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Original Article

Limnic gastropods and trematodes of public health concern in Barreirinhas, Maranhão State, Brazil

Gastrópodes límnicos e trematódeos de interesse na saúde pública no município de Barreirinhas, MA, Brasil

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Abstract

Limnic gastropods are of great importance as both biodiversity components and public health threats. These organisms serve as vectors for some helminths that may be involved in the occurrence of human zoonoses. Previous studies carried out in the region of the Lençóis Maranhenses National Park (LMNP) reported the occurrence of gastropod species, including *Biomphalaria glabrata* (Say, 1818) and *Biomphalaria straminea* (Dunker, 1848), vectors of *Schistosoma mansoni* (Sambon, 1907), the causative agent of schistosomiasis. This study aimed to survey gastropod species occurring in the region to understand their diversity and geographical distribution. Another aim was to analyze the potential infection of these organisms by trematodes. The municipality of Barreirinhas experiences a large influx of people due to its importance as a Brazilian tourist hub in the LMNP. Four surveys were carried out in Barreirinhas. Based on reports from the population about mollusk occurrences, six bodies of water in the municipality were investigated, distributed in urban and rural areas. The collected specimens were identified using morphological methods and analyzed weekly for 45 days to detect trematodes. The survey carried out in Barreirinhas from October 2021 to August 2022 revealed the occurrence of mollusks of interest, totaling 1273 specimens of the species *Melanoides tuberculata* (Müller, 1774), *Pomacea* sp. (Perry, 1810), and *B. straminea*. The predominant species was *B. straminea*, with 777 specimens (61%), followed by *M. tuberculata* with 347 specimens (27.3%), and *Pomacea* sp., with 149 specimens (11.7%). Larvae of Xiphidiocercaria (Microphallidae) and Gymnocephala (Gymnophallidae) were found parasitizing *Pomacea* sp. Brevifurcate apharyngeate distome larvae were detected in *B. straminea*.

Keywords: vector ecology, pathogenic flatworms, Lençóis Maranhenses National Park.

Resumo

Os gastrópodes límnicos apresentam grande importância como componentes da biodiversidade e para a saúde pública, pois esses organismos desempenham o papel de vetores de alguns helmintos que podem estar envolvidos na ocorrência de zoonoses que afetam o ser humano. Estudos prévios realizados na região do Parque Nacional dos Lençóis Maranhenses (PNLM) relataram a ocorrência de espécies de gastrópodes, incluindo *Biomphalaria glabrata* (Say, 1818) e *Biomphalaria straminea* (Dunker, 1848), vetores do *Schistosoma mansoni* (Sambon, 1907) agente causador da esquistossomose. Objetivou-se com este estudo realizar o levantamento de espécies de gastrópodes que ocorrem na região com o objetivo de conhecer a diversidade e a distribuição geográfica, assim como analisar a possível infecção desses organismos por trematódeos, pois o município de Barreirinhas tem um grande fluxo de pessoas, devido sua importância como um polo turístico brasileiro no Parque Nacional dos Lençóis Maranhenses. Foram realizadas quatro coletas no município de Barreirinhas. Com base nos relatos da população sobre a ocorrência de moluscos, foram investigados seis corpos hídricos do município distribuídos na zona urbana e rural. Os espécimes coletados foram identificados por métodos morfológicos e analisados semanalmente durante quarenta e cinco dias para detecção de trematódeo. No estudo realizado no município de Barreirinhas, durante o período de outubro de 2021 a agosto de 2022 foi verificada a ocorrência 273 espécimes, distribuídos entre as espécies de *Melanoides tuberculata* (Müller, 1774), *Pomacea* sp. (Perry, 1810) e *B. straminea*. O predomínio foi de *B. straminea* com 777 espécimes coletados (61%), seguido por *Melanoides tuberculata* com 347 (27,3%) e *Pomacea*

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sp. com 149 (11, 7%). Foram encontradas parasitando *Pomacea* sp. larvas de Xifideocercária (Microphallidae) e Gimnocéfala (Gymnophallidae). Em *B. straminea* foram detectadas larvas do tipo brevifurcada distoma afaringeada.

Palavras-chave: ecologia de vetores, platelmintos patogênicos, Parque Nacional dos Lençóis Maranhenses (PNLM).

