Reflex of urban space changes and climate conditions in *Biomphalaria glabrata* population dynamics on potential schistosomiasis foci in Sergipe state, Brazil

Reflexo das mudanças do espaço urbano e das condições de clima na dinâmica populacional de *Biomphalaria glabrata* em potenciais focos de esquistossomose no estado de Sergipe, Brasil

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To understand better the space-disease process of urban schistosomiasis mansoni in northeastern Brazil, this study assessed four sites considered to be potential foci in municipality of Aracaju, Sergipe. Molluscs were collected monthly between January to December 2010, were assessed for species and infection, quantified, and measured; rainfall data were obtained; and water samples were analysed for faecal coliform. The specimens collected were identified as *Biomphalaria glabrata*. At all sites, we observed high levels of faecal coliforms. The sanitation projects within the Coqueiral and Japãozinho neighbourhoods positively influenced population of *B. glabrata*. A similar phenomenon occurred in the Soledade neighbourhood, where a portion of the study site was excavated for building construction. A total of 2,445 molluscs were collected and positive for *Schistosoma mansoni* was generally higher in the rainy season. The size of the molluscs clams was influenced by rainfall differently in each collection point. Rainfall associated with human actions influence the dynamics of the focus during the study period, showing that schistosomiasis is well established in Aracaju urban environment. This occurs due mainly to *Biomphalaria* adaptation capacity changes caused by man associated with poor sanitation, which facilitate the installation of breeding.
Keywords: urban esquistosomiasis, sanitation, *Biomphalaria*

Para melhor compreensão do processo espaço-doença da esquistossomose urbana no nordeste do Brasil, este estudo avaliou quatro áreas consideradas como potenciais focos de transmissão da esquistossomose no município de Aracaju, Sergipe. Os moluscos foram coletados mensalmente, entre janeiro a dezembro de 2010, foram avaliados quanto à espécie e infecção, quantificados e medidos; dados de precipitação foram obtidos; e amostras de água foram analisadas para coliformes fecais. Os espécimes coletados foram identificados como *Biomphalaria glabrata*. Em todos os locais, observaram-se níveis elevados de coliformes fecais. Os bairros Coqueiral e Japãozinho receberam obras de saneamento que demonstraram influenciar positivamente o controle populacional de *B. glabrata*. Fato semelhante ocorreu no Bairro Soledade que teve parte da área de estudo aterrada para construção de imóveis. O quantitativo elevado de 2.445 moluscos coletados e a positividade para *Schistosoma mansoni* foram em geral maiores no período chuvoso. O tamanho dos moluscos foi influenciado pelo regime de chuvas de forma diferenciada em cada ponto de coleta. A pluviosidade associada às ações antrópicas influenciaram na dinâmica dos focos durante o período de estudo, mostrando que a esquistossomose se encontra bem estabelecida no ambiente urbano de Aracaju. Isso ocorre devido, principalmente, a capacidade de adaptação de *Biomphalaria* as mudanças provocadas pelo homem associadas ao saneamento precário, que facilitam a instalação dos criadouros.
Palavras-chave: esquistossomose urbana, saneamento, *Biomphalaria*

1. INTRODUCTION

Intestinal schistosomiasis, also known as schistosomiasis mansoni, is an infection in humans caused by the *Schistosoma mansoni* (Sambon, 1907) trematode, which has exhibited high prevalence in developing countries over the past few decades. The spread of this infection may function as an indicator of socioeconomic status, due to its relationship with a given population's poverty and cultural habits coupled with the growth of peripheral areas with poor or non-existent sanitation [1, 2, 3].

A favourable environment for the intestinal schistosomiasis cycle primarily consists of freshwater basins, intermediate hosts, and definitive infected hosts. Initially considered a rural endemic in Brazil, *Schistosoma mansoni* now exhibits high prevalence and an expanded range, probably due to individuals' being displaced from endemic areas as a result of exodus and rural tourism. In contrast, the permanence and establishment of new transmission foci are closely linked to poor socio-environmental conditions and the presence of the *Biomphalaria* mollusc [4, 5, 6, 7, 8].

