Freshwater mollusks from three reservoirs of Piauí, northeastern Brazil

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Abstract: The pronounced dry season determines the characteristics of the semi-arid region of Brazil. Numerous small reservoirs are built to overcome this condition, accumulating multiple uses and causing important changes in the landscape and the local biota. Considering the limited amount of information about the malacoofauna of reservoirs, mainly in the Northeast region of the country, this inventory provides a list of mollusks from three important reservoirs located in the city of São Julião, state of Piauí. The collections were carried out monthly between May/2017 and April/2018, sampling a total of 11,149 mollusks, corresponding to the species Melanoides tuberculata (Müller, 1774) (n = 9,724), Biomphalaria straminea (Dunker, 1848) (n = 1,361) and Pomacea lineata (Spix, 1827) (n = 64). The richness of mollusks from the three reservoirs was low, similar to those described in studies conducted in other regions of Northeast Brazil. There was a significant difference in the abundance of M. tuberculata and B. straminea among the studied reservoirs. These environments are not connected and are installed in urban and rural areas, presenting different ecological conditions. The relationship between the human population and the reservoirs, associated with the lack of sanitation, increases the risks of spreading waterborne diseases besides the development of environmental imbalance by the introduction of exotic species.

Keywords: Ampullariidae, Gastropoda, Planorbidae, species list, Thiaridae.
Introduction

The semiarid region covers a large part of the Northeast and a portion of the Brazilian Southeast (SUDENE 2017). This area is subject to recurrent and severe droughts periods (Ab’Sáber 2003) with spatial rainfall and temporal irregularity, providing edaphic high evapotranspiration and causing a serious water scarcity condition (Agostinho et al. 2007; Malvezzi 2007). Tundisi (2003) considers this scenario the main threat to the Brazilian Northeastern region biodiversity, driving to changes in natural environments dynamics and also in all communities that depend or live in freshwater.

Due to this ecological feature, a set of measures have been taken to reduce the impact of droughts in the Northeast and building dams has been an effective way to store water (Esteves 1998). Despite its intrinsic importance for the human population, the building of a reservoir severely changes local hydrology, moving streams from a lotic state to a lentic or semi-lentic condition (Agostinho et al. 2007, Tundisi et al. 2002). These changes produce considerable alterations in aquatic ecosystems, primarily due to variations in water residence time, habitat fragmentation and exotic species invasion (Tundisi 2008, Agostinho et al. 2005). These circumstances eventually promote the restructuring of the entire biota composition (Baxter 1977), allowing to species substitution and an increase on the abundance of more adapted species to the conditions of the new environment in opposition to the decrease of non-adapted ones.

Mollusca is an extraordinarily varied phylum, with estimates of 80,000-100,000 described species and the total diversity possibly as high as 200,000, they are behind only to arthropods in species richness (Strong et al. 2008). The mollusks have been successful in occupying most of all diverse freshwater habitats (Bogan 2008) with reports of phylogenetically distinct lineages and assemblages, of which Bivalvia and Gastropoda are cited as the most important classes (Lydeard et al. 2004). These animals participate in several ecological interactions within the community acting as filtering agents, herbivores, predators, ectoparasites, and commensal (Colley et al. 2012; Pombo 2016), besides carrying parasites intermediate forms.

Routinely and inadvertently, freshwater mollusks are introduced in new environments with aquatic plants, fish and anthropic action linked with aquaculture (Strong et al. 2008). Negative consequences of this introduction are diverse, including: (1) partial or total natural populations substitution (Freitas et al. 1987, Pointier 1999, Fernandez 2001); (2) health damage to both humans and other animals through the dissemination of larval stages of parasites (Pinto & Melo 2011); and (3) economic, causing damages to companies building structures because of the accumulation of these organisms (Santos et al. 2012, Vogler 2012).