1. Introduction

From the perspective of ecological studies on freshwater environments, gastropods actively participate in the ecosystems they inhabit, playing an important role in the trophic chain by providing food for many species of fish, amphibians, reptiles, birds, and mammals (Maltchik et al., 2010). Some gastropods, however, are invasive species that cause ecological and economic damage and represent a risk to human and animal health (Bezerra et al., 2019). Certain gastropods serve as intermediate hosts for various parasites of medical and veterinary interest, thereby occupying a prominent place in medical limnology (França et al., 2007).

Gastropods can be parasitized by trematodes (Platyhelminthes), which represent a significant portion of helminth diversity. These organisms use various hosts throughout their life cycle and are typically found in ecosystems affected by environmental contamination and poor sanitation (Poulin, 2007). In Brazil, it is estimated that approximately 1.5 million people are infected with the trematode *Schistosoma mansoni* (Sambon, 1907) (Brasil, 2024a). Notification records for schistosomiasis show that the disease is present in at least 19 of the 26 Brazilian states. The most affected regions are the Southeast and Northeast, and incidence rates are directly linked to the presence of intermediate hosts (Brasil, 2017, 2024b; Everton et al., 2018). Gastropods of the genus *Biomphalaria* serve as intermediate hosts for *S. mansoni*, whereas humans act as the definitive host (Santana et al., 2014; Rocha et al., 2016; Lima et al., 2018; Fiocruz, 2022).

Taxonomic determination of parasites associated with gastropod hosts is extremely important for understanding the bioecology of these organisms, especially in areas where parasitic diseases are common. This information is relevant for the implementation of control measures by the responsible health agencies (Coelho et al., 2022).

The region of the Lençóis Maranhenses National Park (LMNP) comprises areas of coastal plains with the largest recorded system of coastal dunes in Brazil, encompassing a strip that extends about 50 km inland from the continent border. This dune system is unique worldwide. Between the dunes, there are thousands of shallow and crystal-clear freshwater lagoons (Carvalho, 2007). These characteristics make the Lençóis Maranhenses one of the main tourist attractions in Maranhão State. The municipality of Barreirinhas serves as a gateway to LMNP. Residents experience health problems caused by trematodes, mainly *S. mansoni*. A total of 734 cases of schistosomiasis were recorded in Barreirinhas between 1997 and 2021, with an annual mean of approximately 30 cases per 1447 exams. However, no gastropod vectors were reported in the region during this period (Brasil, 2024c) In addition to affecting the local population on an annual basis, the disease poses a threat to tourists who frequently visit the park's water bodies and their surroundings.

The presence of several aquatic environments in the region facilitate the reproduction of mollusks potentially contaminated with trematodes, whereas the large circulation of people can lead to the spread of parasitic diseases. In view of these considerations, we raised the hypothesis that environmental conditions in different areas of the Lençóis Maranhenses region may increase the risk of parasitic diseases associated with limnic gastropods contaminated with pathogenic trematodes. The aim of this study was to survey freshwater gastropods and trematode larvae shed from these mollusks, assess species richness and population density, and determine geographical and seasonal variations that may favor the spread of gastropod species in Barreirinhas, Maranhão, Brazil.

2. Material and Methods

2.1. Study area

Barreirinhas is located on the northeastern coast of Maranhão State, approximately 260 km from the capital São Luís. It is part of the Northern Maranhão Mesoregion, within the Lençóis Maranhenses Microregion. The study area is located close to LMNP (Figure 1). Barreirinhas has a territorial area of 3,046.308 km^2, a resident population of 65,589 people, a demographic density of 21.53 inhabitants/km^2, and a municipal human development index of 0.57 (IBGE, 2022).

The region is characterized by a dry sub-humid tropical climate, with an average annual temperature of 26 °C. Annual rainfall ranges from 1200 to 2000 mm. The climate is divided into two well-defined seasons: a rainy season from January to July and a dry season from August to December (Maranhão, 2023). This rainfall regime is an important variable informing the sampling procedure, as the occurrence of live mollusks decreases considerably in dry periods, when only their shells are easily observed.

