Acta Limnologica Brasiliensia

Publication of the Brazilian Association of Limnology

Thematic Section: Limnology in Brazilian Semi-arid Region

Acta Limnologica Brasiliensia, 2018, vol. 30, e103
http://dx.doi.org/10.1590/S2179-975X10616
ISSN 2179-975X on-line version

Effects of invasive species snails in continental aquatic bodies of Pernambucano semiarid

Efeitos de espécies invasoras de moluscos gastrópodes em corpos aquáticos continentais do semiárido Pernambucano

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Cite as: Almeida, P.R.S., Nascimento Filho, S.L. and Viana, G.F.S. Effects of invasive species snails in continental aquatic bodies of Pernambucano semiarid. *Acta Limnologica Brasiliensia*, 2018, vol. 30, e103.

Abstract: Aim: The aim of this study was to survey the species of molluscs and to evaluate the effect of exotic species on the native mollusks of three reservoirs in the Pajeú Basin Cachoeira II, Jazigo and Serrinha. **Methods:** Sampling was carried out with trawl net (5 mm mesh opening) and hand net (2 mm mesh opening). **Results and conclusions:** Were quantified 60,244 specimens, distributed among the species *Melanoides tuberculata* (49,398), *Pomacea lineata* (573), *Biomphalaria straminea* (376) and *Physa marmorata* (01). The invasive exotic species *M. tuberculata* was dominant in all reservoirs with a relative abundance greater than 85% and the other species were classified as occasional and rare, with emphasis in *Physa marmorata* that is present in the red list of species vulnerable to extinction. Regarding the frequency of occurrence, all species were classified as euconstant (occurrence greater than 65%), except *P. lineata* and *P. marmorata*, which were classified as ancillary (occurrence less than 40%). Among the species, *M. tuberculata* were the highest average density (1,636 ind.m^{-2}) in Serrinha reservoir, showed a strong adaptation to the environmental conditions, due to its high dominance in all the reservoirs, being probably the main cause for the low diversity and density indices of native molluscs. Since *P. marmorata* presented low density and frequency, becoming an important point to be investigated as possible species impaired by the dominance of *M. tuberculata*.

Keywords: benthic community; gastropods; bioinvasion; limnic environments.

Resumo: Objetivo: O objetivo do presente estudo foi realizar um levantamento das espécies de moluscos e avaliar o efeito de espécies exóticas sobre os moluscos nativos de três reservatórios da Bacia do Pajeú - Cachoeira II, Jazigo e Serrinha. **Métodos:** A amostragem foi realizada com rede de arrasto (abertura de malha de 5 mm) e puçá (abertura de malha 2 mm). **Resultados e conclusões:** Foram quantificados 60.244 exemplares, distribuídos entre as espécies *Melanoides tuberculata* (49.398), *Pomacea lineata* (573), *Biomphalaria straminea* (376) e *Physa marmorata* (01). A espécie exótica

invasora *M. tuberculata* foi dominante em todos os reservatórios com abundância relativa superior a 85%, as demais espécies foram classificadas como ocasionais e raras com destaque para *Physa marmorata* que está presente na lista vermelha de espécies vulneráveis a extinção. Quanto à frequência de ocorrência, todas as espécies foram classificadas como euconstantes (ocorrência superior a 65%), exceto *P. lineata* e *P. marmorata* que foram classificadas como acessórias (ocorrência inferior a 40%). Dentre as espécies, *M. tuberculata* apresentou a maior densidade média (1.636 ind.m^{-2}) no reservatório Serrinha, demonstrando forte adaptação às condições ambientais, devido sua alta dominância em todos os reservatórios, sendo provavelmente a principal causa pelos baixos índices de diversidade e densidade dos moluscos nativos. Uma vez que *P. marmorata* apresentou baixa densidade e frequência, tornando-se um ponto importante a ser investigado como possível espécie prejudicada pela dominância do *M. tuberculata*.

Palavras-chave: comunidade bentônica; gastrópodes; bioinvasão; ambientes límnicos.