There is no systematized information about native mollusk fauna nor exotic regarding Brazilian reservoirs, and the few existing reports about this group are restricted to large dams, mainly those related to hydroelectric plants (Thiengo et al. 2005, Fernandez et al. 2018, Malvezzi 2007). The verification of normality in the data distribution occurred by applying the Shapiro–Wilks test. After not presenting normal distribution, there was the application of the Kruskal–Wallis nonparametric test to verify the differences in the abundance of mollusks between the reservoirs studied. The Kolmogorov–Smirnov test occurred a posteriori. All analyses used the SYSTAT® software, version 12.0.

2. Sampling and data analysis

Sampling were held monthly between May 2017 and April 2018 in three stations located 1.5 meters from the margin in each reservoir. The field procedures were done according to Silva et al. (2019). Sorting and identification of individuals were carried out at the Laboratory of Ecology, Parasitology and Neglected Diseases (LAPEDONE), at the Instituto Federal do Piauí.

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The entire field procedure was authorized by Chico Mendes Institute for Biodiversity Conservation, through Biodiversity Authorization and Information System (SISBIO) permit number 60423-5. Voucher specimens are housed at Coleção de Moluscos do Instituto Oswaldo Cruz, Fundação Oswaldo Cruz, Rio de Janeiro, Brazil (CMIOC), Museu de Zooloogia da Universidade de São Paulo, São Paulo, Brazil (MZUSP) and at the LAPEDONE collection as well (Table 1).

Results

During the sampling period, 11,149 alive mollusks were captured in the three reservoirs. These animals belong to three Gastropoda species: Melanoides tuberculata (Müller, 1774) (Thiaridae) (n = 9,724; min = 0; max = 795; mean = 30), Biomphalaria straminea (Dunker, 1848) (Planorbidae) (n = 1,361; min = 0, max = 74; mean = 4.2) and Pomacea lineata (Spix, 1827) (Ampullariidae) (n = 64; min = 0; max = 12; mean = 0.2) (Figure 2).

When comparing species abundance among the reservoirs, Dona Maria Zeneide Viana de Andrade Reservoir had the highest number of mollusks (n = 5,417; 48.6%). Emparedade (n = 4,619; 41.4%) was the second most abundant followed by São Julião (n = 1,113; 10%). Despite the species abundance being different between the analyzed reservoirs, their composition remained the same among them.
Figure 1. Sampling locations in São Julião, Piauí, Brazil. Details of reservoirs surveyed a: São Julião; b: Dona Maria Zeneide Viana de Andrade and c: Emparedade (Adapted from Silva et al. 2019).

Table 1. Gastropoda species sampled in the reservoirs of São Julião, Piauí, Brazil, between June 2017 and April 2018.

<table>
<thead>
<tr>
<th>Order/Family</th>
<th>Species</th>
<th>Voucher number</th>
<th>Reservoir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basommatophora/Planorbidae</td>
<td><em>Biomphalaria straminea</em> (Dunker, 1848)</td>
<td>CMIOC 11598</td>
<td>São Julião Reservoir</td>
</tr>
<tr>
<td>Prosobranchia/Thiaridae</td>
<td><em>Melanoideos tuberculata</em> (Müller, 1774)</td>
<td>CMIOC 11599</td>
<td>7°05'02.6&quot;S 40°50'29.0&quot;W</td>
</tr>
<tr>
<td>Prosobranchia/Ampullariida</td>
<td><em>Pomacea lineata</em> (Spix, 1827)</td>
<td>MZUSP 146748</td>
<td>Emparedade Reservoir</td>
</tr>
<tr>
<td>Basommatophora/Planorbidae</td>
<td><em>Biomphalaria straminea</em> (Dunker, 1848)</td>
<td>CMIOC 11601</td>
<td>7°05'02.6&quot;S 40°50'29.0&quot;W</td>
</tr>
<tr>
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<td><em>Melanoideos tuberculata</em> (Müller, 1774)</td>
<td>CMIOC 11602</td>
<td>Dona Maria Zeneide Viana de Andrade Reservoir</td>
</tr>
<tr>
<td>Prosobranchia/Ampullariida</td>
<td><em>Pomacea lineata</em> (Spix, 1827)</td>
<td>MZUSP 146750</td>
<td>7°05'02.6&quot;S 40°50'29.0&quot;W</td>
</tr>
</tbody>
</table>
Figure 2. Mollusk species sampled in the reservoirs of São Julião, Piauí, Brazil. a: Melanoides tuberculata; b: Biomphalaria straminea and c: Pomacea lineata. Scale bars = a: 10mm, b: 5mm and c: 10mm.
Melanoides tuberculata was the most abundant species among the three reservoirs, corresponding to 9,724 individuals (87.2% of total sampled). This species had 4,894 specimens (50.3%; min = 0; max = 401; mean = 45.3) in Dona Maria Zeneide Viana de Andrade Reservoir, while in Emparedade there were 3,762 individuals (38.7%; min = 0; max = 795; mean = 34.8), and 1,068 in São Julião Reservoir (11%; min = 0; max = 111; mean = 9.9). It was verified a significant difference in the abundance of individuals among the studied dams, of which only São Julião Reservoir differed in its results (P ≤ 0.05; d.f. = 2; X² = 24.88) (Figure 3a).