The municipality is part of the Preguiças River basin, which receives most of the region's streams and rivers. The Preguiças River is considered the most important river in the Lençóis Maranhenses because it is navigable and serves as an access channel to the sea (Souza dos Santos and Santos, 2015; IMESC, 2020). The characteristic biome is the Cerrado, encompassing areas of restinga, open dune fields, and the ocean coast, with beaches, mangroves, and an open sea delta. In addition to the Cerrado, the vegetation is strongly influenced by the Caatinga and the Amazon, containing species common to all three biomes (Souza dos Santos and Santos, 2015; IMESC, 2020).

2.2. Field procedure

Four malacological collections were carried out at six points during the dry and rainy periods. The collections were quarterly and lasted one week at each point. The following biotopes were sampled in the urban perimeter and rural areas with favorable characteristics to the occurrence of limnic mollusks: sewage-polluted streams (points A

Figure 1. Area where the gastropods were collected in the urban (Points A, B, C, and F) and rural (D and E) zones of the municipality of Barreirinhas, in the years 2020 and 2021.

Table 1. Geographic coordinates of malacological collection stations.

COLLECTION LOCATIONS	CHARACTERISTICS OF COLLECTION POINTS	COORDINATES	
		LATITUDE	LONGITUDE
POINT A	Streams polluted by sewage	2º75'050"S	42º82'942"W
POINT B	Streams polluted by sewage	2º75'251"S	42º82'795"W
POINT C	Marshes	2º45'365"S	42º49'473"W
POINT D	Lagoons with flooded Fields	2º44'818"S	42º37'442"W
POINT E	Lagoons with flooded Fields	2º46'739"S	42º50'259"W
POINT F	Drainage ditches	2º44'546"S	42º37'454"W

Point A: Market located in the center of Barreirinhas. Point B: Tiburcio Creek passing through Pousada do Buriti, Center of Barreirinhas. Point C: Tiburcio Creek passing through Pousada do Riacho in district of Riacho, Barreirinhas. Point D: Perennial Lagoon located in the Pequenos Lençóis Maranhenses, near cattle and goat farming. Point E: Temporary Lagoon located in the Pequenos Lençóis Maranhenses, closer to the sea. Point F: Temporary water collection located in district Cidade Nova-Barreirinhas.

and B), marshes (point C), drainage ditches (point F), and lagoons with flooded fields (points D and E) (Table 1). Georeferencing data for collection sites were obtained using Global Positioning System equipment (GPS Garmin eTrex 10).

2.3. Gastropod analysis

The biological material was collected using the method described by Olivier and Schneiderman (1956). The sampling effort at each site totaled 20 min. Mollusks were captured using tweezers and metal shells. The specimens were then transported to the Zoology Laboratory at the State University of Maranhão (UEMA), where they were placed in glass aquariums containing filtered dechlorinated water, substrate, and lettuce. All gastropods were analyzed for the presence of trematode larval stages at night and after 6 h of light exposure during four weeks using a stereoscopic and an optical microscope.

After the trematode analysis period, mollusk specimens were anesthetized, fixed, and identified by morphological analysis, following the identification keys described by Deslandes (1951) and Paraense (1975, 1981). Shell morphology was analyzed according to the protocol reported by Fernandez et al. (2008) and Paraense (1986).

Statistical analysis of gastropod data was carried out using PAST software version 4.6. The Bray–Curtis similarity index was used to assess the similarity of gastropod populations between environments, as proposed by Clarke (1993). The Shannon index (*H'*) was used to assess the species diversity and evenness of gastropod communities at six sampling points, covering urban and rural areas during rainy and dry periods. Rarefaction curves were applied to verify the sufficiency of sampling effort and the relationship between the number of individuals collected and observed species richness. Together, these methods allowed for an understanding of biodiversity patterns as a function of seasonality and location, highlighting differences between the analyzed scenarios.

Linear correlation (Pearson's *r*) tests were carried out at the 95% confidence level (5% significance level) using BioStat software version 5.3. Differences in the number of sampled gastropods between dry and rainy periods were assessed by two-way analysis of variance (ANOVA), followed by Turkey's test at the 5% significance level using BioStat software version 5.3.

