 30 minutes/person. *Melanoides tuberculata* and *P. acuta* were searched using a handled metallic scoop in freshwater streams for 30 minutes/person. At each village were recorded the “presence” or “absence” regarding the occurrence of the target invasive species: *A. fulica*, *M. tuberculata*, and *P. acuta*. All collecting stations were georeferenced using a Garmin Etrex. Samples of live molluscs were placed in plastic bags or pots and took back to the laboratory for biological observations, taxonomic identification, and further parasitological studies.

Voucher specimens are housed at the Malacological Collection of the Universidade do Estado do Rio de Janeiro (UERJ).

Results

Sixteen localities of Ilha Grande present at least one invasive mollusc species: *M. tuberculata*, *P. acuta*, or *A. fulica* (Figure 1 and Table 1). In most localities only *A. fulica* was found; in Praia Vermelha, two species were recorded (*M. tuberculata* and *P. acuta*), and on Vila do Abraão, all the three species occurs. There are only two villages with invasive species on the oceanic side (Provetá and Vila Dois Rios), and 14 on the continental side (Figure 1 and Table 1). All the records of freshwater invasive molluscs were on the continental side, on only two villages (Vila do Abraão and Praia Vermelha). *Achatina fulica* has distributed along 16 (64%) villages: 14 on the continental side and two on the oceanic side. *Achatina fulica* was found colonizing not only the urban environments but also the surroundings of the villages in areas of secondary Atlantic Forest. The two freshwater invasive gastropods were found only at impacted water bodies, *M. tuberculata* in sandy bottoms, and *P. acuta* attached to aquatic vegetation. The two species also colonize debris and/or man-made habitats.

Most of the records were done on the borders of Ilha Grande State Park (Fig. 1), except for the occurrence of *A. fulica* in Vila Dois Rios that is inside the park. On Praia do Sul Biological Reserve no invasive molluscs were found.

Discussion

Achatina fulica was widespread on villages of Ilha Grande (Figure 1 and Table 1), this is related to some features of this species like

