



## ECOSYSTEMS

# Diversity of non-marine gastropods of the Fiocruz Atlantic Forest Biological Station and adjacent urban areas, Rio de Janeiro, RJ, Brasil

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**Abstract:** Our main objective was to perform a preliminary survey of the non-marine gastropods at the Estação Biológica Fiocruz Mata Atlântica (EFMA) and its adjacent urban areas, also considering samples from other localities of the Parque Estadual da Pedra Branca received as donation, in Rio de Janeiro, RJ, Brazil. Infection by larval helminths of medical and veterinary importance was also investigated in 348 specimens of five freshwater species and two specimens of the terrestrial species *Achatina fulica*. In all, 584 samples of molluscs from 34 collection sites were obtained. They represented 31 species classified in 16 families. Fifteen species were exclusive to the EFMA area. In the urban area mainly exotic and/or synanthropic species were found. Some of them were found in the forest border as well. The freshwater *Biomphalaria tenagophila*, an intermediate host of the trematode that causes schistosomiasis mansoni, was found parasitized by *Xiphidiocercaria cercariae* and the Afro-asiatic *Melanooides tuberculata* by *Pleurolophocercus cercaria*. The finding of endemic and exotic species, including transmitters of parasites, demonstrate the importance of fast surveys such as the present study. However, considering the great diversity of endemic molluscs found in a relatively small part of the EFMA, we highlight the necessity of further additional studies.

**Key words:** Atlantic Forest, Gastropoda, biodiversity, associated helminths.

## INTRODUCTION

Introduction and establishment of exotic and invasive species are facilitated in environments altered by human action. This fact has caused serious problems that affect native species conservation, as well as human health. Faunal inventories/surveys play an important role in assessing and managing these invasive species as well as the management of wildlife resources. (MMA 2006).

Gastropod species are considered good bioindicators of environmental health due to their relative lower dispersion capacity, associated to stable microclimate dependence,

relatively strict habitat preferences and high sensitivity to environmental conditions (Kappes et al. 2009, Altaf et al. 2017, Nicolai & Ansart 2017). On the other hand, freshwater and terrestrial gastropods can act as intermediate hosts of helminths that cause diseases to human and animals (MS 2008, Ohlweiler et al. 2010). Other species can be invasive, becoming important crop and urban pests that can compete with native species for resources (Barker 2002, Fernandez et al. 2003, Dreves et al. 2017).

The Parque Estadual da Pedra Branca (PEPB) is recognized as one of the largest urban forests in the world and the largest in Brazil (INEA 2013). It has an important role in the water and climate

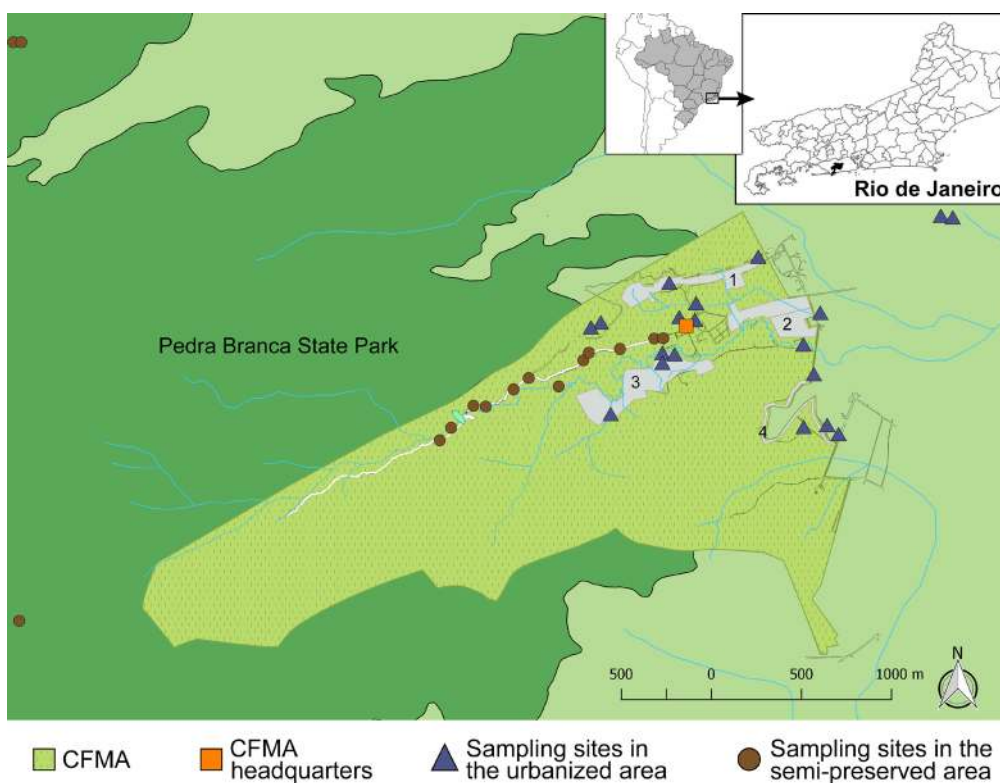
balance of Rio de Janeiro, occupying about 10% of its territory. It has an area of 125 km<sup>2</sup> and it protects more than 50% of what remains of the Atlantic Forest in the city (INEA 2013). The Campus Fiocruz Mata Atlântica (CFMA) is located in the neighborhood of Jacarepaguá, Rio de Janeiro, RJ and belongs to the Fundação Oswaldo Cruz. It is bordered by PEPB, between an Atlantic Forest area and a disordered urban area, with high interaction between wild and domestic animals. The Campus includes a secondary Atlantic Forest vegetation (Souza et al. 2015), representing the Estação Biológica Fiocruz Mata Atlântica (EFMA), which overlapping its area with the PEPB.