This new phase of schistosomiasis is the product of human waste contamination in both natural and artificial streams and canals in urban areas as a result of uncertain sanitary conditions and the presence of intermediate hosts at these sites [9, 10].

Brazil is a major focus for schistosomiasis mansoni in Latin America, which currently covers 19 states. Brazil has a population of approximately 26 million people who are exposed to the risk of infection and approximately 2.528 million infected individuals [11, 12, 13].

In northeastern Brazil, schistosomiasis mansoni is widely distributed in both rural and urban areas. This situation is also observed in the city of Aracaju, the capital of Sergipe State, Brazil, primarily because it consists of flat terrain, which favours formation of temporary or permanent basins that can serve as breeding sites for the mollusc vector. These characteristics, along with precarious basic sanitary conditions and lack of health education, allow for the establishment/maintenance of the transmission cycle in these areas [14, 15].

The urbanisation of given infectious and parasitic diseases in a rural context and the rise of diseases considered to be controlled in cities have been subjects of concern that have been studied by various health institutions. *Schistosoma mansoni* infection is among the most prevalent waterborne diseases. The prevention and control schistosomiasis mansoni in urban areas requires different approaches from those used in rural areas, specifically, approaches that consider different forms of occupation and the transformation of the physical environment, as well as how the population comes into contact with the disease [16, 17, 18].

Thus, this study aimed to assess how changes in the urban space and climate conditions affect *Biomphalaria glabrata* population dynamics at potential schistosomiasis foci in the city of Aracaju, SE, Brazil.

2. MATERIAL AND METHODS

The study was conducted in Aracaju, the capital of Sergipe State, Brazil, located in northeastern Brazil with a population of 571,149 inhabitants [19]. The study sites were defined according to background information on the presence of molluscs of the genus *Biomphalaria* that was provided by the Schistosomiasis Control Programme (Programa de Controle da Esquistossomose - PCE) within the city and was based on positive diagnosis for schistosomiasis in the city population. Molluscs were sampled in the following neighbourhoods: Aruana, Coqueiral, Japãozinho, and Soledade (Figure 1).
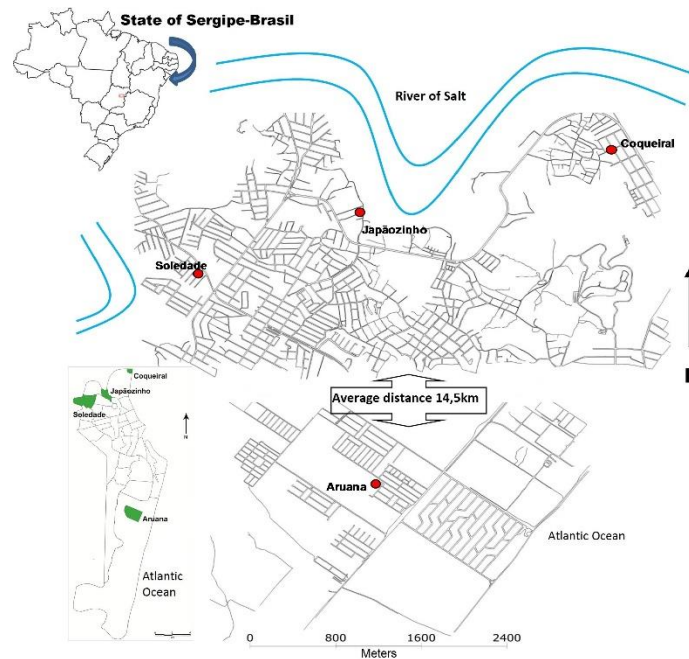
Figure 1: Location of the neighbourhoods (red dots) that were used for Biomphalaria mollusc sampling in the urban area of Aracaju, Sergipe State, Brazil, 2010. Source: TerraView software version 3.6.0.