1. Introduction

Biologists, ecologists and environmental researchers believe that invasions by exotic species are the main causes of native species extinction (Wilcove et al., 1998; Fritts & Rodda, 1998). The introduction of exotic species became a key ecological factor, in which invading organisms increasingly alter aquatic communities (Gurevitch & Padilla, 2004).

The Mollusca phylum comprises over one hundred thousand species, which are found in different environments, such as terrestrial, marine and freshwater. This phylum is represented by the classes Gastropoda and Bivalvia in freshwater environments (Mansur et al., 1987). Brazil has 256 described species of freshwater gastropods and, according to Simone (2006) this number is underestimated compared with the diversity found in other countries. These animals are found in various water habitats such as rivers, weirs, ponds and lakes, living partially or totally buried in the substrate (Mansur et al., 1987) or associated with submerged aquatic macrophytes (Simone, 1999; Santana et al., 2009). According to Simone (1999), a great variability of Mollusks may occur in freshwater environments, however, the occurrence and distribution of this species are related to their adaptation and habitat characteristics.

Freshwater mollusks are among the most endangered group of species, despite their widespread distribution and diversity (Bogan, 2008). The main causes for this species endangerment are related to the high concentrations of agrochemicals in the water, eutrophication, dam constructions and drainage (Allan, 2004). Moreover, the introduction of exotic species has been considered a major impact factor and responsible for the decline of some native species (Mansur et al., 2012). The Mollusca phylum is among the most introduced groups of species (Lucca & Kamada, 2012). These biological invasions have caused significant and noticeable economic effects, damaging hydroelectric power plants, industries, and modifying benthic communities or indirectly affecting other aquatic communities (Garcia & Protogino, 2005).

According to Camargo & Giarrizzo (2009), the mollusks stands out in freshwater environments due to their number of species, biomass and function in trophic chains, since they are primary consumers of and food for many animal groups, especially fish, birds and mammals. Mollusks are important bio-indicators of environmental quality in Brazil (Salánki et al., 2003) and vectors of diseases (Souza et al., 2001; Thiengo et al., 2004), however, few studies have been conducted on the effects of biological invasions.

Most of these studies report invasion of mollusk species, emphasizing the environmental impacts caused to ecosystems and economic and health problems (Fernandez et al., 2003). Most studies in the Brazilian semiarid region are related to their taxonomy, occurrence and systematics. Abílio et al. (2006, 2007) and Santana et al. (2009) assessed the composition and abundance of coastal gastropods associated with aquatic macrophytes of the semiarid in the State of Paraíba. Souza & Abílio (2006) evaluated the taxonomic units of the zoobenthos of two intermittent lakes of the Paraíba semiarid. Santos & Eskinazi-sant'anna (2010) evaluated the occurrence and abundance of the mollusk *Melanoides tuberculata* (Muller, 1774) in the Piranhas River Basin of the State of Rio Grande do Norte. However, studies describing the biology and ecology of mollusks found in the continental water bodies of the Brazilian semiarid are still scarce in the literature. Therefore, studying these animals is important to contribute to the information on this species diversity and distribution.

The objective of this work was to survey mollusk species of the Pajeú River Basin, in the semiarid

region of the State of Pernambuco, Brazil, and to evaluate risks and possible impacts of exotic species on native species, aiming to produce better information on the management, conservation and preservation of the native mollusks.

2. Material and Methods

2.1. Study area

The study was conducted in the Pajeú River Basin located between the coordinates 07°16'20 "and 08°56'01" south latitude, and 36°59'00 "and 38°57'5" west longitude (Pernambuco, 1998). The hydrological basin of Pajeú is fully inserted in the state of Pernambuco (Figure 1) and has an area of 16,685.63 km^2, covering 25 municipalities and is characterized by being the largest basin of Pernambuco state (IBGE, 2010).