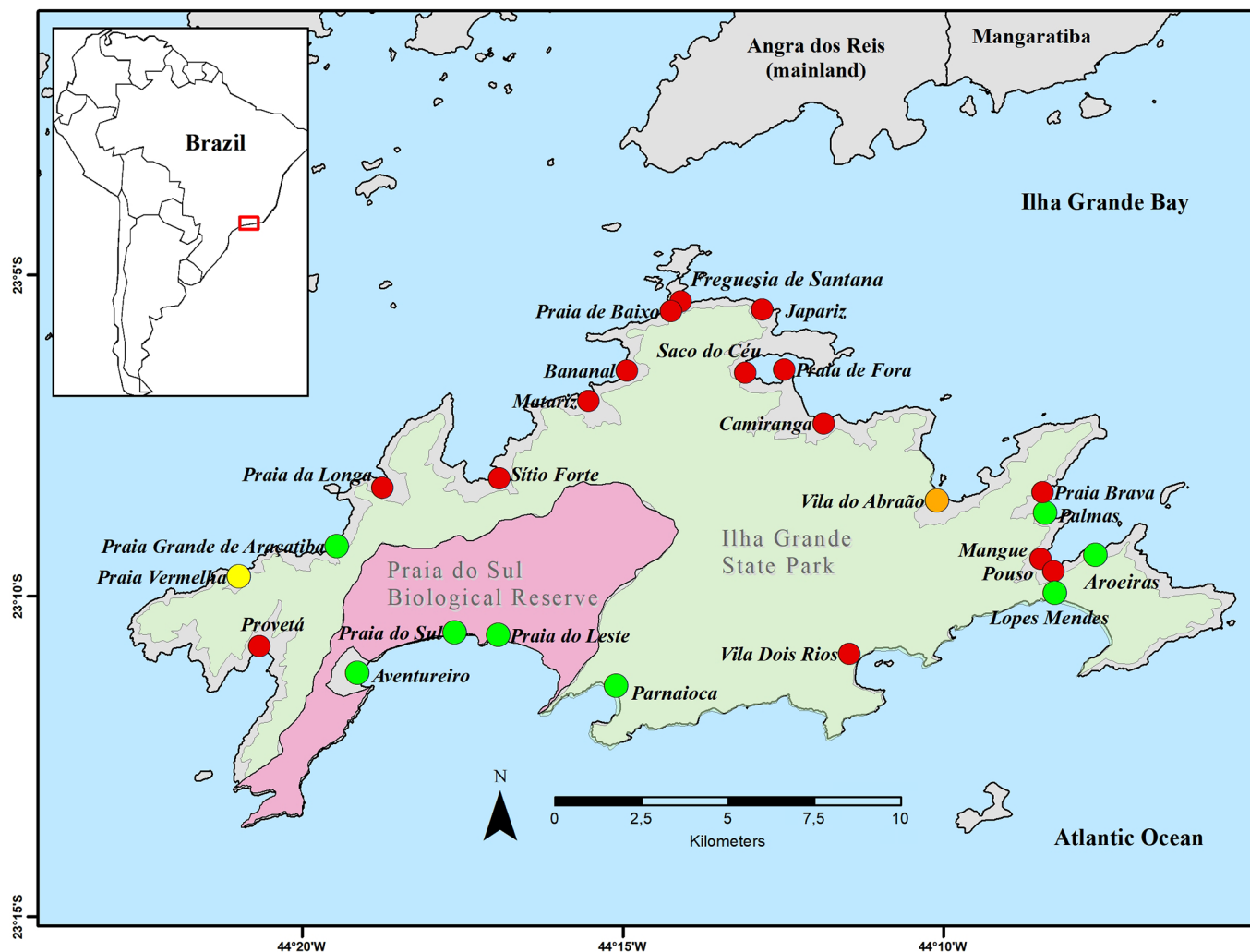


Figure 1. Distribution of *Achatina fulica*, *Melanoides tuberculata*, and *Physa acuta* in several villages of Ilha Grande. Red dots – *Achatina fulica*; Yellow dots – *Melanoides tuberculata* and *Physa acuta*; Orange dots – *A. fulica*, *M. tuberculata*, and *P. acuta*; and Green dots – Invasive molluscs not found.

hermaphroditism, a high number of egg-laying per year (3 to 4), a high number of eggs per laying episode (200 to 400), and high adaptability to environmental conditions (Kosloski et al. 2002, Fischer & Colley 2004). This species was probably dispersed on Ilha Grande attached to plants and other goods. The distribution of *A. fulica* on Ilha Grande seems to be restricted to anthropic and nearby areas of secondary forest. The species was so adapted to the anthropic environment of Ilha Grande that were found at gardens, walls, and streets. Fischer et al. (2008) stated that these urban areas offer resting sites and shelters against predation. Other authors already observed these environmental preferences of *A. fulica* (Colley & Fischer 2009, Goldyn et al. 2017). The urban population can expand to nearby preserved forests (Raut & Baker 2002, Fischer et al. 2006, Faraco 2011). Ilha Grande has a rich and diverse fauna of land snails (Haas 1953, Santos & Monteiro 2001, Santos et al. 2010, Nunes & Santos 2012, Cuezco et al. 2018), but few occur in anthropic habitat, as preferred by *A. fulica*. However, the expansion of this species to preserved areas can increase the negative impacts of giant African land snail on the island; although some studies do not show so drastic outputs (Miranda et al. 2015, Miranda & Pecora 2017, O'Loughlin & Green 2017).