Principal component analysis (PCA) was conducted to identify patterns in multivariate data. A data matrix was constructed with six objects (sampling sites) and three descriptors (species), totaling nine variables measured on

1273 samples from different locations. PCA was performed using a standardized data matrix and ordered according to the variance–covariance matrix. Principal components were selected based on the Kaiser criterion (eigenvalues greater than 1) and by visual analysis of scree plots. The analysis was conducted using PAST software version 4.6. Biplots and scree plots were generated to facilitate the interpretation of principal components and visualize the distribution of samples.

2.4. Trematode analysis

Trematode analysis was carried out at night and after 6 h of artificial light exposure (Fernandez et al., 2008; Melo, 2008). Given the possibility of maturation of larval stages (sporocysts), the diagnostic technique (exposure to artificial light during the day + night evaluation) was carried out once a week for 30 days. After light exposure, the flasks containing water and mollusks were examined for trematode larvae under a magnifying glass. Fresh slides were prepared with drops of water and 10% lugol and analyzed under an optical microscope at 8× and 40× magnification. Morphological characters of larvae were examined and cercariae were identified using specific keys described by Schell (1970), Melo (2008), and Pinto and Melo (2013).

Mollusks and trematode larvae were deposited in the Fauna of Maranhão Collection of Tissues and DNA (COFauMA), UEMA, Brazil.

3. Results and Discussion

A total of 1273 specimens were collected, of which 777 (61%) were identified as *Biomphalaria straminea*, 347 (27.3%) as *Melanoides tuberculata*, and 149 (11.7%) as *Pomacea* sp. The species that compose the collected limnic malacofauna are presented in Table 2. Malacological research previously carried out in Barreirinhas had already revealed the occurrence of *B. straminea* and *Pomacea* sp. (Carvalho et al., 2024ab)

Individual rarefaction was analyzed using the Shannon *H*-index. The analysis showed that the most abundant gastropod species was *B. straminea* (Figure 2). *B. straminea* occurs in various Brazilian municipalities (1327 municipalities) across 24 states and the Federal District, with the exception of Amapá and Rondônia States (Brasil, 2024a). According to Marchiori (1999), in the Northeast, the species plays an important role in the transmission of schistosomiasis, serving as an intermediate host for *S. mansoni*. Therefore, *B. straminea* may present a risk to the population. No specimens of *B. straminea* infected with *S. mansoni* were found in this study.

The identified species have been reported in other studies on limnic gastropods of medical importance in Brazilian cities, such as in Rio de Janeiro, Rio de Janeiro State (Fernandez et al., 2001) and in Uberlândia (Lima et al., 2018) and Belo Horizonte, Minas Gerais State (Coelho, 2020). The most dominant species in the region was *M. tuberculata*, with a dominance index (*D*) of 0.87, followed by *B. straminea* and *Pomacea* sp., both with a *D* value of 0.38 (Figure 3).

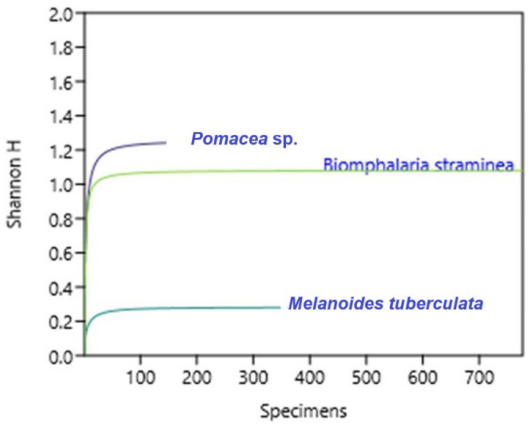

Figure 2. Curve of Rarefaction of gastropod individuals through the analysis of the Shannon index performed based on a 95% confidence interval.

Table 2. Total number of limnic gastropod specimens obtained at each collection point in 2021 and 2022.