Studies on the land molluscs of the Rio de Janeiro state are scarce and none has dealt with the area of PEPB. The results of Santos et al. (2003) in the PEPB were restricted to freshwater species. Thus, the objective of present study was to perform a preliminary survey of the non-marine gastropods in the EFMA, as well as in its

adjacent urban areas, also considering samples from other localities of the PEPB received as donation. Parasitological analyses of some species (all freshwater and one terrestrial) were also performed, aiming to investigate possible infection by larval helminths of medical importance, such as those that cause schistosomiasis and angiostrongyliasis (abdominal and cerebral).

## MATERIALS AND METHODS

Mollusc samples were obtained from 34 sites distributed in two different areas within CFMA: a semi-preserved forest at the EFMA and an urban and adjacent area to EFMA (Figures 1, 10a, Collection License number 51246-2- Instituto Estadual do Meio Ambiente - INEA). Fifteen sites were in the forest area near the main EFMA trail. The other nineteen sites were in urbanized areas in the following communities: Fincão, 1.



Caminho da cachoeira; 2. Sampaio Correa and Viana do Castelo; 3. Fincão; 4. Faixa Azul and Nossa Senhora dos Remédios and the CFMA building area. Samples from the locality Pau da Fome, which is not part of EFMA but belongs to the PEPB, were received as a donation, and were also analyzed. The geographic coordinates of each collection site were used to construct a map using the QGIS (2.0) georeferencing program (QGIS Development Team 2017). The collection sites were chosen to compare the species in both areas, aiming to identify the native fauna and to investigate the exotic and/or intermediate hosts species of helminths of importance. Sampling was carried out from November 2017 to March 2018, representing the rainy season (Siciliano et al. 2018). Shells and live animals were sampled using active search method with all specimens being hand-collected in the field and photographed at the laboratory. In the forest the search was made in lower trunks, leaves and branches of trees, shrubs, and leaf litter. The collectors ranged from four to six per sampled site and dedicated 20 minutes per site. All the sampled specimens are deposited at the Coleção de Moluscos do Instituto Oswaldo Cruz (CMIOC 11.106 – 11.206, 11649-11650) (Table I).

Freshwater specimens were fixed according to MS (2008), except for *Melanoides tuberculata* (Müller, 1774) and *Pomacea sordida* (Swainson, 1823) that followed Fukuda et al. (2008). All live freshwater specimens were exposed to four hours of light and four hours of darkness to induce possible cercarial shedding according to Thiengo et al. (2012). Cercarian types were identified based on Pinto & Melo (2013). Procedures for the morphological identification of freshwater snails followed Simone (2006), MS (2008), Ohlweiler et al. (2010) and Thiengo et al. (2011).

Terrestrial specimens were fixed according to Thomé (1975) and classification of the families followed Bouchet et al. (2017). Several annotated type catalogues were used to species identification (Simone 2006, Breure & Ablett 2011, 2012, 2014, 2015, Breure & Araújo 2016).

Two specimens of the African giant snail *Achatina (Lissachatina) fulica* Bowdich, 1822 were digested with chloridric acid 0.7% solution (Graeff-Teixeira & Morera 1995), to recover possible nematode larvae of medical and veterinary interest.

## RESULTS

In total, 584 samples of molluscs were obtained (shells and living specimens). A total of 31 species were found, of which 26 were terrestrial (12 families) and five were freshwater species (four families) (Table I, Figure 9a-e). Among the terrestrial families, Subulinidae, Bulimulidae and Simpulopsidae were those with the highest number of species, whereas for freshwater was Physidae.

Most species were collected alive and those represented only by shells were: *Anthinus multicolor* (Rang 1831), *Lopesianus crenulatus* Weyrauch, 1958, *Tamayoa banghaasi* (Thiele 1927), *Beckianum beckianum* (Pfeiffer 1846), *Allopeas micrum* (d'Orbigny 1835) and *Allopeas gracile* (Hutton 1834).

### Atlantic Forest area

In the semi-preserved Atlantic Forest (EFMA) among the 20 collected species only one was freshwater, the Afro-asiatic *Melanoides tuberculata* (Figure 9d) (Table I). The terrestrial taxa belong to the following families: Bulimulidae, Helicinidae, Megaspiridae, Neocyclotidae, Simpulopsidae, Streptaxidae, Scolodontidae, Strophocheilidae, Subulinidae

**Table I. List of continental mollusc species found in the Pedra Branca State Park, Rio de Janeiro, RJ and adjacent urban areas, including their Family, area where they were found (Forest or Urban area), number of the lots in the Coleção de Moluscos do Instituto Oswaldo Cruz, number of collected specimens (N°) and if is considered exotic or native in Brazil.**