According to Peel et al. (2007), the dominant climate in region is the semiarid with annual rainfall of less than 431.8 mm and predominant vegetation of the caatinga type (Freire & Pacheco, 2011), showing a great hydric deficit, high temperatures, high rates of evaporation, a rainy period between January and June and periods of drought between July and December. Serra Talhada city is located in the semiarid region of the hydrological basin of Pajeú, the large reservoirs, are: Serrinha II (311,000,000 m^3), Cachoeira II (21,031,145 m^3), Jazigo (15,543,300 m^3) and Saco I (36,000,000 m^3), these reservoirs are of great importance to the population around them, mainly due to the fishing potential, irrigation and supply (Nascimento-Filho et al., 2014; Lima & Shinozaki-Mendes, 2015).

2.2. Limnological variables

During the whole study, was measured the monthly average rainfall (P), in millimeters and water temperature (T° degrees Celsius) for the period from August 2008 to July 2009 and from May to November 2012 (source: INPE).

2.3. Field methodology

The study was held with from monthly daytime collection held in three reservoirs (Cachoeira II e Jazigo – august/2008 to july/2009 and may to November/2012; Serrinha – may to November/2012), reflecting the seasonal periodicity (dry and rainy). Sampling was carried out a trawl net with mesh opening of 5 mm (width: 1.85 m x height: 0.85 m) and hand net with aluminum frame, with 60 cm of diameter and meh opening of 2 mm. Were held with the trawl net tree manual trawled trough a 5 meters area, in transects parallels to margin, in depths varying from 50 cm to 1.5 meters.

The dip net was utilized to capture the epiphany associed to margin vegetation (one meter of margin distance). The samples were obtained in tree points with depths varying from 20 to 50 cm, with tree

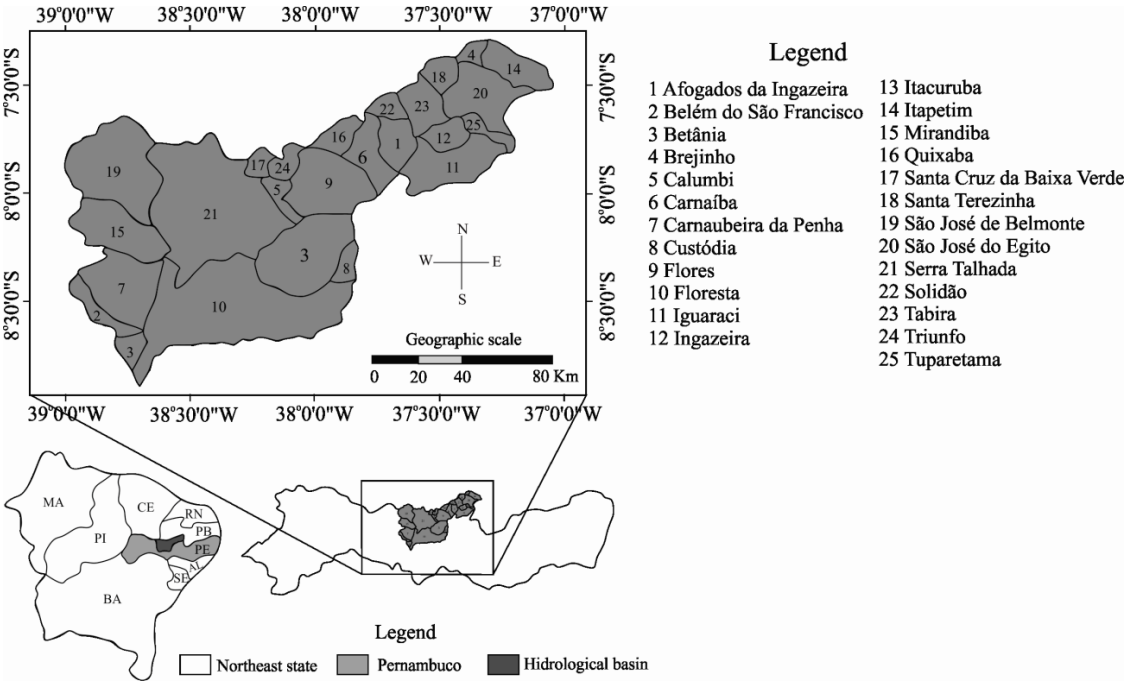

Figure 1. Location of the Pajeú River basin located of Pernambuco state, Brazil.

repetitions. The collected material was packed in plastic bags labeled and fished with 10% neutral formalin. In the laboratory, the samples were washed on site through a net with mesh size 2.1, 0.5 and 0.25 mm. Then the material was replaced by 70% ethanol. Afterwards, the material was identified with the aid of a stereomicroscope and identification bibliography suggested by Simone (2006) and Barbosa (1995).

