Mapping the risk for transmission of urban schistosomiasis in the Brazilian Northeast

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Abstract

This is an analysis of the risk of schistosomiasis transmission in the city of Recife in the Northeast of Brazil based on the number of schistosomiasis cases (Schistosoma mansoni) registered for the period 2007-2017 together with data resulting from active search of breeding sites of the Biomphalaria snail intermediate host. The analyses were performed using Kernel Density Estimation (KDE), SaTScan and Map Algebra methodology using human socio-demographic data and biotic and abiotic data from the snail breeding sites. Investigating 44 breeding sites resulted in a total of 3,800 snails, 31.8% of which were positive for S. mansoni DNA. These data were considered in relation to total of 652 schistosomiasis cases. The KDE showed two high-risk and two medium-risk clusters, while three significant clusters were identified by SaTScan. Combining these data with the Map Algebra methodology showed that all high-risk neighbourhoods had breeding sites with snails positive for S. mansoni. It was concluded that schistosomiasis transmission cannot be controlled without basic sanitation and sewage management in the presence of Biomphalaria snails. The technique of Map Algebra was found to be fundamental for the analysis and demonstration of areas with a high probability of schistosomiasis transmission.

Introduction

Schistosomiasis, caused by various species of the genus Schistosoma, is one of the main parasitic infectious diseases in the tropical world. According to the World Health Organization (WHO), the transmission of this helminth infection currently occurs in 78 countries, 52 of which requires preventive therapy, but due shortages of drug administration only 97.2 million of the 290.8 million needing drug treatment with praziquantel received it as late as 2018 (WHO, 2020). In addition, it is estimated that schistosomiasis is globally responsible for more than 200,000 deaths annually (WHO, 2020). According to the Pan American Health Organization (Organização Pan-Americana da Saúde, OPAS) about 46 million children in Latin America including the Caribbean live in places at high risk of infection or reinfection with helminths transmitted by soil and 25 million people suffer from schistosomiasis (OPAS, 2017).

In Brazil, the number of reported cases of this disease has been increasing in urban areas, such as Belo Horizonte, Salvador and Fortaleza (Guimarães et al., 1993; Guimarães and Tavares-Neto, 2006). It is estimated that in the north-eastern and south-eastern regions of the country, schistosomiasis affects about 1.3% and 2.4% of the population, respectively, and that 25 million humans are exposed to the risk of contracting the disease in the country (Moh, 2014).

The Brazilian state of Pernambuco ranks third with respect to prevalence of schistosomiasis. The cases occur in 102 municipalities, 12.7% of which belong to the metropolitan region of Recife, constituting a serious public health problem because of high prevalence and severity of clinical outcomes. From 1999 to 2013, there were 2,578 deaths due to schistosomiasis and 473 hospitalizations in Pernambuco. From 1999 to 2014, there were 1,943 new schistosomal cases of people born, resident in Pernambuco and Fortaleza (Guimarães et al., 2011; Barbosa et al., 2011; Porto de Galinhas (Gonçalves et al., 1991; Barbosa et al., 2011;
Barbosa et al., 2013), which denotes the failure to control this disease in Pernambuco (Maricato, 2003).

Unplanned urbanization results in socio-spatial inequality, which has been demonstrated in the expanding urban peripheries where it results in spatial and environmental segregation due to creation of regions characterized by poverty (Oliveira et al., 2018). According to the Trata Brasil Institute (Instituto Trat Brasil, ITB), poor water quality, dysfunctional waste disposal and deposition of human excrements pollute the environment due to crowding by workers inhabiting the growing city peripheries with inadequate sanitation which, consequently, leads to proliferation of diseases, such as schistosomiasis (ITB, 2019). Thus, urbanization unassisted by infrastructure investment produces poor areas where sewage and waste are thrown into the peri-domicile (the area around the household) and ending up in canals rather being taken care of in a rational way. This promotes environmental contamination and infection of the snails that live in these canals (Flauzino et al., 2009), which during rains frequently overflow and flush the snails into streets where people easily can become infected (Barbosa et al., 2011).

According to the ITB, Recife is in 77th position among the 100 largest municipalities in the country with respect to basic sanitation (ITB, 2018). The presence of poor people living in inadequate housing structures not far from the intermediate host snails allows the establishment of urban transmission of schistosomiasis (Oliveira et al., 2018). In 2013, autochthonous cases were confirmed in Recife, and although the positive individuals had never left the city, it was not possible to identify the mode of transmission (Barbosa et al., 2013). However, one of the reasons for the occurrence of these cases is due to the combination of the following factors: people with active schistosomiasis, lack of sanitation and the presence of breeding sites with the Biomphalaria intermediate snail host, which together constitute a predictive epidemiological scenario for the introduction and local maintenance of this disease (Barbosa et al., 2013).

