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Freshwater gastropods in the Northern littoral mesoregion of Espírito Santo, Brazil

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ABSTRACT. Studies on the distribution of molluscs in Brazil have been conducted since the beginning of the twentieth and the knowledge of the species distributed in the country represent important findings, which contribute to the understanding of human diseases and those of veterinary importance, transmitted by them. In order to verify the distribution of freshwater gastropods in Espírito Santo, a malacological survey was carried out in nine municipalities that comprise the Northern mesoregion of the State, between January 2010 and February 2015. Initially the water collections occurring in the municipality were verified and the lotic systems at different levels of use and conservation were determined. Molluscs were collected monthly using a hand net adapted to a stick steel. An individual sample effort of 30 minutes was applied, by scanning, at about ten meters in each one of the selected habitats. A total of 6,000 specimens were collected, represented by genera *Melanoides*, *Drepanotrema*, *Physa*, *Biomphalaria* and *Pomacea*. Among the molluscs, some specimens were positive for flatworm larvae of medical and veterinary importance. The results contributed to the knowledge of the current distribution of freshwater gastropods in the Northern region of Espírito Santo whose the only record for the region dates back to 1983.

Keywords: zoology, invertebrates, molluscs, habitats diversity, ecology.

Gastrópodes de água doce da mesorregião Litoral Norte do Espírito Santo, Brasil

RESUMO. Estudos sobre a distribuição de moluscos no Brasil vêm sendo realizados desde os primórdios do século XX e o conhecimento das espécies distribuídas no país representam achados importantíssimos ao entendimento das doenças humanas e de importância veterinária. Com o objetivo de verificar a distribuição dos gastrópodes de água doce no Espírito Santo, realizou-se um levantamento malacológico em nove municípios que compõem a mesorregião Norte do Estado, entre janeiro de 2010 e fevereiro de 2015. Inicialmente, foi realizada uma verificação das coleções hídricas ocorrentes nos municípios e os sistemas lóticos em diferentes níveis de utilização e conservação foram determinados. Os moluscos foram coletados mensalmente, utilizando-se de uma rede de mão (puçá), adaptada a um cabo de madeira. Foi aplicado um esforço amostral individual de 30 minutos, por varredura, em cerca de dez metros de extensão, em cada um dos habitats selecionados. Foram coletados 6.000 espécimes de moluscos, representados pelos gêneros *Melanoides*, *Drepanotrema*, *Physa*, *Biomphalaria* e *Pomacea*. Alguns exemplares apresentaram-se positivos para larvas de trematódeos de importância médico-veterinária. Os resultados contribuíram para o conhecimento da atual distribuição dos gastrópodes de água doce da região Norte do estado do Espírito Santo, cujo único registro para a região data do ano de 1983.

Palavras-chave: zoologia, invertebrados, moluscos, diversidade de habitats, ecologia.

Introduction

Limnic molluscs play a relevant role in the ecosystems they inhabit. They play an important role in the trophic chain, and are used as food by fish, amphibians, reptiles, birds and mammals, among them, man (Drügg-Hahn, Lopes-Pitoni, Cunha, & Carvalho, 2007).

Estimates of the number of species in the world are very variable, up to two hundred thousand. It is estimated that there are approximately 4,000 species of freshwater gastropods, of which 224 are in Brazil

(Simone, 2006; Strong, Gargominy, Ponder, & Bouchet, 2008). Despite this enormous diversity, studies on this group are not very frequent, since half of the existing mollusc species have not yet been described (Mansur et al., 2003). On the other hand they are of special importance in freshwater collections by the number of species and function in the trophic chains, serving as food for a large number of animals, such as fish, birds and mammals (Drügg-Hahn et al., 2007).

In Brazil, the most common gastropods belong to the families Planorbidae, Ampullariidae,

Hydrobiidae, Thiaridae and Pleuroceridae (Drügg-Hahn et al., 2007) and practices such as barrier construction, canalization, drainage and pollution of water bodies, especially by the indiscriminate use of pesticides in crops, have contributed to the destruction of the natural habitat of many species, causing their disappearance, as observed in several records of anthropogenic actions over time (Mansur et al., 2003; Allan, 2004; Souza & Melo, 2012; Muller, Granada & Sperotto, 2016). Additionally, the introduction of exotic mollusc species such as *Melanooides tuberculata* has contributed to the elimination of certain native species (Avellar, 1999; Mansur et al., 2012).