Family	Terrestrial species	Area	Lots- CMIOC	N°	Exotic/ Native
Achatinidae	<i>Achatina fulica</i>	Urban	11190, 11199, 11205	5	Exotic
Helicinidae	<i>Helicina angulata</i>	Forest	11106, 11110, 11168, 11175	10	Native
Neocyclotidae	<i>Neocyclotus prominulus</i>	Forest	11115, 11155, 11160, 11172, 11179, 11184	31	Native
Veronicellidae	<i>Latipes</i> sp.	Urban	11137	2	Native
	<i>Phyllocaulis boraceiensis</i>	Forest	11203	1	Native
Agriolimacidae	<i>Deroceras laeve</i>	Urban	11124, 11144, 11200	3	Exotic
Bulimulidae	<i>Bulimulus tenuissimus</i>	Forest/Urban	11112, 11114, 11131, 11143	3/24	Native
	<i>Drymaeus papyraceus</i>	Urban	111148, 10005	2	Native
	<i>Lopesianus crenulatus</i>	Forest	11159	1	Native
Simpulopsidae	<i>Leiostracus perlucidus</i>	Forest	11111, 11117, 11121, 11122, 11154, 11174, 11180, 11185	13	Native
	<i>Rhinus ciliatus</i>	Forest	11118, 11163, 11166, 11167, 11181	5	Native
	<i>Simpulopsis sulculosa</i>	Forest	11173, 11176, 11177	4	Native
Megaspiridae	<i>Thaumastus taunaisii</i>	Forest	11135	5	Native
	<i>Megaspira elatior</i>	Forest	11157, 11161	8	Native
Streptaxidae	<i>Streptaxis crossei</i>	Forest	11156, 11182	3	Native
	<i>Streptaxis</i> sp.	Forest	11178	2	Native
Scolodontidae	<i>Tamayoa banghaasi</i>	Forest/Urban	1108, 11131, 11170	4/1	Native
	<i>Happia vitrina</i>	Forest	11162, 11204	4	Native
Strophocheilidae	<i>Anthinus multicolor</i>	Forest	11164, 11183	2	Native
	<i>Gonyostomus gonyostomus</i>	Forest	11120	1	Native
	<i>Megalobulimus ovatus</i>	Forest	11136	2	Native
Subulinidae	<i>Allopeas micra</i>	Urban	11126, 11132, 11141	6	Exotic
	<i>Allopeas gracile</i>	Urban	11127	2	Exotic
	<i>Leptinaria unilamellata</i>	Forest/Urban	11109, 11138, 11142, 11169, 11193	4/6	Exotic
	<i>Beckianum beckianum</i>	Forest/Urban	11107, 11128, 11133, 11153, 11158, 11171, 11194, 11201	18/13	Exotic
	<i>Subulina octona</i>	Urban	11129, 11140, 11202, 11206	12	Exotic
	<i>Freshwater species</i>				
Planorbidae	<i>Biomphalaria tenagophila</i>	Urban	11149, 11196	105	Native
Ampullariidae	<i>Pomacea sordida</i>	Urban	11147, 11152, 11187, 11191	34	Native
Physidae	<i>Physa acuta</i>	Urban	11150, 11197	89	Exotic
	<i>Stenophysa marmorata</i>	Urban	11146, 11151, 11198	13	Native
Thiaridae	<i>Melanoides tuberculata</i>	Forest/Urban	11113, 11125, 11134, 11186	36/71	Exotic

and Veronicellidae. Among these species 15 were restricted to this area (Table I). The remaining species included mainly exotic or native synanthropic species, commonly found in disturbed and synanthropic areas from Rio de Janeiro state (Table I). They were collected in the forest border near the headquarters of the CFMA and included two species of subulinids, *Leptinaria unilamellata* (Orbigny 1835) and *Beckianum beckianum*, the bulimulids *Bulimulus tenuissimus* (d'Orbigny 1835) and *Tamayoa banghaasi*, besides the freshwater snail *M. tuberculata*.

The terrestrial families with the highest number of samples in the Atlantic Forest (EFMA) were Neocyclotidae, Subulinidae and Simpulopsidae (Table I). The most found species in the area was the operculate *Neocyclotus prominulus* (d'Orbigny 1835) (31 samples) (Figures 2d, 7c), which was collected in the leaf litter on the woodland floor. The second most common species and exclusive of this area was the snail *Leiostracus perlucidus* (Spix 1827) (13 samples) (Figures 3i, 6c), followed by the operculate snail *Helicina angulata* Sowerby, 1873 (10 samples) (Figures 3g, 7f), both arboreal snails. Other arboreal species restricted to this

area were *Simpulopsis sulculosa* (Férussac 1821) (Figures 3h, 6a) and *Rhinus ciliatus* (Gould 1846) (Figure 6d).

Another well-represented native species in the leaf litter was the megaspirid *Megaspira elatior* (Spix, 1827) (Figures 3d, 6g, h) that, however, was represented mainly by empty shells (8 samples), with only one specimen collected alive. The shell presents many whorls (the shell in the lengthiest specimen had 19 whorls, 49.66 mm in length and 7.93 mm in width). Adult specimens present three columellar lamellae and one parietal lamella in the aperture, which are not visible in the juvenile specimens (Figure 6g). Surprisingly, when the soft body is retracted it occupies only the first whorls of the shell.