The Aruana coastal region is located in southern Aracaju and is considered to be an expansion zone and is primarily occupied by recent real estate development [20]. Most public routes have sidewalks, and there are no open sewers or ditches. Stormwater is captured from the streets by a drainage system and directed to channels that are connected to specific chambers for this purpose. Several permanent ponds are found in this neighbourhood that are influenced by rainfall.

In the Coqueiral neighbourhood, the major routes are paved and have drainage and basic sanitation systems; however, when moving away from the main avenue, there is lack of basic sanitation, and domestic sewage is released into shallow ditches located along public routes and discharged into uncovered culverts. The Japãozinho neighbourhood is located on the border between the cities of Nossa Senhora do Socorro and Aracaju in the estuarian region of the Rio do Sal (Sal River), a tributary of the Rio Sergipe drainage basin. The sampling point is close to a mangrove site; it is a natural water collection area, where ditches discharge medical waste due to the lack of a sewage system. The basin studied in the Soledade neighbourhood, located in the northern Aracaju region, is characterised by being below street level and covered by vegetation (field observations).

Molluscs were collected using M80 sieves by two people for one hour each month from January to December 2010 in the morning period. Subsequently, the molluscs collected were cleaned under running water and counted, their shell diameters were measured, and they were later placed in aquariums.

To determine infection, molluscs obtained in the field were exposed to light en mass for a 2-hour period to verify the elimination of cercariae. In groups in which the presence of cercariae was positive, the molluscs were individually exposed to light for positive identification. The negative molluscs were exposed once per week for three weeks.

Molluscs were taxonomically identified by dissecting specimens from each sampling point, chosen at random according to Barbosa (1995) [21].

To determine faecal and thermotolerant coliforms, water was collected at the sites once at the end of the dry season (March) and a second time at the end of the rainy season (July). In the case of urban areas with precarious sanitation, the presence of these organisms shows the risk that this material is coming from human feces, which would increase the probability of having eggs of *S. mansoni* eliminated by infected humans. Water was collected in sterile containers and analysed by the multiple tube method [22, 23]. The faecal and thermotolerant coliform levels

were analysed and compared with the limits set by the CONAMA 357 resolution of March 2005, which provides information on freshwater class III.

Rainfall data were obtained from the Department of Water Resources of Sergipe State (Secretaria de Recursos Hídricos do Estado de Sergipe - SRH-SE), which defines the rainfall distribution during the following three periods: January, February, and March are considered to be low rainfall (pre-rainy); April, May, June, and July are considered to be higher rainfall (rainy); and the other five months have low rainfall (post-rainy).

The study sites were defined by marking with GPS coordinates, and data for each were entered into a database.

Data were analysed using Statistica software, version 7.0. One-way ANOVA was used followed by Tukey's test to test for differences between the monthly diameters and by rainfall regime, considering a 5% significance level.

3. RESULTS

The internal morphological structures of specimens from all collection points were assessed such that *Biomphalaria glabrata* specimens could be identified. During the experimental period, 3,842 mollusc specimens were collected, of which 45 (1.17%) were positive for *S. mansoni* infection. Of the basins studied, only the one in the Aruana neighbourhood can be considered permanent, whereas in the other neighbourhoods, samples were taken where water accumulates product, primarily when there is lack of sanitation. Aquatic macrophytes were observed at all sampling points, and the rate of mollusc infection by *S. mansoni* at the sampling sites ranged from 0 to 1.4% (Table 1).

Table 1: Environmental parameters observed in four schistosomiasis foci in the city of Aracaju, Sergipe State, Brazil, 2010.