Geoprocessing has been efficiently applied in the analysis of environmental data in the search for associations with the occurrence of communicable diseases (Flauzino et al., 2009), while spatial health analysis comprises the study of dynamic disease distribution. The use of Geographical Information System (GIS) has proved to be an important tool for disease control and monitoring. It assists prophylaxis measures and enables a constant assessment of the control measures employed, while providing updated information on the actual epidemiological situation in the geographic space (Barbosa et al., 2017).

Kernel Density Estimation (KDE) and Map Algebra are useful for the production of risk maps for disease occurrence and are already well known for health data analysis (Carvalho et al., 2017; Santos et al., 2016; Santos et al., 2017). KDE demonstrates risk areas by spatial scanning of points that represent health events aiming at identifying potential clusters. It is a non-parametric technique that estimates the intensity of the occurrence of cases in the study area (Barbosa et al., 2017; Carvalho et al., 2017). While kernel mapping by KDE is relatively straightforward, Map Algebra consists of a specialized language with mathematical functions for analyzing geographic data with numerical values, such as those delivered by GIS. It can be used through operative functions applied to one or more quantitative and/or qualitative data layers that can be viewed as individual variables. Established functions are homogeneously applied to points of the map, enabling the identification of risk areas for disease transmission or other occurrences (Tomlin, 1994).

In 2010, a study to map the breeding sites of the city of Recife identified 30 breeding sites of B. straminea, a common intermediate host of S. mansoni in Brazil, four of which were positive for S. mansoni and classified as potential transmission foci. However, no risk analysis for the transmission of schistosomiasis has been performed since then (Barbosa et al., 2013). In light of this, the objective of this study was to update and analyze the risk for schistosomiasis transmission in the city of Recife, Pernambuco, using epidemiological data and the analytic tools mentioned above. Our analysis aimed at describing the spatial patterns of morbidity and the factors associated with these patterns by identification of the relationships between the different environmental variables involved. In this way, we expected to enable a strengthened schistosomiasis surveillance, subsidize planning and expand the health care network.

Materials and methods

Study area

The research was conducted in the city of Recife, capital of Pernambuco, located at the core of the Metropolitan Region (RMR). Recife is divided into 94 neighbourhoods (NHs) and eight health districts (Distrito Sanitário, DS) shown in Figure 1, which present the geographic, demographic and socioeconomic differences in the city. According to the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE), the city has an estimated population for the year 2018 of 1,637,834 inhabitants, with a demographic density of 7,039.64 inhabitants/km² (IBGE, 2018). Recife is located in the tropical area of Brazil at latitude 8° 04’ 03” S and longitude 34° 55’ 00” W (Prefeitura do Recife, 2020).

Data, sources and units of study

This study was composed by the following databases: i) malacological and abiotic data collected in the breeding sites identified in the city of Recife; ii) sociodemographic data obtained from the 2010 IBGE census; iii) residents of the city of Recife infected with schistosomiasis from 2007 to 2017 according to the Brazilian Notifiable Diseases Information System (Sistema Nacional de Agravos de Notificação, SINAN). The study units were the DSs and NHs of the city. The municipal boundary data (DSs, NHs and census tracts) were obtained from IBGE and Recife City Hall. The infectious agent of the study was Schistosoma mansoni, the only schistosome species in Latin America.

Study data were collected in three stages with different foci: i) snail collection and investigation; ii) population and domicile evaluation; and iii) assessment of the number of schistosomiasis cases. This information was grouped by NH and stored in a geographic database (Base de Dados Geográficos, BDG) and then imported into a GIS for analytical procedures.

Stage 1

A malacological survey was carried out from March 2016 to September 2017 to identify intermediate Biomphalaria snail host of S. mansoni, in the water collections of epidemiological importance in Recife. The geographic coordinates of the breeding sites were obtained by a Garmin Montana 650 Global Positioning System.
System (GPS) receiver and transferred to TrackMaker Pro software (Geo Studio Technology, free version 13.9.596), transformed into shapefiles and used in the spatial data analysis.