	Number of limnic gastropod specimens obtained from each collection.			
POINT	Collect 1 (Oct/21)	Collect 2 (Mar/22)	Collect 3 (June/22)	Collect 4 (Nov/22)
A	*Pomacea* sp. (6*)	*Pomacea* sp. (5*)	NF	NF
B	*Pomacea* sp. (2*) *M.tuberculata* (11*)	*Pomacea* sp. (7*)	NF	NF
C	*M.tuberculata* (42*)	*Pomacea* sp. (19*) *M.tuberculata* (63*) *B. straminea* (18*)	*Pomacea* sp. (39*) *M.tuberculata* (171*)	*Pomacea* sp. (27*) *M.tuberculata* (49*)
D	NF	*Pomacea* sp. (31*)	*Pomacea* sp. (3*) *B. straminea* (384*)	*M.tuberculata* (11*) *B. straminea* (20*)
E	NF	NF	*Pomacea* sp. (3*) *B. straminea* (232*)	NF
F	NF	NF	*Pomacea* sp. (4*) *B. straminea* (123*)	*Pomacea* sp. (3*)

NF stands for not found. *Quantity of specimens of molluscks.

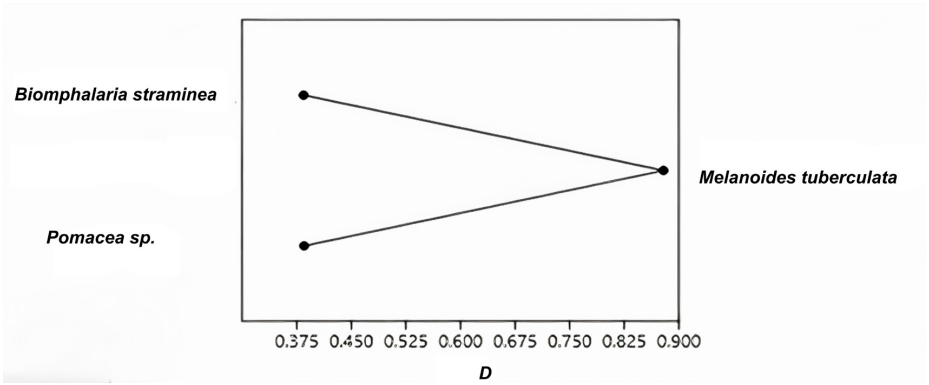

Figure 3. Tests of diversity using the Diversity Index (Dominance D) of limnic gastropods in the municipality of Barreirinhas - MA.

The distribution of *M. tuberculata* in Maranhão is little known and the first record of the occurrence of this snail in the state is recent (Carvalho et al., 2024b). Our work expands the distribution of M. tuberculata in Maranhão, since in the investigations by Carvalho et al. (2024a, b) this gastropod was only verified in Santo Amaro and Tutoia. Our results reinforce the need for further research to monitor this invasive snail. This invasive species belonging to the family Thiaridae is distributed globally and was introduced in Brazil in the mid-1960s. Its first record was made in 1967, in Santos, São Paulo State (Ximenes et al., 2017; Barros et al., 2020). Since then, its distribution has expanded to 19 Brazilian states and the Federal District, being encountered in various water bodies (Santos et al., 2016) and recognized for its ability to resist different environments. Of particular importance, tiarids have dispersed widely; their reproductive potential and ability to colonize various types of habitats limits or excludes certain species of pulmonates, as occurs with planorbid mollusks, which are vectors for parasites related to schistosomiasis (Pointier et al., 2010). *M. tuberculata* was probably introduced to South America via the aquarium trade and/or to combat *Biomphalaria* (Fernandez et al., 2003). In fact, in the current study, we observed a lower occurrence of *B. straminea* in sites with a higher frequency of *M. tuberculata*.

Pearson's correlation analysis was performed to assess the relationship between *Pomacea* sp., *M. tuberculata*, and *B. straminea*. A positive correlation was observed between *Pomacea* sp. and *M. tuberculata* ($r = 0.94$), indicating that the presence of one species was associated with the presence of the other. These mollusks tend to occur at sites with similar characteristics. By contrast, *Pomacea* sp. and *B. straminea* had a nearly null correlation ($r = -0.09$), suggesting a very weak or nonexistent relationship between these species. The correlation between *M. tuberculata* and *B. straminea* was negative and moderate ($r = -0.32$), which suggests that the presence of *M. tuberculata* may be associated with the absence of *B. straminea*, to some extent (Figure 4).