Among the gastropods, a group of more numerous and diverse animals of the phylum Mollusca, the *Biomphalaria* (Planorbidae), intermediate hosts of *Schistosoma mansoni*, stand out, since they are responsible for the maintenance and propagation of schistosomiasis, a disease that affects millions of individuals worldwide and, in Brazil, is still a public health problem (SBMT, 2013; Amorim et al., 2014).

In fact, the three main host species of schistosomiasis occur in the State of Espírito Santo. Paraense (1986) reports that the most important species, both for amplitude distribution and transmission efficiency, is *Biomphalaria glabrata* (Say, 1818), which is responsible for most of the disease outbreaks in the Southeastern region of Brazil (Souza et al., 2001; Guimarães et al., 2009). However, although *B. straminea* (Dunker, 1848) is the species found in almost all the watersheds of the country and adapted to climatic variations, its natural infection occurs predominantly in Northeastern states (Favre et al., 2016). On the other hand, the main intermediate host species of schistosomiasis in the South and part of Southeastern Brazil is *B. tenagophila* (Orbigny, 1835) (Paraense, 1986; Guimarães et al., 2009).

The first reference to a planorbidae mollusc in Espírito Santo was described by Giemsa & Nauck (1939) and, since then, records on mollusc collections of different orders and species, as well as the occurrence of schistosomiasis in the State, have been reported in a discontinuous way. The emphasis has been on ecology, on the control of intermediate host molluscs and on the epidemiological disease determinants.

As in most parts of Brazil, the Northern region of Espírito Santo presents municipalities with serious public sanitation problems, which provides ideal conditions for the maintenance of mollusc breeding sites, such as schistosomiasis transmitters.

On the other hand, little is known about the presence of limnic molluscs in the region and on individuals parasitized by *S. mansoni* since the study conducted by Paraense, Aires de Alencar, and Corrêa (1983) and the data of the Schistosomiasis Control Program are the main references in the State.

In this context, considering the scarcity of information on the distribution of freshwater gastropods in the Northern region of Espírito Santo a protocol for evaluating habitat diversity was applied as a tool to aid the development of the research, and the results obtained brought current information about the real distribution of these invertebrates in the State.

Material and methods

Study area

Espírito Santo, one of Brazil's 27 federative units, located in the Southeast region, borders the Atlantic Ocean to the East, Bahia to the North, Minas Gerais to the West and Northwest, and the state of Rio de Janeiro to the South. Its area is 46,089,390 km² and it still houses an important strip of Atlantic forest remaining in the country (IBGE, 2016).

This study covered the municipalities: Boa Esperança (18° 32' 24" S 40° 17' 45" W), Conceição da Barra (18° 35' 36" S 39° 43' 56" W), Jaguaré (18° 54' 20" S 40° 04' 34" W), Montanha (18° 07' 37" S 40° 21' 48" W), Mucurici (18° 05' 36" S 40° 30' 57" W), Pedro Canário (18° 01' 49" S 40° 09' 02" W), Pinheiros (18° 22' 13" S 40° 12' 48" W), Ponto Belo (18° 07' 25" S 40° 32' 28" W) and São Mateus (18° 42' 58" S 39° 51' 32" W), belonging to the Northern littoral mesoregion of Espírito Santo, are presented in the map shown in Figure 1 (SIT, 2016).

Assessment of habitat diversity

Initially, a verification of the water collections performed in the municipalities was carried out. The lotic systems at different levels of use and conservation that may represent the ecological variability within the basins that comprise the municipality were determined. A protocol was applied, according to Callisto, Ferreira, Moreno, Goulart, & Petrucio (2002) with modifications, for evaluating habitat diversity as a tool for the development of the study (Table 1). Observations of geographic location, water pH, vegetation, hypsometric characteristics and territorial morphological units of the municipalities were included in this study.