We also found some carnivorous species restricted to the Forest area. Two species of Scolodontidae were found in the leaf litter: *Happia vitrina* (Wagner 1827) (four shells) and *Tamayoa banghaasi* (Thiele 1927) (four shells), both small molluscs (Figure 7d, e). The largest specimen of *T. banghaasi* had a shell with 4.54 mm in width. Two species of Streptaxidae were also collected in the leaf litter: *Rectartemon* sp. and *Streptaxis crossei* (Pfeiffer 1867). *Rectartemon* sp. has a very characteristic orange body color and *S. crossei* has a peculiar small shell with eight whorls of similar diameter, and lamellae in the aperture (Figures 3e, 7b).

The largest native molluscs were found in the locality of Pau da Fome: *Megalobulimus ovatus* (Müller 1774) (Figures 3a, 8b) (two specimens), *Thaumastus taunaisii* (Férussac, 1821) (five specimens), (Figures 3b, 8c) and the slug *Phyllocaulis boraceiensis* Thomé, 1972 (one) (Figure 4b) that was found in activity on the ground, in a humid day. In addition, we found one specimen of the macromollusc *Gonyostomus gonyostomus* (Férussac 1821) (Figures 3c, 8d) and a shell and a live specimen of *Anthinus multicolor*, which curiously was collected at the



**Figure 2.** Alive specimens. a. *Subulina octona* (CMIOC 11202), b. *Leptinaria unilamellata* (CMIOC 11138), c. *Bulimulus tenuissimus* (CMIOC 11130), d. *Neocyclotus prominulus* (CMIOC 11160).



**Figure 3. Alive specimens. a.** *Megalobulimus ovatus* (CMIOC 11136), **b.** *Thaumastus taunaisii* (CMIOC 11135), **c.** *Gonyostomus gonyostomus* (CMIOC 11120), **d.** *Megaspira elatior* (CMIOC 11161), **e.** *Streptaxis* sp. (CMIOC 11178), **f.** *Drymaeus papyraceus* (CMIOC 10005), **g.** *Helicina angulata* (CMIOC 11106), **h.** *Simpulopsis sulculosa* (CMIOC 11173), **i.** *Leiostracus perlucidus* (CMIOC 11122).

moment it was being eaten by a planarian (Figure 4a). They were photographed, but the planarian specimen became decomposed before being fixed and identified.

### Adjacent urban areas

In total, 16 species were collected, including 11 land and five freshwater species (Table I). Parasitological analyzes of the following species: *Achatina fulica*, *Pomacea sordida*, *Physa acuta* (Draparnaud 1805), *Stenophysa marmorata* (Guilding 1828), *Biomphalaria tenagophila* (d'Orbigny 1835) and *Melanoides tuberculata* did not reveal infection with medically important nematodes and trematodes. Subulinidae was the most representative family in the urban area, with five species found: *Subulina octona* (Brugüière, 1789), *A. micrum*, *A. gracile*, *B. beckianum* and *L. unilamellata* (Figures 2a, b, 5). All these species were widespread and were collected in urban gardens and forest borders. Two live specimens and 24 shells of *B. tenuissimus* were found in the urban area (Figures 2c, 6f).

A shell and a live specimen of the native and arboreal snail *Drymaeus papyraceus* (Mawe

1823) were also found in a garden and at the CFMA Headquarters, respectively (Figures 3f, 6b).

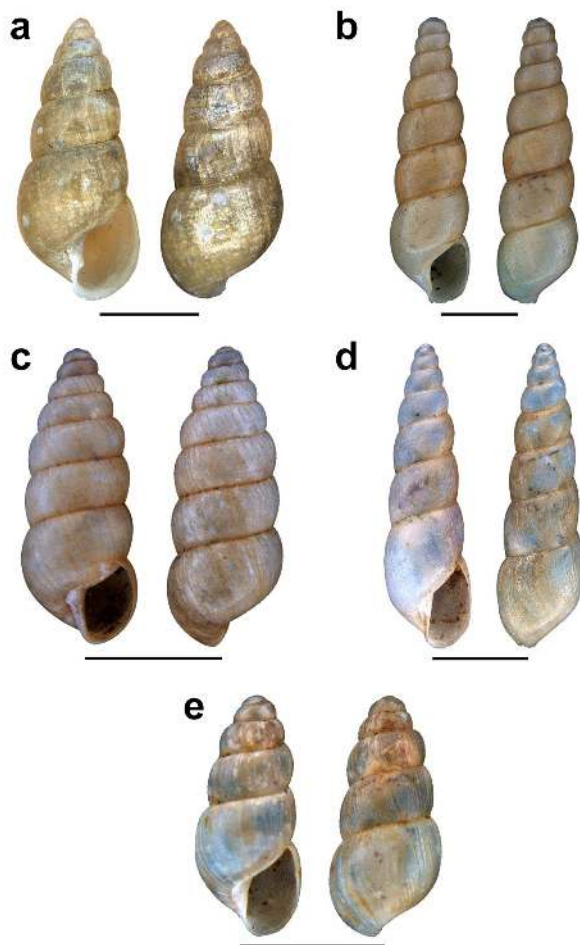
Two species of slugs were found in a domestic sewage ditch: two specimens of *Latipes* sp. (Veronicellidae), and three specimens of *D. laeve* (Figure 4c, d) (Agriolimacidae), which were collected under fallen trunks, in gardens and near the forest border (Table I).