The second most abundant species in the study is B. straminea, corresponding to 1,361 individuals (12.2% of the entire sample). A total of 821 individuals were collected in Emparedade Reservoir (60.3%; min = 0; max = 74; mean = 7.7), 512 individuals (37.6%; min = 0; max = 64; mean = 4.8) in Dona Maria Zeneide Viana de Andrade Reservoir and 28 individuals (2.1%; min = 0; max = 4; mean = 0.3) in São Julião reservoir, the least abundant of all. There was a significant difference in the abundance of mollusks of this species among the studied reservoirs, of which São Julião differed from the others surveyed (P ≤ 0.05; d.f. = 2; X² = 78.79) (Figure 3b).

Pomacea lineata was least abundant in all three reservoirs, comprising 64 individuals (0.6% of sampled animals). This species had 36 individuals in Emparedade reservoir (56.3%; min = 0; max = 12; mean = 0.3), followed by 17 individuals in São Julião (26.6%; min = 0; max = 5; mean = 0.2), and only 11 specimens in Dona Maria Zeneide Viana de Andrade Reservoir (17.2%; min = 0; max = 5; mean = 0.1). There was no significant difference in the abundance of individuals of this species among the reservoirs studied (P = 0.06; d.f. = 2; X² = 5.54) (Figure 3c).

Discussion

Similar to other freshwater and marine invertebrates, freshwater gastropods present an overall pattern of high diversity in tropics, with decreasing species richness as well as decreasing endemicity at higher latitudes (Strog et al. 2008). According to the latter author, the rivers and streams of South America are surprisingly species-poor, however, it is not yet clear if this is a sampling/study artifact or an actual pattern. The fauna of mollusks sampled in the three reservoirs of São Julião is, in fact, not diverse, consisting of three species from only three families of Gastropoda. These results are similar to those described by studies carried out in the Brazilian Northeastern, a region which accumulates a history of low species diversity (Abilio et al. 2007, Oliveira & Viana 2019).

Santos & Eskinazi-Sant'Anna (2010) attempted to explain the relatively low variety observed in semiarid tropical regions, attributing to prolonged dry periods a condition that selects to snail's community. Considering this assertion, in case of intermittent rivers dammed, the time of water residence is a factor that can play an important role in this phenomenon because drives the stratification processes and nutrient availability, causing considerably changes in water properties (Straškraba 1999, Londe et al. 2016). Bennion et al. (2005) described that retention periods longer than 30 days are very sensitive to enrichment, making the water more susceptible to eutrophication. According to the latter authors, shallow and completely mixed aquatic environments present a very low potential for recovery. These attributes are similar to the ones verified in the reservoir complex studied in São Julião.