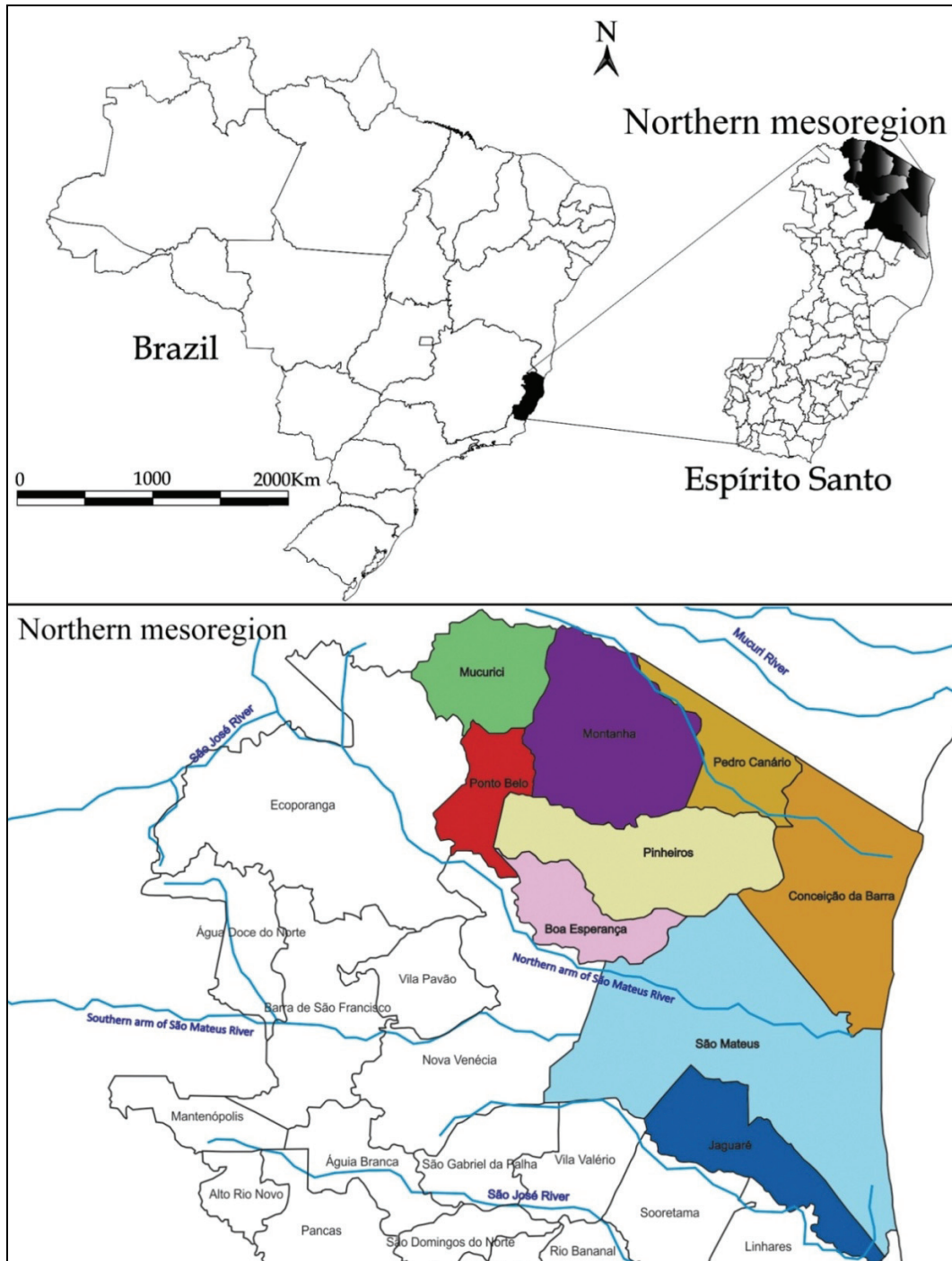


Figure 1. Northern littoral mesoregion of Espírito Santo. Source: Souza, 2016. Personal archive.

Mollusc collection

The molluscs were collected monthly for 60 months, between January 2010 and February 2015, using a hand net (“puçá”), made of nylon (50 cm wide, 40 cm high, 30 cm open and 1 mm² mesh), adapted to a wooden or steel handle (150 cm long). An individual sample effort of 30 minutes per sweep was applied, in about 10 (ten) meters in each of the

selected habitats (Souza, Souza, Machado-Coelho, & Melo, 2006). In each of the municipalities under study three annual collections were carried out, making a total of 10 collections over a period of 5 years. All collected material was packed in plastic bags, labeled and transported to the Parasitology Laboratory of Northern Espírito Santo University Center, *Universidade Federal do Espírito Santo*, for sorting and identification.