Parameters	Aruana	Coqueiral	Japãozinho	Soledade
Type of basin /breeding site	Permanent	Temporary	Temporary	Temporary
Faecal contamination rate (nmp/100 ml)*	Dry Season			
	2.4×10^3	5.4×10^3	5.4×10^5	3.5×10^2
	Rainy Season			
	2.8×10^5	1.9×10^9	4.9×10^7	4.9×10^7
Characteristic vegetation	Aquatic macrophytes			
Mollusc positivity rate	1.2% (5)	1.4% (20)	0% (0)	1.2% (20)
Paving of public routes	Asphalt and cobblestone	Asphalt, cobblestone, and tiles	Cobblestone and tiles	Asphalt and tiles

* Reference value - CONAMA Freshwater Class III - 2.5×10^2 nmp/100 ml.

At the Aruana neighbourhood sampling site (37°4'54.647" W/ 11°0'36.240" S), molluscs only began to be observed at the onset of the rainy season (Figure 2), even though as a permanent basin, the water level is dependent on rain, and certain areas of the pond remain dry during certain periods of low rainfall. Significant differences were detected between the mean shell diameters of molluscs collected in different months. Infected molluscs were detected from this site during the rainy and post-rainy periods (Table 2). Water analysis during the dry and rainy seasons revealed values of 2.4×10^3 nmp/100 ml and 2.8×10^5 nmp/100 ml faecal coliforms, respectively (Table 1).
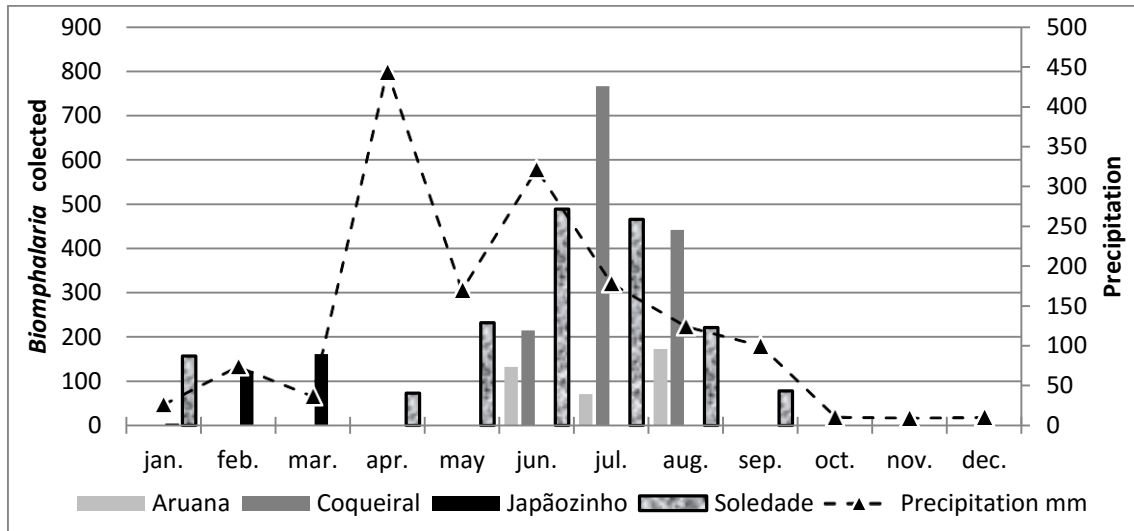
Figure 2: Rainfall (mm³) and total number of Biomphalaria captured monthly in neighborhoods Aruana, Coqueiral Japãozinho and Soledade, localized in the urban area of the municipality of Aracaju, Sergipe State, Brazil, 2010.

In the Coqueiral neighbourhood (37°3'15.769" W/10°52'24.673" S), the molluscs were collected in open ditches in which water runs down the street's entire length. Of the 1,422 molluscs collected, 20 (1.4%) were collected during the rainy season and were positive for *S. mansoni*. The highest mean diameter of 13.3±2.4 mm was recorded during the post-rainy period (Table 2).