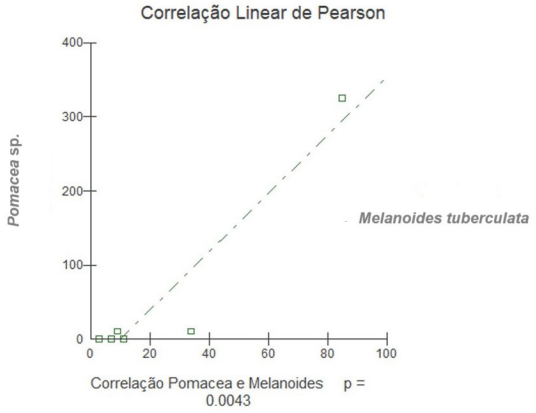

Figure 4. Pearson's Linear Correlation Test between the limnic molluscs collected in the municipality of Barreirinhas - MA.

3.1. Distribution of gastropods according to collection points

There was a greater distribution of *Pomacea* sp. and *M. tuberculata* in the urban area of Barreirinhas and a greater presence of *B. straminea* in the rural area. PCA was performed to reduce the data's dimensionality and detect patterns among the measured variables. The data matrix consisted of six objects (sampling sites) and three descriptors (species), resulting in a total of nine variables from 1273 samples taken from various locations. The first principal components explained a large proportion of the total variance, making them the primary axes of variation in sampling sites and species. PCA revealed that the first two principal components (PC 1 and PC 2) together explained 67.98% of the total variance, representing sufficient explanatory effort in terms of species variation in and between sampling sites.

PCA biplots allowed clearly visualizing the distribution of samples and variables along the principal axes, contributing to the interpretation of the observed patterns. Samples were projected onto six observer sites, emphasizing the similarity of sampling in relation to the studied descriptors. This approach aided in understanding the ecological relationships between species and sampling sites. The spatial distribution of points showed the generation of two clusters. The first referred to the occurrence of gastropods in the urban region, and the second, to the occurrence of gastropods in the rural region (Figure 5).

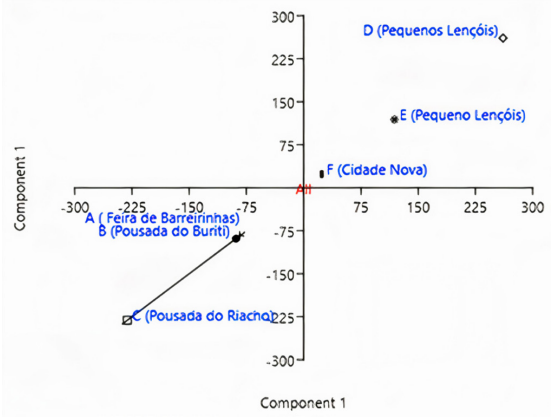

Figure 5. A plot of the variation axis (PC1) of the Principal Component Analysis for the dataset of limnic gastropods in the municipality of Barreirinhas, Maranhão, shows the generation of two clusters indicating two groups.

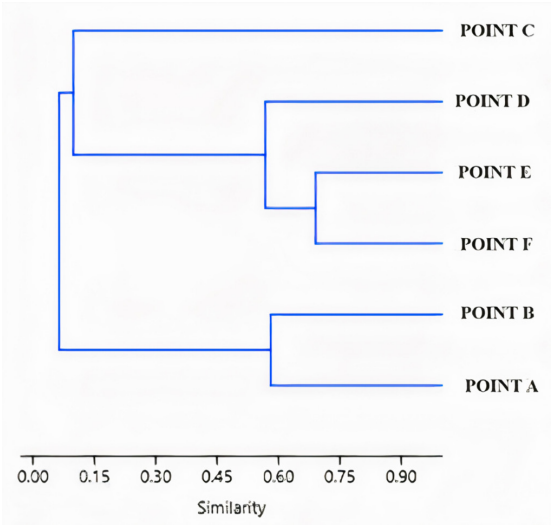

Figure 6. The similarity dendrogram obtained by the UPGMA clustering method for the Bray-Curtis coefficient for collection points in relation to the presence of gastropods.