Table 1. Rapid assessment of habitat diversity in watershed areas, modified from the protocol of the Environmental Protection Agency (Callisto et al., 2002). Note: 4 points (natural situation), 2 and 0 points (slightly or deeply altered).

Location:		Date of collection:	
Time of collection:		Time (situation of the day):	
Collection mode (Collector):		Water pH:	
Type of environment:			
Stream () River () Lake () Pond () Waterfall ()			
Parameters	Score		
	4 points	2 points	0 point
1 - Type of occupation at the margin of water bodies (main activity)	Native vegetation	Pasture/Agriculture/Monoculture/Reforestation	Residential/Commercial/Industrial
2 - Erosion near river margins and silting of the riverbed	Absent	Moderate	Accentuated
3 -Anthropic alterations	Absent	Alterations of domestic origin (sewage, garbage)	Alterations of industrial/urban origin (factories, iron and steel industry, canalization, reuse of the river course)
4 - Plant coverage in the riverbed	Partial	Total	Absent
5 - Water odor	None	Sewage (rotten egg)	Oil/Industrial
6 - Water oiliness	Absent	Moderate	Abundant
7 - Water transparency	Transparent	Turbid	Opaque or colorful
8 - Odor of the sediment (bottom)	None	Sewage (rotten egg)	Oil/Industrial
9 - Bottom oiliness	Absent	Moderate	Abundant
10 - Type of bottom	Rocks/rubble	Mud/sand	Cement/canalized

Identification of molluscs

For species identification, conchological and morphological parameters were considered, according PAHO (1968) and Paraense (1975).

Results

Molluscs were found in the following municipalities: Boa Esperança, Conceição da Barra, Jaguaré, Montanha, Mucurici, Pedro Canário, Pinheiros, Ponto Belo and São Mateus, which make up the Northern littoral mesoregion of Espírito Santo. A total of 6,000 specimens was verified in the collection stations previously determined, with 976 *Biomphalaria glabrata*, 1991 *B. straminea*, 96 *Drepanotrema cimex*, 168 *D. lucidum*, 244 *Physa ornata*, 2491 *M. tuberculata* and 34 *Pomacea lineata* (Table 2).

The results of the application of the habitat diversity protocol at the sites defined for mollusc collections, indicated some type of anthropic alteration (Figure 2).

It was also observed that most of the collected molluscs were found in aquatic collections that presented anthropic alterations of domestic origin, such as the presence of garbage and/or sewage, or changes of industrial/urban origin, such as the presence of factories and/or steel plants with waste disposal to the aquatic collection or canalization and/or reuse of the water course. It was also verified that the collection stations where the molluscs were found presented altitudes ranging from 7.3 m to 266.7 m in relation to sea level (Table 3).

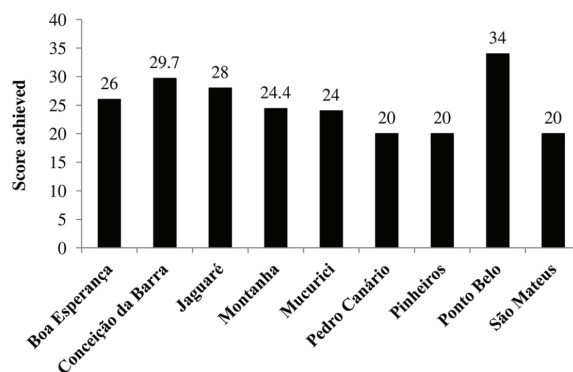


Figure 2. Rapid assessment of habitat diversity. Collection sites in municipalities from Northern Espírito Santo. Impacted areas: up to 20 points; Altered areas: > 20 < 36 points; Natural areas: > 36 points. Northern mesoregion of Espírito Santo.

Discussion

Over time, more and more man-made environmental changes have been observed in the State, which was indeed verified in this study, and this poses a serious risk to aquatic fauna, especially freshwater molluscs, such as what has occurred in Brazil (Souza & Melo, 2012; Muller et al., 2016).