Melanoides tuberculata and *P. acuta* were restricted to two localities of Ilha Grande (Figure 1 and Table 1); the first record of *M. tuberculata* was in 2005 in Vila do Abraão (Santos et al. 2007) and *P. acuta* was in 2009 (Miyahira 2010) in the same locality. The population of *M. tuberculata* at Vila do Abraão was initially found in low numbers (Santos et al. 2007), therefore the population increased, also affecting negatively the native fauna (Braga et al. 2014). A subsequent record of *M. tuberculata* was done at Praia Vermelha (Gonçalves et al. 2012) in low numbers, probably indicating a recent introduction event, but the population still present on the following collecting events, probably indicating that population was established. This last locality is far from Vila do Abraão, therefore it is probable that this distribution extension was human-mediated (e.g. discharge of aquarium water with aquatic plants and snails). The aquatic species need more factors to be transported from one place to another, resulting in a slower dispersion, and narrow distributions on Ilha Grande. Another factor that possibly restricts the distribution of aquatic invaders is the morphology of the streams of Ilha Grande, usually small and running across small stretch before reaches the sea. Thus, these are streams with a low amount of nutrients and conductivity, preventing some newly introduced species to

Table 1. The surveyed localities of Ilha Grande (Angra dos Reis, Rio de Janeiro, Brazil) and the date of first sighting of the three invasive species. N.F.= Not Found.

	Localities	GPS	<i>Achatina fulica</i>	<i>Melanooides tuberculata</i>	<i>Physa acuta</i>
Continental/North side	Vila do Abraão	23°08'49.5"S 44°10'13.4"W	Jan-2002	Aug-2005	Feb-2009
	Camiranga	23°07'17.81"S 44°11'56.39"W	Aug-2008	N.F.	N.F.
	Praia de Fora	23°06'48.48"S 44°12'19.14"W	Aug-2008	N.F.	N.F.
	Saco do Céu	23°06'37.87"S 44°13'00.39"W	Aug-2008	N.F.	N.F.
	Japariz	23°05'34.36"S 44°12'48.79"W	Aug-2008	N.F.	N.F.
	Freguesia de Santana	23°05'22.34"S 44°14'06.85"W	Sep-2007	N.F.	N.F.
	Praia de Baixo	23°05'30.0"S 44°14'13.7"W	Aug-2008	N.F.	N.F.
	Bananal	23°06'20.37"S 44°14'51.77"W	2004	N.F.	N.F.
	Matariz	23°06'58.96"S 44°15'31.35"W	2004	N.F.	N.F.
	Sítio Forte	23°07'31.68"S 44°16'25.85"W	Sep-2006	N.F.	N.F.
	Praia da Longa	23°08'17.13"S 44°18'39.16"W	Aug-2008	N.F.	N.F.
	Praia Grande de Araçatiba	23°09'11.95"S 44°19'20.67"W	N.F.	N.F.	N.F.
	Praia Vermelha	23°09'41.08"S 44°20'57.62"W	N.F.	Jun-2009	Jun-2009
	Mangue	23°09'35.36"S 44°08'14.12"W	Aug-2008	N.F.	N.F.
	Aroeiras	23°09'21.49"S 44°07'38.39"W	N.F.	N.F.	N.F.
	Oceanic/South side	Pouso	23°09'30.19"S 44°08'25.68"W	Aug-2008	N.F.
Palmas		23°08'46.21"S 44°08'21.82"W	N.F.	N.F.	N.F.
Praia Brava		23°08'22.12"S 44°08'26.41"W	Aug-2008	N.F.	N.F.
Praia do Leste		23°10'35.5"S 44°17'05.7"W	N.F.	N.F.	N.F.
Praia do Sul		23°10'36.7"S 44°18'03.1"W	N.F.	N.F.	N.F.
Provetá		23°10'48.29"S 44°20'34.34"W	Mar-2006	N.F.	N.F.
Aventureiro		23°11'10.43"S 44°19'06.96"W	N.F.	N.F.	N.F.
Parnaioca		23°11'28.73"S 44°15'02.32"W	N.F.	N.F.	N.F.
Vila Dois Rios		23°11'01.8"S 44° 11' 63.5"W	Sep-2006	N.F.	N.F.
Lopes Mendes		23°10'21.32"S 44°07'29.61"W	N.F.	N.F.	N.F.

establish, and the dispersion of the exiting species to other places. The shell morphology of *M. tuberculata* is also different in both populations (Gonçalves et al. 2012). *Physa acuta* occurs at the same stream of *M. tuberculata* in Vila do Abraão and Praia Vermelha. This pulmonate snail was the last invader to be found on the island, and the impacts of this species over native fauna are scarce on the literature but cannot be neglected (Zukowski and Walker 2009). Gonçalves et al. (2014) reported *Omalonyx matheroni* (Potiez & Michaud, 1835) in Villa do Abraão, but the introduction was not successful after periodic site visits (personal communication).