Five freshwater species were collected (Table I): the planorbid *Biomphalaria tenagophila* (105 live specimens) (Figure 9e), the physid *Stenophysa marmorata* (13 live specimens) (Figure 9b), and live specimens of the ampullariid *Pomacea sordida* (33 specimens) (Figure 9c) from a domestic sewage ditch and a polluted stream. The other two species were exotic: *Physa acuta* collected in a garden drainage ditch (89 live specimens) that receives domestic sewage (Figure 9a), and the thiarid *Melanoides tuberculata* (71 live specimens) from a polluted stream (Figure 9d).

Two individuals of *B. tenagophila* (Figure 9e) were found parasitized by Xiphidiocercarie (Ubiquita) and 41 individuals of *M. tuberculata* were parasitized by *Pleurolophocercus cercaria*.



**Figure 4.** Alive specimens. a. Young *Anthinus multicolor* (CMIOC 11116) being eaten by a planarian. b. *Phyllocaulis boraceiense* (CMIOC 11203). c. *Latipes* sp. (CMIOC 11145), d. *Deroceras laeve* (CMIOC 11200).



**Figure 5.** Shell in different views. a. *Leptinaria unilamellata* (CMIOC 11138), b. *Subulina octona* (CMIOC 11129), c. *Beckianum beckianum* (CMIOC 11133), d. *Allopeas gracile* (CMIOC 11127), e. *Allopeas micrum* (CMIOC 11126). Scale: 5 mm.

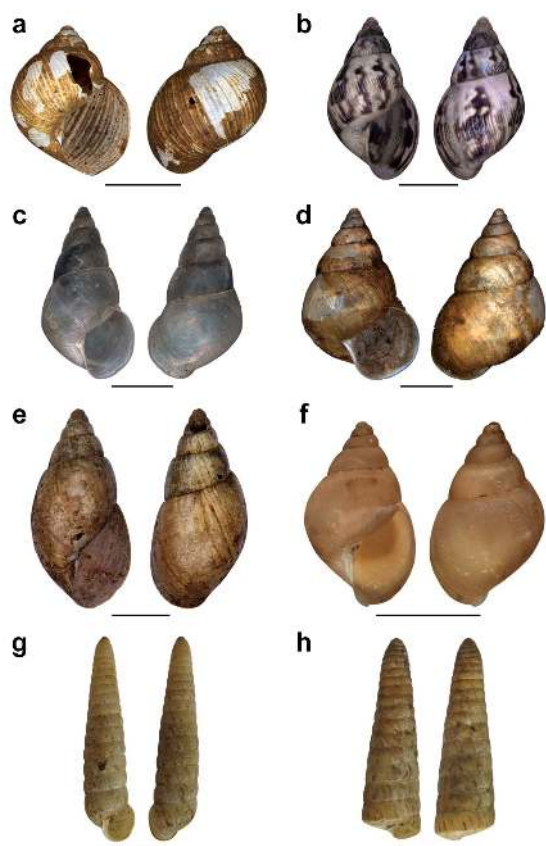
## DISCUSSION

The biodiversity of molluscs found in the present study is high in view of the short sampling period, and the relatively small sampled area. Twelve families of terrestrial molluscs and four of freshwater were found. The number of species of land molluscs was lower in the urban area (11 species), although more freshwater species (five species) and water bodies were investigated in this area in relation to the Forest area. Similarly, Alexandre et al. (2017) carried out a survey of the Urca campus of the Universidade Federal do Estado do Rio de Janeiro, which is bordered by

Parque Natural Municipal da Paisagem Carioca and is within the buffer zone of Monumento Natural dos Morros do Pão de Açúcar e da Urca (MONA), and found 18 species and 12 families. Peres (2019) developed a similar study in São Paulo state and reported 13 species in a survey of malacofauna in an Atlantic Forest area with similar characteristics (Carmo Park, São Paulo). *Simpulopsis sulculosa* was the only species found in both studies.

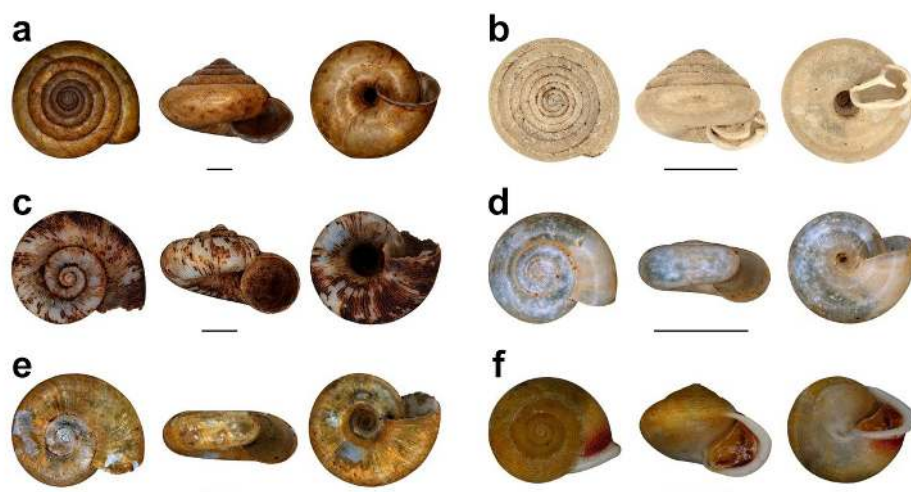
In the present study was possible to distinguish two communities of species, one in the forest and another in the urbanized area. Fifteen species were restricted to the forest area and *N. prominulus*, *L. perlucidus* and *H. angulata*, were among the most common species. The Caenogastropoda *N. prominulus* was found only in the forest leaf litter. It is reported from Paraná, São Paulo, Rio de Janeiro and Minas Gerais States (Simone 2006). Santos & Monteiro (2001) reported that *N. prominulus* was only found in the most preserved area of the Atlantic Forest in the locality of Vila Dois Rios, in Ilha Grande, State of Rio de Janeiro, where there was no human occupation. Santos et al. (2009) aiming the conservation of both terrestrial molluscs and the Atlantic Forest proposed the species *L. perlucidus* as one of the umbrella or flag species. *Helicina angulata*, which is another Caenogastropoda, is recorded to the states of Rio de Janeiro, São Paulo and Bahia (Simone 2006).