In this context, the assessment of habitat diversity provided an opportunity to analyze the levels of anthropogenic impacts on watershed stretches of municipalities in the Northern littoral mesoregion of Espírito Santo, and it is an important tool in environmental monitoring programs (Callisto et al., 2002).

Table 2. Distribution of freshwater molluscs in the Northern littoral mesoregion of Espírito Santo, 2016.

Municipality	Collection Station	Species	Number of specimens	Geographic coordinates
Boa Esperança	1	<i>Physa ornata</i> (Haas, 1938)	8	S 18° 25' 51.8" W 040° 23' 31.6"
Conceição da Barra	1	<i>Drepanotrema cimex</i> (Moricand, 1839)	12	S 18° 25' 37.5" W 039° 56' 05.4"
	2	<i>Drepanotrema lucidum</i> (Pfeiffer, 1839)	7	S 18° 34' 10.5" W 039° 45' 13.9"
Jaguapé	1	<i>D. lucidum</i>	14	S 18° 54' 41.31" W 40° 4' 14.03"
Montanha	1	<i>Biomphalaria straminea</i> (Dunker, 1848)	500	S 18° 07' 22.6" W 040° 22' 08.1"
		<i>Melanooides tuberculata</i> (Muller, 1774)	450	
		<i>B. straminea</i>	510	
	2	<i>B. straminea</i>	933	S 18° 07' 19.6" W 040° 22' 04.8"
		<i>D. lucidum</i>	48	
		<i>Biomphalaria glabrata</i> (Say, 1818)	713	
	3	<i>P. ornata</i>	16	S 18° 11' 52.0" W 040° 15' 41.7"
		<i>B. glabrata</i>	98	
		<i>D. lucidum</i>	73	
		<i>Pomacea lineata</i> (Spix, 1827)	22	
Mucurici	1	<i>P. ornata</i>	49	S 18° 12' 08.4" W 040° 15' 45.3"
		<i>B. straminea</i>	6	
		<i>D. cimex</i>	4	
	2	<i>B. straminea</i>	625	S 18° 01' 37.0" W 040° 38' 24.6"
		<i>D. cimex</i>	27	
		<i>P. lineata</i>	7	
		<i>P. ornata</i>	67	
	1	<i>B. straminea</i>	250	S 18° 05' 46.4" W 040° 31' 03.2"
		<i>P. lineata</i>	5	
Pedro Canário	2	<i>B. straminea</i>	1	S 18° 17' 54.8" W 039° 57' 18.9"
				S 18° 04' 52.9" W 040° 06' 29.2"
Pinheiros	1	<i>B. glabrata</i>	70	S 18° 24' 31.2" W 040° 13' 05.8"
		<i>P. ornata</i>	3	
	2	<i>B. glabrata</i>	135	S 18° 26' 28.8" W 040° 12' 56.1"
		<i>D. cimex</i>	53	
Ponto Belo	1	<i>P. ornata</i>	69	S 18° 07' 47.2" W 040° 29' 15.3"
		<i>B. straminea</i>	50	
São Mateus	1	<i>M. tuberculata</i>	1108	S 18° 07' 47.2" W 040° 29' 15.3"
		<i>D. lucidum</i>	26	
	2	<i>P. ornata</i>	32	S 18° 43' 4.53" W 39° 51' 10.35"
		<i>B. straminea</i>	9	S 18° 46' 21.93" W 39° 48' 23.49"

Table 3. Anthropic alterations and altitude of mollusc collection stations in the Northern littoral mesoregion of Espírito Santo, 2016.

Municipality	Collection station	Altitude (m)*	Type of alteration
Boa Esperança	1	144.2	Alterations of domestic origin (sewage, garbage)
Conceição da Barra	1	7.3	Alterations of domestic origin (sewage, garbage)
	2	17.0	Alterations of industrial / urban origin (factories, iron and steel industry, canalization, reuse of the river course)
Jaguapé	1	69.0	Alterations of industrial / urban origin (factories, iron and steel industry, canalization, reuse of the river course)
Montanha	1	168.2	Alterations of domestic origin (sewage, garbage)
	2	149.5	Alterations of domestic origin (sewage, garbage)
	3	108.2	Alterations of industrial / urban origin (factories, iron and steel industry, canalization, reuse of the river course)
	4	104.8	Alterations of domestic origin (sewage, garbage)
Mucurici	1	266.7	Absence of alterations
	2	215.2	Alterations of domestic origin (sewage, garbage)
Pedro Canário	1	64.6	Alterations of industrial / urban origin (factories, iron and steel industry, canalization, reuse of the river course)
	2	98.7	Alterations of industrial / urban origin (factories, iron and steel industry, canalization, reuse of the river course)
Pinheiros	1	110.6	Alterations of industrial / urban origin (factories, iron and steel industry, canalization, reuse of the river course)
	2	96.0	Alterations of domestic origin (sewage, garbage)
Ponto Belo	1	218.8	Alterations of industrial / urban origin (factories, iron and steel industry, canalization, reuse of the river course)
São Mateus	1	24.0	Alterations of domestic origin (sewage, garbage)
	2	6.0	Absence of alterations