The data were initially treated in order to verify the distribution of normality of distribution errors and homoscedasticity of variances test Shapiro-Wilk ($p > 0.05$) (Mendes, 1999). As variances showed non-homogeneous, was use non-parametric test Kruskal-Wallis to verify significant differences in the densities in the dry and rainy period. We calculated the richness of species, relative abundance (%) proposed by Mccullough & Jackson (1985), density of individuals per square meter (ind.m^{-2}), frequency of occurrence (%), Jablonska & Paturej (1999), diversity of Shannon-Wiener (H') and equitability (J'). For equitability the months with zero or only one species were disregarded. We checked the similarity of the molluscs distribution among the different reservoirs of the region, a cluster analysis using Bray-Curtis distance. We use Spearman's correlation to check possible relation between temperature, rainfall and density species.

3. Results

Over the sample period were quantified a total of 60,244 individuals, all belonging to Gastropoda class, distributed among species *Melanoides tuberculata* (Muller, 1774) located in Thiaridae family, Neotaenioglossa order and *Pomacea lineata* (Spix, 1827) belonging to Ampullariidae family, Architaenioglossa order, *Biomphalaria straminea* (Say, 1818), located at Planorbidae family, order Pulmonata and *Physa marmorata* Guilding, 1828, included in Physidae family.

In Cachoeira II reservoir (August/2008 to July/2009), were collected 3,857 individuals, distributed among the species *M. tuberculata* (3,662 specimens), *P. lineata* (195 specimens). *M. tuberculata* being the dominant species with relative abundance greater than 90%. As for the frequency of occurrence, both species present constants. In Jazigo reservoir same period, were collected 4,968 individuals, distributed among the species *M. tuberculata* (4,408 specimens), *B. straminea* (376 specimens), *P. lineata* (184 specimens). *M. tuberculata* showed higher relative abundance 85%, while the other two species showed relative abundance of 7.57 and 3.70%, respectively. Despite the dominance of *M. tuberculata* all described species were detected during the study occurred with a frequency of 80%. The gastropod showed dominance in the two aforementioned reservoirs (relative abundance greater than 85%). Simultaneously, despite the large occurrence of Thiaridae over the months, all species were constant throughout the sampling period (frequency of occurrence greater than 66%).

In the same reservoir between the months of May to November/2012, was collected 2,569 individuals, represented by the species *M. tuberculata* (2,565) specimens, *P. lineata* (3) and *P. marmorata* only (1) specimen. *M. tuberculata* was dominant (relative abundance greater than 90%) and constant (frequency of occurrence than 80%) during the study, while the remaining species were classified as occasional (less than 10% occurrence). Study conducted Serrinha reservoir, in the same period were observed a total abundance of 49,589 specimens, represented by the species *M. tuberculata* (49,398) and *P. lineata* (191) specimens. *M. tuberculata* was dominant (relative abundance greater than 90%) and *P. lineata* rare (less than 10%). *M. tuberculata* showed constant throughout the study (above 80%) and *P. lineata* frequent (75% frequency of occurrence) (Table 1).