Most records of invasive molluscs in Ilha Grande were done on the North (or continental) side, facing the mainland. The two sides of the island present different environmental conditions (Nunes & Santos 2012) but it is probably that observed distribution is not related to those environmental factors. On the North side, there is a large number of villages, and an easier movement of goods and people, thus increasing the likelihood of an introduction. Vila do Abraão, the village with a greater flow of people on the island, was the unique place where the three invasive species were found together. The two villages on the oceanic side that presented invasive species were Provetá and Vila Dois Rios. Provetá has the second-largest resident population of the island, and

Vila Dois Rios is connected by road to Vila do Abraão, one of the few roads on the island. Thus, the uncontrolled movement of people and goods seems to be important to understand and mitigate the spread of invasive molluscs on the island. This phenomenon was probably related to the explosive increase of touristic activities after the closing of Ilha Grande's Prison in 1994 (Prado 2003, Cadei et al. 2009), although a previously detailed inventory of non-marine molluscs is not available. Haas (1953) pointed out some species of land and freshwater molluscs of Ilha Grande, and at that time, no non-native species were reported.

In addition to the tourism, the villages have experienced population growth and urban expansion, this can easily be noted at Vila do Abraão, Provetá, Bananal, Matariz, and Longa. In these villages there were always new buildings that demand a continuous trade of goods with the mainland, increasing the risk of unwanted introduction of species. Moreover, Ilha Grande doesn't have any kind of sanitary barrier; villagers and tourists can bring almost all kinds of animals and plants to the island. This lack of inspection can be a highway to the introduction of non-native species. The eight villages that do not present invasive species on Ilha Grande, also do not present a great touristic flow, except for Palmas.

Most records of invasive molluscs on Ilha Grande were out of restrictive conservation areas, except for *A. fulica* inside the Ilha Grande State Park.

This record inside the park and those on the borders of conservation areas causes concern and calls attention to the need for inspection on the goods transported to the island. Those three invaders can expand their distribution on the island if the proper conditions were offered.

Another important consequence of the dispersion of invasive species is the introduction and dispersal of parasites (Font 2003). Oliveira & Santos (2019) recorded cysts of the nematode *Strongyluris* Müller, 1894 in the pallial system of *A. fulica* collected in two populations from Ilha Grande: Vila do Abraão and Vila Dois Rios. This parasite has as final host lizards or rarely anurans (Vicente et al. 1993, Bursey et al. 2003), although *A. fulica* can also harbor other helminths that have the man as the final common host (Thiengo et al. 2007). Some habitat of this species, like coprophagy, can make easy the establishment of new cycles (Mead 1961, Fischer 2009, Goldyn et al. 2017). Ximenes et al. (2017) reported the occurrence of *Centrocestus formosanus* (Nishigori, 1924) in *M. tuberculata* in the population from Vila do Abraão, a helminth that has birds as the final hosts.

The occurrence of *A. fulica*, *M. tuberculata*, and *P. acuta* represent a risk to conservation of native species and public health, an effort to control those species must be done together with environmental education, public health, and environmental authorities to prevent and mitigate the spread of these invasive species on Ilha Grande.

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Author Contributions

Jaqueline L. de Oliveira: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

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Gleisse Kelly M. Nunes: Contribution to data collection; Contribution to data analysis and interpretation; Contribution to manuscript preparation.

Sonia B. dos Santos: Substantial contribution in the concept and design of the study; Contribution to data collection; Contribution to manuscript preparation; Contribution to critical revision, adding intellectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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