* Altitude (m) of the collection station in relation to sea level

In fact, in this study, the largest number of places with the presence of molluscs had residential occupancy along the water body, changes of domestic origin, such as garbage and sewage, and the presence of plant cover in the bed, very favorable to mollusc fixation, especially *M. tuberculata*, an exotic species, resistant to low concentrations of dissolved oxygen and of the genus *Biomphalaria* (Dudgeon, 1986; Vaz, Teles, Correa, & Leite, 1986; Freitas, Bedê, De Marco Jr., Rocha, & Santos, 1987). In areas previously determined for mollusc collections, a predominance of fields and pastures was also observed, indistinctly represented by regions devoid of arboreal vegetation and by regions deforested by human activity, with soft terrains, whose altitudes are lower than 300 m, as verified by Souza and Melo (2012), in studies conducted in Minas Gerais, Pernambuco and Espírito Santo.

The soft undulating relief unit has the largest distribution in the area of Espírito Santo, where slopes lower than 35% predominate. This characteristic is in agreement with the hypsometric analysis carried out in the municipalities of the northern region of Espírito Santo, where the largest number of locations with molluscs was found in regions of lower altitude. In fact, in these regions are the best conditions for urban development, and consequently, there is a greater human performance (PDUAM, 2003; Ges, 2017).

Regarding molluscs, the specimens *D. cimex*, *D. lucidum*, *M. tuberculata*, *P. lineata*, *Physa ornata*, besides *B. glabrata* and *B. straminea* should be highlighted in the municipalities of the northern region of Espírito Santo.

A fact of particular importance is that Thiara (*M. tuberculata*) have been widely spread, and their reproductive potential has facilitated the rapid development of populations. They are natural to Asia and are found in many tropical and subtropical countries, whose ability to colonize various types of habitats limits or excludes certain species of pulmonates, particularly those related to schistosomiasis (Freitas et al., 1987; Pointier & McCullough, 1989; Pinto & Melo, 2013). In Brazil, they were mentioned for the first time in São Paulo by Vaz et al. (1986), who emphasized the role of this mollusc as an intermediate host of *Clonorchis sinensis*, and the species was found in Rio de Janeiro and Minas Gerais, harboring trematode larvae (Boaventura, Fernandez, Thiengo, Silva, & Melo, 2002; Pinto & Melo, 2013).

Not less important, the presence of molluscs *Biomphalaria*, *S. mansoni* intermediates, was related to impacted areas (Souza & Melo, 2012), especially in the municipalities of Mucurici, Montanha,

Pinheiros and Pedro Canário. Several collection stations presented environmental conditions with some anthropic modification and, although none of the molluscs showed positive for *S. mansoni*, the very presence of infected residents or seasonal workers in the region, as verified by Amorim et al. (2014), may favor the spread of schistosomiasis.

It is also worth mentioning that in higher areas and in places with greater anthropogenic contribution, *P. ornata* and *P. lineata*, associated with *B. glabrata* and *B. straminea*, were found. In general, the distribution of molluscs between aquatic systems occurs passively, which provides them with a large range of distribution, with waterbirds as the main dispersing agents of these organisms (Russell-Hunt, 1978).

Conclusion

Considering that the only record on the distribution of molluscs in the northern region of Espírito Santo was performed by Paraense et al. (1983) the results of this study provide new information on the dynamics of freshwater gastropods in the State and contribute to the development of research on species richness and their interactions with the environment. In addition, they reveal the need for permanent monitoring, due to the significant presence of invading molluscs, which can change the dynamics of population densities.

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