In Cachoeira II reservoir maximum density values were observed in the months of December/2008, January and February/2009, mainly represented by *M. tuberculata* 105.94 ind.m^{-2}, 102.13 and 118.49 ind.m^{-2}, respectively (Figure 2-1A). In Jazigo reservoir highest densities of mollusks were observed between the months of November/2008 to February/2009, with an average of 88.97 ind.m^{-2} (Figure 2-1B). Over that sample period the highest densities were observed for invasive *M. tuberculata,* with higher values 85.51 ind.m^{-2} individuals. Between May to November/2012 the same reservoir maximum density values were observed in the months of June and October/2012, with 87.66 and 62.08 ind.m^{-2}. Represented mostly by *M. tuberculata* 87.16 and 62.08 ind.m^{-2}, respectively (Figure 2-1C). In Serrinha reservoir the highest densities were observed in May 1,856 ind.m^{-2} and June 1,431 ind.m^{-2}, represented in most of the gastropod *M. tuberculata* with 1,845 and 1,427 ind.m^{-2}, respectively (Figure 2-1D).

In Cachoeira II and Jazigo reservoirs between (August/2008 to July/2009) the equitability (J) maximum values were observed (1) in the months

Table 1. Relative abundance and frequency of occurrence for Gastropoda species collected in three reservoirs in the Pajeú River basin between 2008 and 2009 and 2012.

Relative Abundance (%)					
Reservoirs	**Cachoeira (2008/09)**	**Jazigo (2008/09)(2012)**		**Serrinha (2012)**	**Classification**
Melanoides tuberculata	91.80	87.14	99.84	99.53	Dominant
Biomphalaria straminea	-	7.76	-	-	Occasional
Pomacea lineata	8.20	2.98	0.1	0.37	Occasional/ Rare
Physa marmorata	-	-	0.05	-	Rare
Occurrence Abundance (%)					
Melanoides tuberculata	66.7	100	100	100	Euconstant
Biomphalaria straminea	-	77.30	-	-	Euconstant
Pomacea lineata	66.7	81.8	25	75	Euconstant and Acessory
Physa marmorata	-	-	25	-	Acessory