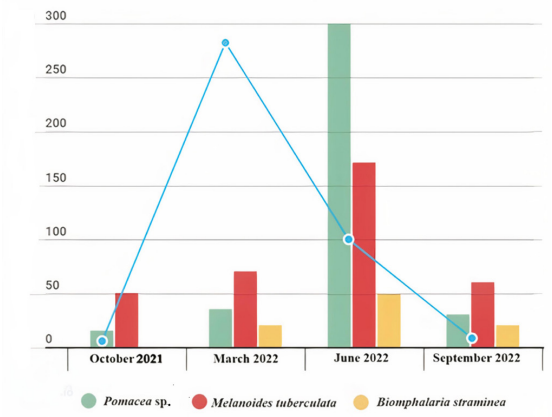

Figure 7. The quantity of gastropods collected during the dry period (October 2021 and September 2022) and the rainy period (March and June 2022) in the municipality of Barreirinhas, Maranhão, Brazil. The line indicates the rainfall index in mm for period.

Statistical analysis showed the similarity of the presence of limnic gastropods between collection points (Figure 6). The analysis allowed separating collection sites into two main groups. The first group consisted of sites in rural areas (D, E and F) and an isolated subgroup (C). The second group consisted of sites located in urban areas (A and B). Based on the results obtained, we suggest that gastropods occur at the points investigated, at least one of the three species was recorded at some point during the year. It is important to note that collection point C refers to Riacho Tibúrcio, which runs through the urban center of the municipality of Barreirinhas. At this point, we observed the simultaneous presence of the three species of gastropods, with emphasis on *M. tuberculata*, which was observed throughout the collection period. Regarding the establishment of mollusc populations in urban areas, David et al. (2018) suggest the existence of a high concentration of snail breeding sites in urbanized territories, which, in turn, are influenced by characteristics resulting from human actions.

3.2. Seasonal frequency of gastropods

The frequency of gastropods at each collection point in the dry and rainy seasons was evaluated using ANOVA. The *F*-value (treatments) was 5.1808 and the *p*-value (treatments) was 0.0022, indicating significant differences between treatment means ($p < 0.05$). This result may refer to differences between gastropod species, collection points, or collection periods. Regarding blocks, the *F*-value (blocks) was 1.0194 and the *p*-value (blocks) was 0.4480, demonstrating that the combination of different factors (collection points and periods) did not provide significant differences. This finding suggests that the variation between blocks was not significant, with a *p*-value greater than 0.05.

Multiple comparison of treatment means was carried out using Tukey's test. The results were as follows: (1 to 2) = 0.4383, (1 to 3) = 0.1516, and (2 to 3) = 0.5898, where 1 represents species, 2 represents collection points, and 3 represents collection periods (dry or rainy). No significant differences were found between the means of treatments 1 and 2, 1 and 3, and 2 and 3. However, the mean of treatment 4 (number of collected species) differed from that of treatments 1, 2, and 3, with mean results of (1 to 4) = 4.6203, (2 to 4) = 4.1820, and (3 to 4) = 4.7718, all of which were significant. These findings suggest that the combination of the analyzed points and collection periods had an effect on the number of sampled species.

Statistical analyses indicated that the number of mollusk specimens was influenced by the dry (October/2021 and September 2022), rainy (March/2022) and post-rainy (June/2022) periods (Figure 7). The level of precipitation can be a determining factor in the quantity and diversity of freshwater gastropods in the region. We observed that the post-rainy period (June/2022) is the most favorable for the establishment of gastropod populations in the breeding grounds, as the quantity of the three species was more expressive during this period.

During the rainy season, there was a reduction in the number of mollusks in the breeding grounds. Some studies suggest that David et al. (2018) suggest that heavy rains

Table 3. The quantity of limnic mollusk specimens obtained at each collection point during the period from 2021 to 2022, highlighting the positivity for trematode larvae.

Gastropods	Trematode		
	Xiphidiocercaria (Ubiquitous)	Brevifurcate Pharyngeal Distome	Gymnocephala
Melanoides tuberculata	NF	NF	NF
***Pomacea* sp.**	28	NE	5
Biomphalaria straminea	NF	14	NF

NE = not found.

cause this local decrease, as there is a drag effect where the snails are dispersed to other locations, forming new breeding grounds (David et al., 2018; Giovanelli et al., 2001; Borges et al., 2023). On the other hand, light rains do not cause this dispersion and during the rainy season a demographic explosion of these animals can occur, especially of snails in aestivation (Cantanhede, 2015).