During the survey period, in different opportunities egg clutches were observed in vegetation and garbage from different sources that were located in water collections, especially in rainy periods associated with the presence of molluscs.

*Table 2. Abundance (frequency) of collected, infected and diameter of molluscs per sampling point in neighbourhoods within the city of Aracaju (January to December 2010), by rainfall regime. *PP: pluviometric precipitation (accumulated), MD: mean diameter, ***Not applicable.*

Assessment parameters	Neighbourhoods				
	Aruana	**Coqueiral**	**Japaozinho**	**Soledade**	**Total**
Pre-rainy (PP = 139.2 mm)					
Nº· molluscs collected	-	-	288 (100%)	157 (9.2%)	445 (11.6%)
Nº· positive molluscs	-	-	-	-	-
MD (mm)	-	-	12.7±2.7	20.1±2.7	***
Rainy (PP = 1,116.6 mm)					
Nº· molluscs collected	203 (48.8%)	982 (69.1%)	-	1,260 (73.4%)	2,445 (63.6%)
Nº· positive molluscs	2 (0.98%)	20 (2%)	-	14 (1.1%)	36 (6.8%)
MD (mm)	13.6±2.6	12.8±2.7	-	12.4±2.7	***
Post-rainy (PP = 261.1 mm)					
Nº· molluscs collected	213 (51.2%)	440 (30.9%)	-	299 (17.4%)	952 (24.8%)
Nº· positive molluscs	3 (1.4%)	-	-	6 (2%)	9 (17.7%)
MD (mm)	12.3±2.5	13.3±2.4	-	10.9±2.2	***

However, sanitation projects that were halted during the rainy season left many drains in the streets open to heavy traffic, causing the accumulation of rainwater and sewage that helped re-establish *B. glabrata* breeding. Water analysis from this sampling point revealed high faecal contamination during the dry and rainy seasons (Table 1).

In the Japãozinho neighbourhood (37°4'21.216" W/10°52'43.877" S), 288 molluscs were collected during the pre-rainy period only (Figure 2; Table 2). There were no molluscs that were positive for *S. mansoni*. Improvement projects were undertaken at this sampling point, which included projects involving sewage, storm water drainage, pavement with cobblestones, sidewalk construction, and filling in of the land on which the studied basin was located.

Water analysis revealed high levels of water contamination during the dry (5.4×10^5 nmp/100 ml) and rainy seasons (4.9×10^7 nmp/100 ml) (Table 1).

In the Soledade neighbourhood (37°5'5.056" W/10°53'1.738" S), samples were collected in trenches located along the street edges and on land that accumulates rainwater or sewage from residences. During the study period, 1,716 molluscs of the genus *Biomphalaria* were collected (Figure 2), and of these molluscs, 20 (1.16%) were positive for *S. mansoni*. During the rainy season, 73.4% of all molluscs were collected, of which 1.1% were infected with *S. mansoni*, whereas infected molluscs were not found during the pre-rainy period (Table 2).

In analysing the accumulated rain water during the dry season, a value of 350 nmp/100 ml was obtained for faecal coliforms, which is below the value recommended by CONAMA. However, this finding was not observed during the rainy season when the value was on the order of 4.9×10^7 nmp/100 ml (Table 1).

With respect to the body size of *B. glabrata* collected in the Aruana and Coqueiral neighbourhoods, molluscs exhibited diameters ranging from 12.3±2.5 mm (post-rainy period) and 13.6±2.6 mm (rainy period) with a peak growth in July (14.9±2.8 mm).

While mollusc body development followed a downward trend during the post-rainy period for the Soledade and Aruana neighbourhoods, there was a trend of increased diameter for the Coqueiral neighbourhood. It was not possible to observe mollusc shell diameter during the different periods for the Japãozinho neighbourhood.

At the schistosomiasis focus in the Japãozinho neighbourhood, there were significant differences (p<0.05) in mollusc body size between January to March 2010, the period during which it was possible to sample the molluscs. However, after March 2010, molluscs were no longer found due to the sanitation projects carried out on the site.