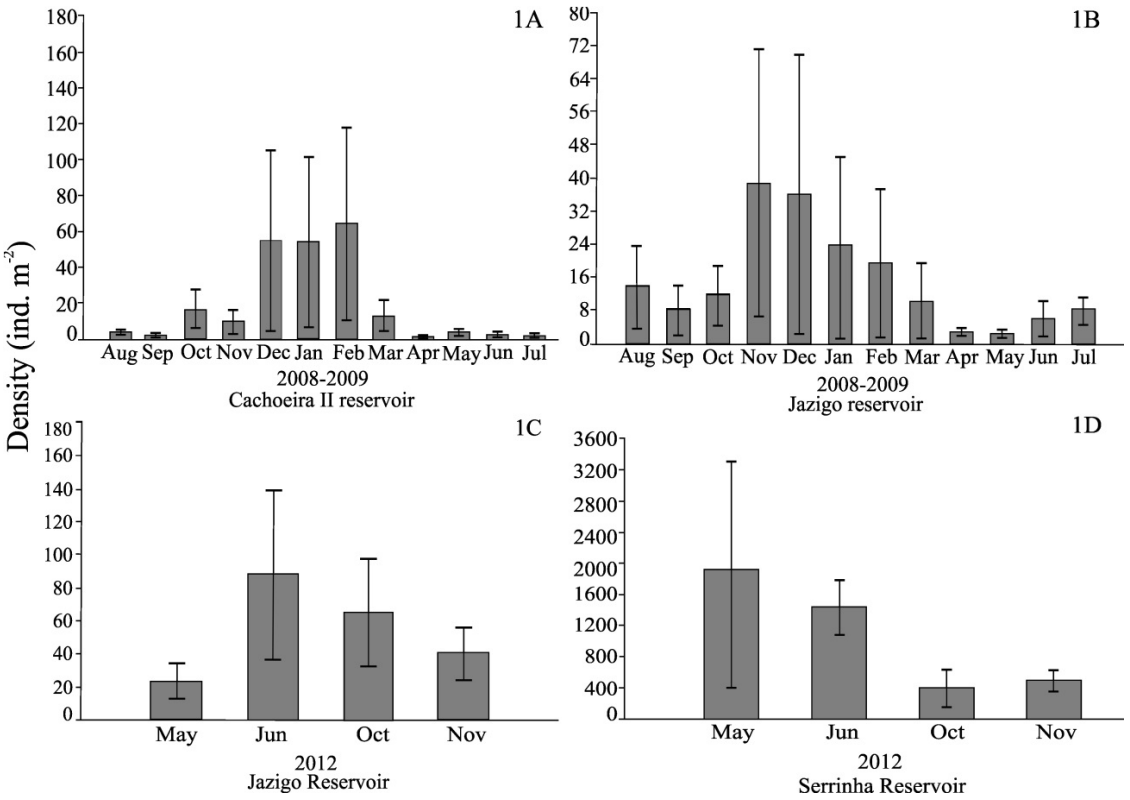

Figure 2. Mean values of density (ind.m^{-2}) in Cachoeira II and Jazigo/2008-2009 (1A and 1B), Jazigo/2012 (1C) and Serrinha/2012 (1D) reservoirs, located in Pajeú river basin, Serra Talhada, Brazil.

August and September and minimum 0.04 in October. Shannon diversity (H') showed maximum value 0.69 nats.ind^{-1} in the months from August to September and minimum value 0.03 nats.ind^{-1} in October/2008. In Jazigo reservoir presented maximum value (0.86) in April and minimum value (0.17) in December, with 0.96 nats.ind^{-1} maximum (H') in April and minimum 0.13 nats.ind^{-1} in January and February (Figure 3). In the same reservoir between May to Nov/12, the (J) ranged from zero to 0.02 in the months of May and October/2012. (H') ranged zero and 0.014 nats.ind^{-1}, with higher values in the months of June and November. Same period the Serrinha reservoir presented the (J) ranged from 0.001 to 0.05 and a (H') with representation from 0.001 to 0.035 nats.ind^{-1} (Figure 4).

In Figure 5, the dendrogram of the application of the Bray-Curtis index is presented. Note that distinct groups were formed, where the greatest similarity was obtained between the Cachoeira II

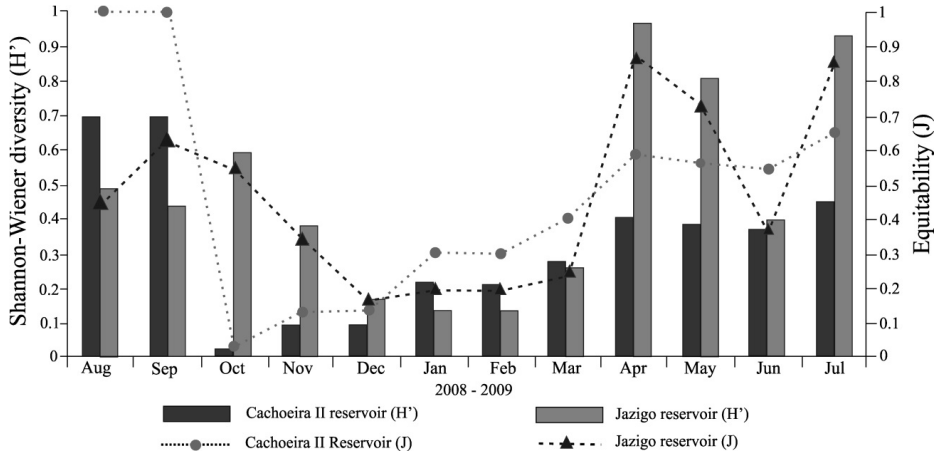

Figure 3. Shannon-Wiener's diversity (H') nats.ind^{-1} and equitability (J) for the mollusks sampled of Cachoeira II and Jazigo reservoirs in year 2008 and 2009, Serra Talhada, Brazil.