We highlight the occurrence of some large molluscs in the Atlantic Forest area, as *M. ovatus*, that ranges from the coast of Rio de Janeiro to Santa Catarina (Simone 2006) and *G. goniostomus*, which has a smaller and slender shell (Figure 8d). According to Leme (1973) *Gonyostomus* Beck, 1837 is endemic to Southeast Brazil, inhabiting tropical and humid forests, with species rarely collected. *Thaumastus taunaisii*, whose largest specimen had a shell reaching 7.2



**Figure 6.** Shell in different views. a. *Simpulopsis sulculosa* (CMIOC 11173), b. *Drymaeus papyraceus* (CMIOC 11148), c. *Leiostracus perlucidus* (CMIOC 11154), d. *Rhinus ciliatus* (CMIOC 11163), e. *Lopesianus crenulatus* (CMIOC 11159), f. *Bulimulus tenuissimus* (CMIOC 11123), g-h. *Megaspira elatior* adult (g) and younger (h) (CMIOC 11161). Scale: 1 cm.





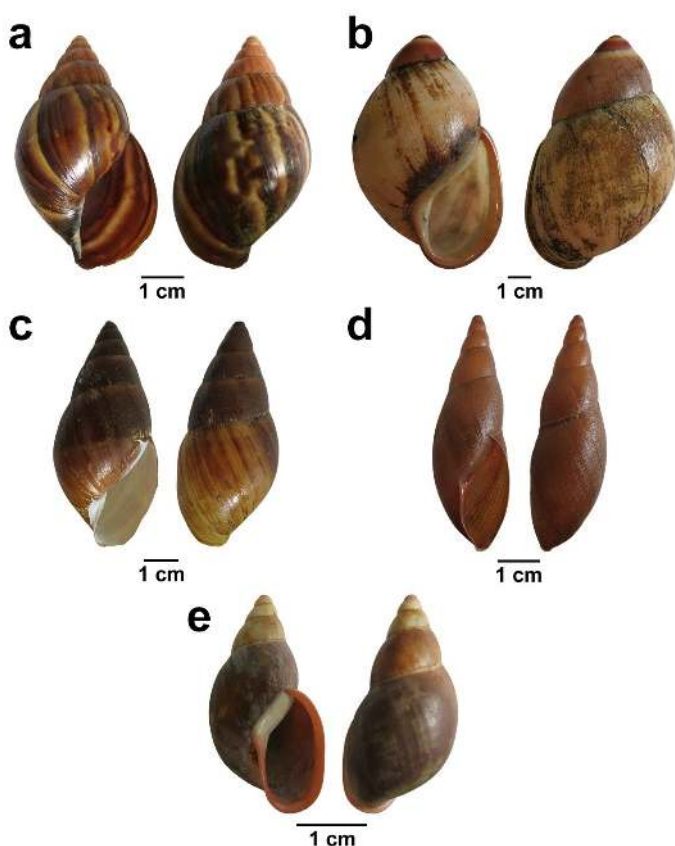
**Figure 7.** Shell in different views. a. *Streptaxis* sp. (CMIOC 11649), b. *Streptaxis crosseii* (CMIOC 11182), c. *Neocyclotus prominulus* (CMIOC 11160), d. *Tamayoa banghaasi* (CMIOC 11131), e. *Happia vitrina* (CMIOC 11650), f. *Helicina angulata* (CMIOC 11106). Scale: 5mm.

cm in length and 3.0 cm in diameter, is reported to the states of Santa Catarina, São Paulo, Minas Gerais and Rio de Janeiro (Salgado et al. 1995, Simone 2006). The slug *P. boraceiensis* is reported to southeastern Brazil, in the states of Minas Gerais, Rio de Janeiro, São Paulo, Paraná and Santa Catarina (Thomé 1972, Thomé et al. 2006, Simone 2006) and it is considered the largest species of Veronicellidae (more than 20 cm in length) (Thomé 1972, Thomé et al. 2006).