Although geographically close, the studied reservoirs are not connected. This autonomy implies that each environment will present a peculiar response to environmental variations. Emparedade and Dona Maria Zeneide Viana de Andrade reservoirs are located in a rural area, far from urban influence. It is possible to verify a large deforested area along the reservoirs margin, which allows the exposure of water column to light, causing a consequent increase in primary productivity. Conversely, São Julião reservoir is in urban perimeter, having significantly more vegetation at its margin, and it receives a considerable amount of non-treated sewage. Thus, these particularities of each of the studied reservoirs may have been responsible for the significant difference in mollusks abundance.

Previous studies conducted in different regions of the country considered the species found in the three reservoirs of São Julião tolerant and very adapted to environmental diversity. Biomphalaria straminea is widely distributed in Brazil, as a result of their ability to adapt to different climates and ecological conditions (Paranense, 1986). According to Kotzman & Amaral (2013), B. straminea occurrence in water bodies of the semiarid region can be explained by their tolerance to dry periods, thus severe semi-arid conditions are not barriers to their survival. This species is the most important host of Schistosoma mansoni (Sambon, 1907) in Brazilian Northeastern. Pomacea lineata, in its turn, although less abundant, is quite resistant to desiccation. In a recent study, Glasheen et al. (2017) confirmed that the survival capacity of these animals to drought conditions, due to the behavior of fully burying itself in the substrate. Regarding M. tuberculata, this species has combined high tolerance to both salinities’ levels (Farani et al., 2000, Silva & Barros 2015, Bolaji et al., 2011) and temperature variations (Pointier 1993), and it also supports longer desiccation periods. Allied to this, it has a high reproductive capacity through parthenogenesis (Jacob 1957) and sexual reproduction (Samadi et al. 1999).

In São Julião reservoir complex, the abundance of M. tuberculata is seven times higher than all other native species registered. The high number of individuals observed is a consequence of the set of biological traits mentioned, which allows M. tuberculata to become a successful competitor in new environments, capable of even suppressing the growth of native species population. The role of this invasive species in the reduction of native species have been described in different environments (Freitas et al. 1987, Pointier 1999, Fernandez 2001, Almeida et al. 2018). There are reports of the decline in B. glabrata and B. straminea densities from the Southeastern region (Giovaneli et al. 2003, Almeida et al. 2018), as well as it was responsible for the low diversity and density indices of native species in Northeastern reservoirs (Almeida et al. 2018). Although the effect of M. tuberculata on mollusk community of the São Julião reservoirs has not been evaluated, the expressive differences observed among abundances of this species, B. straminea and Pomacea lineata, suggest attention to a putative interspecific competition.

The history of severe droughts in the region of São Julião promoted a larger interaction between human populations and their reservoirs. However, without proper sanitation conditions that this interaction requires, the risk of spreading water-borne diseases and environmental imbalance through the introduction of exotic species is imminent. The
Figure 3. Abundance of Gastropoda species sampled in the three reservoirs of São Julião, Piauí, Brazil, between May 2017 and April 2018. Details of statistical tests in a: *Melanoides tuberculata*; b: *Biomphalaria straminea* and c: *Pomacea lineata*. Images of species out of scale.
results obtained with this survey allowed us to make inferences about the influence of these water bodies on the malaco fauna composition of the semiarid region as well as their interaction with the environment, besides recording the presence of *B. straminea*, which is the intermediate host of *S. mansoni*, in the studied region. This information is of paramount importance to local populations who depend on these water resources for a variety of activities.

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**Author contributions**

Edson Lourenço da Silva: Contribution to data analysis and interpretation.
Adriana Josefa da Rocha: Contribution to data collection.
Manuella Feitosa Leal: Contribution to data collection.
Orianna dos Santos: Contribution to data collection.
João Hemerson de Sousa: Contribution to data collection.
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Karina Ketelen Silva Dantas: Contribution to data collection.
Erika Maria Matos Rulim: Contribution to data collection.
Emerson Santos Castro: Contribution to data collection.
Ana Carolina Landim Pacheco: Contribution to critical revision, adding intellectual content.
Tamaris Gimenez Pinheiro: 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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