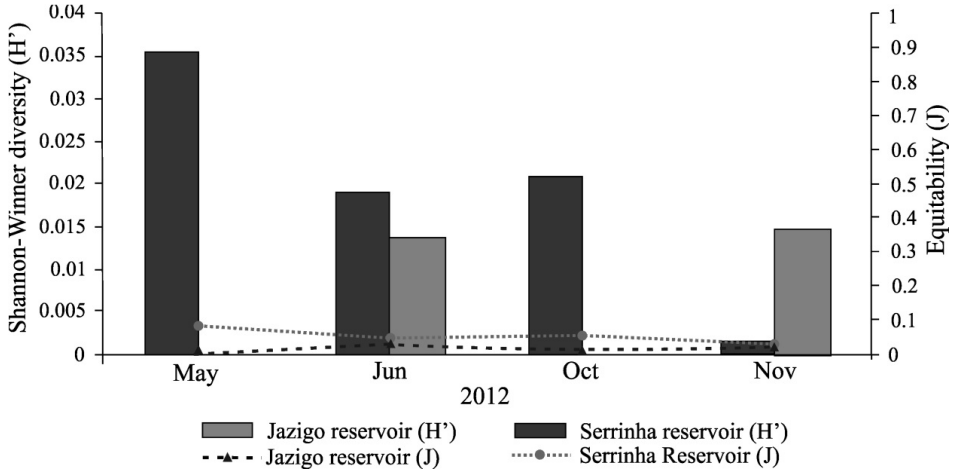

Figure 4. Shannon-Wiener's diversity (H') nats.ind^{-1} and equitability (J) for the mollusks sampled Serrinha and Jazigo reservoirs in year 2012, Serra Talhada, Brazil.

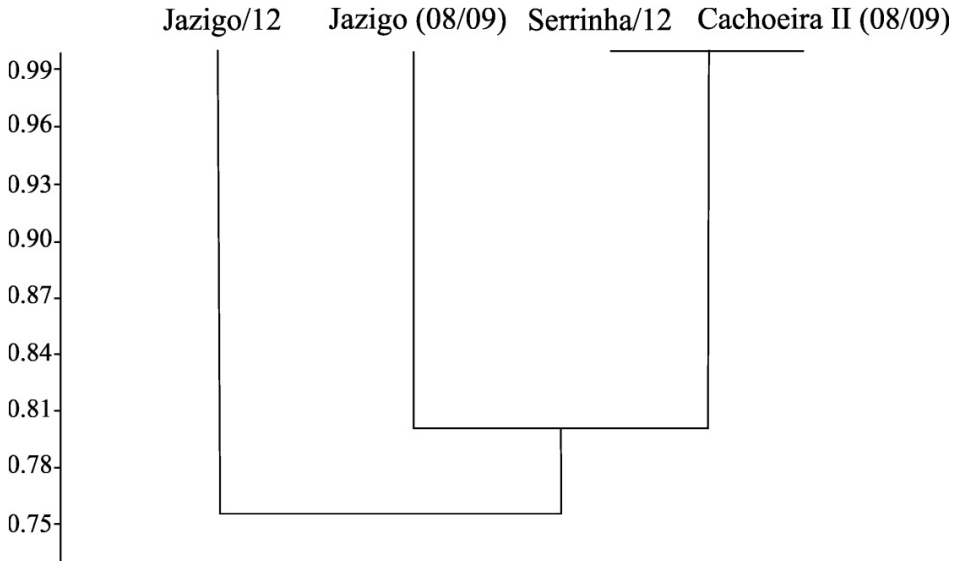

Figure 5. Dendrogram similarity of mollusks in continental water bodies of Pernambuco semiarid, using Similarity index Bray-Curtis's.

and Serrinha reservoirs (> 99%). The Jazigo reservoir 2008/2009 formed a group with previous reservoirs (80%) of similarity. The Jazigo reservoir/2012 was connected to the other reservoirs with similarity equal to 75%.

There was no significant influence of rainfall and water temperature in relation to the abundance and distribution of the species (Jazigo reservoir, $p = 0.991$ and Cachoeira II reservoir in 2008/2009, $p = 0.241$; Serrinha reservoir in 2012, $p = 0.08$).