Despite being a native species from Atlantic forest areas, including Rio de Janeiro that is its type-locality, the arboreal snail *Drymaeus papyraceus* was only found in the urban area, although the species probably also occurs in the PEPB. The species is widespread in Brazil, being reported to Paraíba, Pernambuco, Alagoas, Bahia, Espírito Santo, Rio de Janeiro, Paraná and Rio Grande do Sul (Rezende 1975, Dutra-Clarke & Souza 1991, Silva & Castro 2003). Other countries where the species occurs are Paraguay, Argentina and Uruguay (Simone 2006). On the other hand, some species found in the Forest area, have a more restricted distribution, as *R. ciliatus*, *M. elatior* and *G. goniostomus*, which are so far reported only from the state of Rio de Janeiro (Simone 2006). *Bulimulus tenuissimus*, *T. banghaasi* and the subulinids *A. micra*, *L.*

*unilamellata* and *B. beckianum*, besides *M. tuberculata*, were collected in both areas. Most are common in disturbed and urban areas from Rio de Janeiro State (Santos et al. 2010, Alexandre et al. 2017), and found in disturbed and preserved areas from other Brazilian States (Simone & Cesati 2013, Salvador et al. 2018, Ramos-de-Souza et al. 2018, Coelho et al. 2018, Silva et al. 2019).

Some species found in the urban areas were already naturally found hosting the nematodes *Angiostrongylus cantonensis* (Chen, 1935) and *Angiostrongylus costaricensis* Morera & Céspedes, 1971, which cause eosinophilic meningitis and/or abdominal angiostrongyliasis, respectively (Ohlweiler et al. 2010, Morassutti et al. 2014). They were *S. octona* (infected by *A. cantonensis*), *B. tenuissimus* (*A. cantonensis*), *A. fulica* (*A. cantonensis*) and *D. laeve* (*A. costaricensis*) (Ohlweiler et al. 2010, Ramos-de-Souza et al. 2018). We call attention to the two last species since they are important agricultural and urban pests. *Achatina fulica* has been introduced in several parts of the world including Brazil, where it is very widespread and considered an urban pest (Thiengo et al. 2007). It has been associated with the expansion of eosinophilic meningitis in Brazil (Morassutti et al.

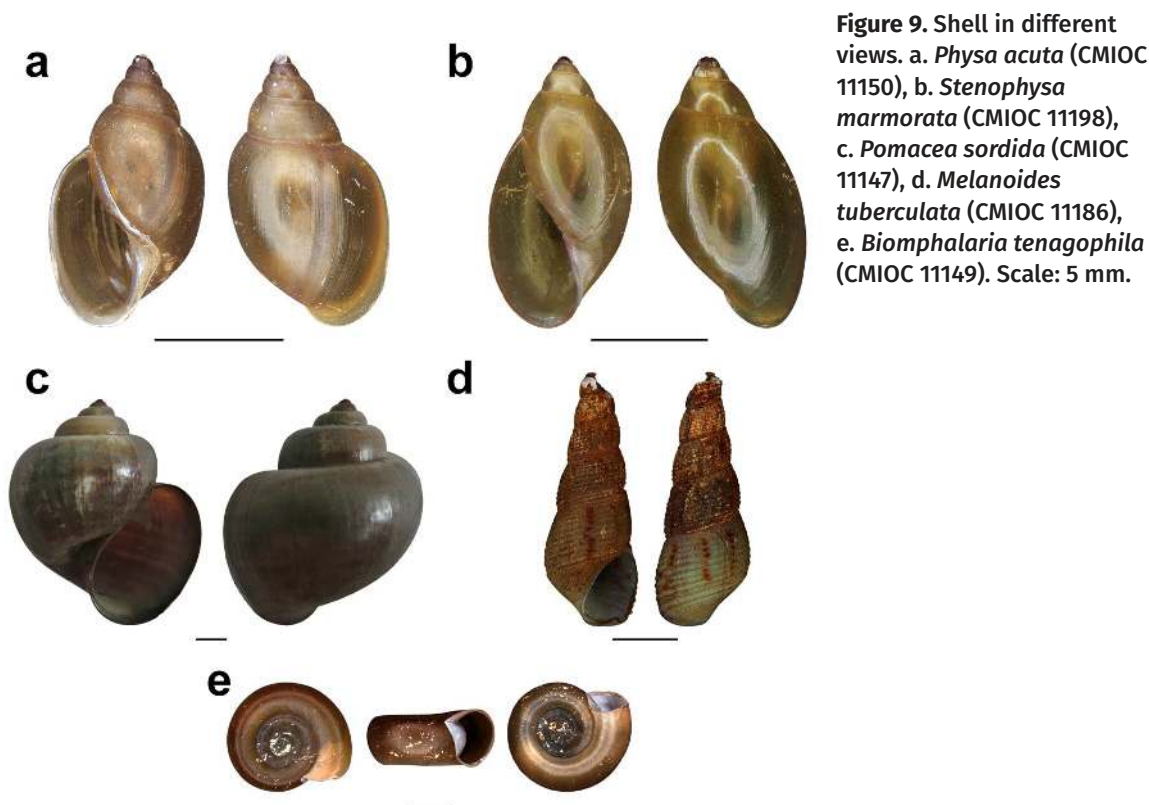


**Figure 8.** Shell in different views. a. *Achatina fulica* (CMIOC 11205), b. *Megalobulimus ovatus* (CMIOC 11136), c. *Thaumastus taunaisii* (CMIOC 11135), d. *Gonyostomus gonyostomus* (CMIOC 11120), e. *Anthinus multicolor* (CMIOC 11164). Scale: 1 cm.