The survey carried out by Tchakonté et al. (2014) confirms that the occurrence of rainfall considerably increases the malacological population, the onset of the rainy season increases habitat and food availability as urban and domestic organic matter is drained into rivers through surface runoff. Several studies have shown that the reproduction periods of benthic macroinvertebrates, along with many other organisms, coincide with seasonal changes, habitat quality, and food availability (Garcia-Roger et al., 2011; Martinez and Rogowski, 2011). We also observed that specimens of *M. tuberculata* and *Pomacea* sp. were present in all periods (Figure 7). It is important to highlight the adaptation of these two species to the dry period. The presence of the operculum on the shell of these gastropods prevents excessive evaporation of water, especially in dry environments or during periods of water stress (Simone, 2020).

3.3. Infection of mollusks by trematodes

Laboratory analysis identified 47 trematode larvae shed during the day and night, corresponding to a frequency of 3.91%. Assessment of mollusk infection with trematode larvae showed that two species were acting as intermediate hosts, namely *Pomacea* sp. and *B. straminea.* Infection rates for each mollusk species are shown in Table 3.

Three types of trematode larvae were found in the cercarial stage. Xiphidiocercaria (Microphallidae) larvae, characterized by having a stylus on the oral sucker, and Gymnocephala (Gymnophallidae) larvae were found in *Pomacea* sp. Both species were identified when exposed to light and at night. In *B. straminea*, a trematode larva of the brevifurcate apharyngeate distome type was found.

M. tuberculata, despite being collected in large numbers at bathing spots, was negative for trematodes. The recent introduction of these organisms to Maranhão State may explain the lack of positivity for trematodes, as these vectors are recent in the parasitic cycle of helminths in the region. Monitoring is important, as the species is a known vector, being associated with liver diseases in humans. The identified cercariae do not pose a direct risk to humans, although contact with watercourses containing brevifurcate apharyngeate distomes can cause cercarial dermatitis. Attention is needed, as these trematodes are found in places used for bathing.

Among the observed mollusk–trematode interactions, the most frequent was the *Pomacea* sp.–Xiphidiocercaria interaction, with a positivity rate of 18.79%. The cercaria found in *Pomacea* sp. is a Xiphidiocercaria of the ubiquita group of the family Microphallidae. This cercaria is characterized by having a stylus on the oral sucker. The occurrence of Xiphidiocercaria in *Pomacea maculata* (Perry, 1810) was recorded for the first time in the Pampulha Reservoir in Belo Horizonte (Pinto and Melo, 2013). Larvae of the ubiquita group, characteristic of some species of the family Microphallidae, parasitize the intestines of birds, the probable definitive host for these trematodes. Humans are not part of their life cycle. Metacercariae develop in crustaceans or in the intermediate host (mollusks) (Pinto and Melo, 2013).

Cantanhede (2015) found a similar result regarding the diversity of trematode larval forms in analyzing the diversity of trematodes in mollusks from breeding sites in Maranhão. Ampulariids are the largest family of limnic gastropods and are the main components of freshwater ecosystems in Brazilian breeding grounds. They are distributed in the western part of Brazil, on the Paraguayan border, to the south and north of the Amazon Basin, and are important components of the freshwater mollusk biodiversity of the Pantanal (Hayes et al., 2012).

4. Conclusion

Analysis of the relationship between climate and mollusk sampling, particularly the influence of rainfall on the quantity and diversity of limnic gastropods in the region, demonstrated that dry periods favor organisms better adapted to drought, such as *M. tuberculata*. The species' survival rates remain stable between dry and rainy seasons. The presence of *B. straminea* in the region is worrisome, given its role as an intermediate host of *S. mansoni*, the causative agent of schistosomiasis. Further research is necessary to assess the frequency of these species and their potential for infection by the parasite. The detection of circulating trematodes in Barreirinhas, mainly associated with *Pomacea* sp., underscores the importance of preventive monitoring to mitigate the

spread of diseases transmitted by these organisms. Although the identified trematodes do not participate directly in human–parasite cycles, they can cause cercarial dermatitis and influence the cycle of wild animals. As such, monitoring is necessary to prevent the extension of the parasite cycle to humans and domestic animals. Despite not being infected by trematodes in the analyzed sample, *M. tuberculata* requires continuous monitoring, as it can act as a vector for pathogenic helminths.

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