4. Discussion

Freshwater mollusks are represented by the classes Gastropoda and Bivalvia, with 305 species known in Brazil, 115 from the Bivalvia and 193 from the Gastropoda class (Avelar, 1999). Only mollusks form the Gastropoda class were sampled for the present study, with the *Melanoides tuberculata* (Thiaridae) as the first and *Pomacea lineata* (Ampullariidae) as the second most representative species of this class. A study carried out in a semiarid seasonal lake by Abílio et al. (2007) presented *P. lineata* among the five most found species, confirming the results of the present study.

The species *Biomphalaria straminea* (Planorbidae) and *Physa marmorata* (Physidae) were little represented, with low abundance compared with the exotic mollusk *M. tuberculata.* The greater abundance of this species is due to its capacity to explore different environments and tolerance to limnological variation and different types of substrates (Freitas et al., 1987). A low biodiversity of mollusks was found in the studied reservoirs, probably due to the presence of the exotic mollusk species *M. tuberculata.* According to Allan & Flecker (1993), the dispersion of exotic species is the second major cause of loss of aquatic biodiversity. The exotic species *M. tuberculata* has spread in Brazil in the last decades, from the South to the North and Northeast regions, with more than 60 occurrences reported in the country (Fernandez et al., 2003).

The competition between the *M. tuberculata* and the native mollusks is widely reported in the literature (Pointier & Augustin, 1999). Many studies in Brazil indicated that native populations of *Aylacostoma* (Reeve, 1860) have been replaced by *M. tuberculata* populations (Fernandez et al., 2003). *M. tuberculata* was the most abundant and frequently found species in the reservoirs during the study, as expected. The *M. tuberculata* growth, reproductive rates, tolerances and food preferences (Rader et al., 2003; Coat et al., 2009) may explain its ability to colonize and dominate clusters of freshwater mollusks in tropical and subtropical regions (Pointier et al., 1994; El-Kady et al., 2000; Guimarães et al., 2001).

According to Lima et al. (2013), this species is a great competitor and has successfully reduced populations of species of the genus *Biomphalaria*, which are intermediate hosts of schistosomiasis. However, species of the family Thiaridae has caused significant effects on native mollusks (Pointier & Augustin, 1999; Guimarães et al., 2001; Giovanelli et al., 2003, 2005). The small number of individuals of *Pomacea lineata* and *Biomphalaria straminea*, which presented densities below 100 ind.m^{-2}, intensifies the effect of the exotic species *M. tuberculata*, reducing the native populations in the reservoirs.

The information shown in the present study clearly denote the efficiency of this species in colonizing artificial reservoirs in the semiarid region of the Pajeú River Basin, presenting high density (1.856 ind.m^{-2}) compared with the estimated population densities found worldwide (100 to 13.400 ind.m^{-2}) (Lévèque, 1971; Pointier et al., 1989). However, the large amount of empty shells and the size of the individuals suggest that their population have been controlled by some events, which are forms of control to be investigated to control this exotic species.

The abundance of species had no significant correlation with the rainfall and temperature of the water, however, the months without rainfalls and higher temperatures presented greater amounts of individuals. The number of individuals increases in the dry season, probably because of the increased availability of food, such as plant residues, during the dry season in arid and semiarid regions, making the environment to support a higher density of individuals (Extence, 1981). The results found contribute to the understanding of the snails of continental water bodies, provide bases for future researches and can be used as a source of information in the case of native species become extinct over the years due to the proliferation of *M. tuberculata*, as well as for researches related to evolution of species. The development of researches, monitoring the aquatic ecosystems of the Caatinga biome, is important, in order to understand their structure and functioning regarding the benthic fauna, since these ecosystems can be used as bioindicators of environmental quality, and are important to public health.

The exotic species *M. tuberculata* was the most frequent and abundant in all the studied

reservoirs probably adapt well the variations of abiotic local factors and also the lack of a natural predator. The results may reflect that effect on native populations *Biomphalaria straminea* and *Physa marmorata*, the latter, there is to be vulnerable species extinction.

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Received: 08 December 2016
Accepted: 14 August 2017