4. DISCUSSION

In Brazil, the sustainable development indicators of sanitation, urban drainage, and water supply still represent a challenge for the country. The low coverage of a portion of these services, such as sewage treatment, explains the high number of hospitalisations due to sanitation-related diseases and the persistence of such diseases as schistosomiasis. Collecting domestic sewage undoubtedly brings significant improvement to the environmental quality of the immediate surroundings of homes; however, it is not enough to eliminate the harmful environmental effects arising from the contamination of water bodies [24]. Although northeastern Brazil has experienced a substantial gain in the treatment of domestic sewage on the outskirts of major cities such as Aracaju, the situation is still precarious.

The northern region of Aracaju has physical environmental conditions that favour the formation and maintenance of active schistosomiasis foci. The proximity to higher-salinity regions has not been shown to be a barrier for the development and proliferation of molluscs as intermediate hosts and infection by *S. mansoni*. *B. glabrata* specimens have been found surviving in waters with salinity 15 times higher than the maximum acceptable for freshwater habitats [25]. Molluscs were sampled by collecting water that resulted from a lack of sanitation, and the collected water was strongly influenced by rainfall. Aquatic macrophytes that may serve as a substrate for the reproduction and protection of spawning molluscs were observed in all sampling sites [26].

In the only sampling site considered a permanent water collection area, the molluscs were only observed after the onset of the rainy season, whereas rain scarcity most likely caused mollusc aestivation until appropriate environmental conditions were present [27, 28]. In contrast, sites with deeper pond depths have more fish, such as "traíra" and tilapia, that may include molluscs as part of their diet, thereby hampering the detection of *Biomphalaria* during months with lower rainfall. It is important to note that fish can be used as a means of controlling the mollusc population [29]. Increased pond levels during the rainy season could also allow molluscs to find better shelter from possible predators (fish), especially in areas with higher concentrations of plants that serve as substrates for feeding, locomotion, and fixing spawns.

In the Aruana neighbourhood, faecal coliform rates were considered high, although the neighbourhood has good sanitation conditions; however, the pond in question includes passages for swimmers from other neighbourhoods heading to the beach, and they often use the pond to shower and perform other activities. Schistosome infection of individuals in basins populated by *B. glabrata* near beaches has been observed in other coastal regions of northeastern Brazil [30].

In the Coqueiral neighbourhood, during the study period, drainage and rainwater sewage system projects were undertaken at the site. Construction began in November 2009 when a portion of the open ditches were thoroughly cleaned and several were removed. This occurred primarily during the pre-rainy period, which may explain the lack of detection of molluscs from January to May. This fact was most evident starting in September when the projects were resumed at an accelerated rate because of rain-related delay. However, halted sanitation projects during the rainy season left many ditches in the streets open to heavy traffic, allowing the accumulation of rainwater and sewage that helped re-establish *B. glabrata* breeding sites. This scenario may temporarily affect the pattern of human risk for schistosome infection, including those who live and work in the area. It is noted that sanitation projects have positive effects on combating intestinal parasites, such as waterborne diseases or those that depend on water to develop their life cycle [25, 31].

In the Japãozinho neighbourhood, although the study site had lost its schistosomiasis focus characteristics due to the absence of molluscs after sanitation projects, it continued accumulating water during rainy periods and showed high levels of faecal contamination. Thus, the site remains a risk area from the standpoint of public health. Drainage projects and the installation of a sanitary sewage system were effective in neutralising *B. glabrata* breeding; however, projects only have this effect when fully completed, as breeding reappeared during their development or soon after. Thus, planning the execution of infrastructure projects is extremely important to prevent creating environments that enable the establishment and reproduction of vectors not only of schistosomiasis but also of other diseases [32].