2014, Thiengo & Fernandez 2016). *Deroceras laeve* is a cosmopolitan species, described originally from Europe and accidentally introduced to various parts of Brazil and the world (Barker 1999, Ohlweiler et al. 2010). It is considered a horticultural and garden pest (Barker 1999). Maurer et al. (2002) emphasized the potential of *D. laeve* as transmitter of parasites due to the small size of this slug that is often found between vegetable leaves and can easily be accidentally ingested.

Subulinidae and Bulimulidae were the most diverse families and found in the preserved forest area and in the urban area. The same was observed by other authors such as Lopes et al. (2012) in the state of Rio de Janeiro. Subulinidae was also the most diverse family in the campus of the Centro Universitário CIDADE (Madureira neighborhood), Rio de Janeiro city,

where four species were found according to Alexandre et al. (2017). In the present study five species were found: *L. unilamellata*, *S. octona*, *A. micrum*, *A. gracile* and *B. beckianum*. *Leptinaria unilamellata* is considered cosmopolitan, with distribution expanded mainly by anthropic action (Araújo 1982). In Brazil, it occurs in the states of Amazonas, Pará, Rondônia, Mato Grosso, Alagoas, Pernambuco, Bahia, Minas Gerais, Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul (Morretes 1949, Araújo 1982, Agudo-Padrón 2008, Araújo & Keller 1993, Salvador et al. 2018, Silva et al. 2019). According to Cowie et al. (2017), *Allopeas micrum* has a natural distribution in the Caribbean, Central and North America. In Rio de Janeiro, that is the type-locality of *A. micrum*, this species, as well as other subulinids, is found in anthropic and/or urbanized areas (Lopes et al.



2012). *Allopeas gracile* is widely distributed in tropical and subtropical areas of Asia, Australia, and Polynesia, as well as Central and South America (Capinera 2017). Its exact origin is not known, although Capinera (2017) suggested that it is South America. According to Santos et al. (2010) *A. gracile* is a synanthropic species, and it can live in habitats with lower humidity as other synanthropic subulinids. *Beckianum beckianum* has a wide distribution in the American continent and Caribbean Islands. It is reported to Mexico, Central America (continent and some islands) and South America (Colombia, Venezuela, Brazil and Peru) (Simone 2006, Velázquez et al. 2010). In Brazil, *B. beckianum* is also widespread: states of Pará, Fernando de Noronha, Rio Grande do Norte, Roraima, Bahia, Rio de Janeiro and São Paulo (Birckolz et al. 2016).

Santos & Monteiro (2001) examined different levels of anthropic influence in two areas of Atlantic Forest in Ilha Grande, RJ, and analyzed the relationship between the malacofauna diversity in relation to the anthropic effect and the environmental heterogeneity in the studied areas. They reported the presence of *B. beckianum* (Subulinidae) as a possible indicator of anthropic influence in the Jararaca Trail in the locality of Vila Dois Rios, Ilha Grande.

Regarding the freshwater species, the highest number of species was found in the urbanized area, where more sites were sampled. Of the eight species of gastropods mentioned by Santos et al. (2003) for the Pedra Branca State Park, four were collected in the present study: *M. tuberculata*, *P. acuta*, *B. tenagophila* and *P. sordida*. Thiengo et al. (2001) reported *B. tenagophila* to Vargem Grande, and other



**Figure 10.** Two collection sites. a. Site at the forest area near the main trail. b. Site at polluted stream Caminho da Cachoeira.

of the Rio de Janeiro city and pointed out the infection with Xiphidiocercariae in this species. This was the first record of this association in Brazil, followed by Bogéa et al. (2005) also in Rio de Janeiro and by Pinto & Melo (2010) in the Belo Horizonte city, state of Minas Gerais. Adults of Xiphidiocercariae are parasitic of the intestine of birds and in the Pleurolophocercus cercarian type included *Centrocestus formosanus*. The latter parasites the intestine of birds and mammals including humans, in which they cause centrocestiasis. Although this zoonosis is endemic to Asian countries, *M. tuberculata* was already reported infected by this cercaria in Brazil (Pinto & Melo 2010).

*Pomacea sordida* was previously reported to Duque de Caxias and Nova Iguaçu municipalities (Thiengo 1989). It is an endemic species of the state of Rio de Janeiro that is included in the List of Endangered Fauna of Rio Janeiro (ICMBio 2016).

## CONCLUSIONS

Our results demonstrate that even small area assessments can reveal an extraordinary diversity of non-marine gastropods. It was

possible to identify two different gastropod communities. The occurrence of many native species in the preserved area and intermediate hosts in the adjacent urban area demonstrate the relevance of this research, which may help in the conservation of local biodiversity and public health policies. However, considering the great diversity of endemic molluscs found in a relatively small part of the EFMA and PEPB, we highlight the need for additional and continuous studies in both areas.

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FCSR developed the project, carried out morphological and conchiological studies of the samples, and wrote the manuscript. SCT and SRG checked and supervised the identification of the specimens, the development of the project and the writing of the final manuscript. FCSR, SRG, SCT planned and participated in field expeditions to collect the samples. TC helped in the screening, preparing, and storing of the specimens and deposit in the Oswaldo Cruz Institute Mollusc Collection (CMIOC). PSR participated in the data tabulation to compose the map of the study area.