In contrast, sanitation projects must necessarily be accompanied by general improvement to the infrastructure of streets and sidewalks, as these locations can lead to the establishment of new breeding sites when water accumulates during the rainy season. Vacant lots that accumulate water, especially during the rainy season, were also sites conducive to the establishment of schistosomiasis-transmitting mollusc breeding sties. Buildings occupying this land proved effective at neutralising mollusc breeding sites, as did filling the sites.

Faecal coliform rates above the levels recommended by CONAMA indicate a much greater risk of contamination for both molluscs present at the site and people who come into contact with the local water [33]. Contact with contaminated water mostly occurs during the rainy season, when gutters overflow and their water accumulates in the streets or drains into unoccupied land or land under construction. In extreme situations, excess rainfall has caused residential flooding, which further compromises the population's health.

Similar to sampling points in the Japãozinho and Coqueiral neighbourhoods, the sampling point located in the Soledade neighbourhood received numerous anthropogenic actions throughout the sampling period. Lots that were unoccupied before and that accumulated water during the rainy season were gradually filled, and brick houses subsequently were erected, thereby disrupting the favourable environment for *B. glabrata* development.

The sampling point in the Soledade neighbourhood proved to be dependent on rainfall regimes and can be characterised as a temporary breeding site for *B. glabrata*, while breeding

sites found in the Coqueiral neighbourhood were more dependent upon water from sewage or rain catchments that were poorly constructed by the population.

Mollusc body measurements were significantly affected by rainfall ($p<0.05$). In Aruana, the biggest mean shell diameter (13.6 ± 2.6 mm) was recorded during the rainy season, which is most likely due to the lower number of molluscs found in this sampling. A lower number of molluscs would reduce intraspecific competition for food and space [34, 21]. The differences in the diameter of molluscs in different locations and sampling periods (as previously reported by other authors) can be explained by anthropogenic and climate influences and showing molluscs populations in various stages of development [15].

Schistosomal foci in the Coqueiral, Japãozinho, and Soledade neighbourhoods were located in sites bordering mangroves and the Rio do Sal (Salt River) (Figure 1). The influence of rivers on *Biomphalaria* distribution was studied in a city affected by the São Francisco River in Minas Gerais State, Brazil. Determined mollusc distribution, thus defining the areas that are possibly at risk for schistosomiasis transmission [35]. At the sites mentioned above, the river contributes to spreading snails in the rainy season, thereby increasing the risk for the population.

Disorderly occupation has been one of the anthropogenic activities that most contributes to disease development in urban areas. However, appropriate structuring of urban areas has proven to be a long-lasting solution for these and other problems. It becomes increasingly necessary to implement plans to manage and distribute urban areas such that future human installations can be created without harming the population.

Within the setting of the four sampling points studied, there is a notable need for the control of schistosomiasis transmission with actions beyond diagnosis and treatment; the WHO is already stressing the importance of health education and improved sanitation conditions for controlling this disease [31]. Emphasise that anthropogenic alterations that cause pollution of the aquatic environment, such as garbage and sewage, are an important source of organic matter for developing molluscs that serve as schistosomiasis vectors, which was observed in the sampled basins at the sites studied [36].

Have warned of the need for government action involving the following factors: basic sanitation and drinking water projects, health education, and combating snails [37]. The sanitary projects performed in three of the four schistosomiasis foci in Aracaju evidently shows the potential for interrupting the schistosomiasis transmission cycle through engineering for malacological control. This was specifically observed in Japãozinho, where after completing the drainage and sewage projects, the presence of *B. glabrata* was no longer detected.

5. CONCLUSIONS

The study focused on urban regions that have high schistosomiasis prevalence rates and is an important tool for developing measures for preventing and controlling this parasitosis. In addition to diagnosis and treatment, research should involve studies on climate, structural health, malacology, and street infrastructure to define specific actions for each location that are aimed at minimising the population's risk of infection.

6. ACKNOWLEDGMENTS

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