Snails were collected by the method of Olivier & Schneiderman (1956) observing the technique of man/minute/shell according to the height of the rainwater harvesting. This method consists of tweezers to collect snails on the surface and substrate and a catch shell for the molluscs submerged in water (shell/area) every 15 minutes per breeding site. Later, the snails were packaged, identified and sent to the Laboratory and Reference Service for Schistosomiasis at the Aggeu Magalhães Institute, Oswaldo Cruz Foundation (LRE/IAM/Fiocruz). In the laboratory, 10% of the specimens from each breeding site were randomly selected identifying the Biomphalaria species by genital dissection according to Deslandes (1951). The snails were subjected to light exposure to stimulate cercariae shedding – a method that makes it possible to quantify the intensity of infection (Carvalho et al., 2014) - and finally submitted to molecular testing to identify the parasite DNA using nested polymerase chain reaction (Nested PCR) according to Melo et al. (2006).

The harvesting sites were classified as follows: i) breeding sites – all rainwater harvesting that presented Biomphalaria snails; ii) transmission foci – all breeding sites in which snails were found releasing S. mansoni cercariae; and iii) potential foci – all breeding sites in which S. mansoni-infected snails were found using Nested PCR, meaning that parasite DNA was detected in the intermediate snail host even if it was not releasing cercariae. At each identified breeding site an environmental survey was carried out to obtain the
presence (value = 1 - risk area) or absence (value = 0 - no risk) of the following variables: i) human faeces (presence or absence observed in the water body); ii) vegetation cover (presence or absence on the banks of water bodies); iii) flooding (expansion of local water volume in breeding sites due to the volume of rain); iv) number of snails and v) infected snails (presence or absence of snails infected by *S. mansoni*). The variable number of snails received the values 0 (when the number of snails was <10) and 1 (when >10).

**Stage 2**

For analysis around the residence, the following sociodemographic variables extracted from the 2010 Census (IBGE) were used: i) Home without toilet and with waste water discharge via rudimentary sump, ditch, river/lake/sea or another outflow; ii) Combined household income from none to ½ the minimum wage; iii) Lack of paving (no coverage of public roads with asphalt, cement, cobblestones, stones, etc.); lack of manholes or culvert (without opening allowing access to underground boxes, through which rainwater can flow); iv) Presence of open sewage (trench, stream or body of water where domestic sewage is usually released).

The number of permanent private domiciles was counted in each variable category given above and the sum divided by the total number of domiciles in the area. In this way, each variable could be assigned a value ranging between 0 and 1 where 0 means that the home is non-hazardous for schistosomiasis transmission and 1 meaning completely hazardous in this respect.

**Stage 3**

The data related to schistosomiasis cases of residents of Recife from 2007 to 2017 were obtained from SINAN of the Health Secretariat of Recife. Based on Excel software the following data from the notification form were used for the study: i) confirmed cases of schistosomiasis; ii) municipality; and iii) residential NH.

The aquatic environment is the natural snail habitat. For a transmission cycle to be established and maintained, the presence of an infected individual in this NH is necessary for a period of time to initiate contamination leading to snail infections. The geographic coordinates of the schistosomiasis cases that had been reported in the SINAN were obtained using the site BatchGeo (2020) complemented by the use of the Google Maps/Street View site (Google, 2020) and Brazilian ZIP codes (Código de Endereço Postal, CEP), (CEP, 2020).

**Spatial analysis**

KDE with quartic function was used to demonstrate the behaviour of the point patterns of human schistosomiasis cases reported in the SINAN, as well as for finding breeding site clusters of potential foci of *Biomphalaria* infected with *S. mansoni* based on the snails collected (calculation of density and adaptive radius). The analysis was performed using TerraView software developed by the National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais, INPE; SP, BR Version 4.2.2), a userfriendly GIS interface allowing view and manipulation of both vector and raster data.

### Table 1. Snails collected by neighbourhood in Recife, Pernambuco from March 2016 to September 2017.

| Neighbourhood    | Breeding sites (no.) | Snails collected (no.) | *S. mansoni* DNA detected |
|------------------|----------------------|------------------------|---------------------------|
| Apipucos         | 06                   | 238                    | Yes                       |
| Arruda           | 01                   | 04                     | No                        |
| Barro            | 02                   | 212                    | Yes                       |
| Bongi            | 01                   | 05                     | No                        |
| Campo Grande     | 01                   | 04                     | No                        |
| Casa Forte       | 01                   | 67                     | Yes                       |
| Cidade Universit.| 01                   | 78                     | Yes                       |
| Curado           | 01                   | 101                    | Yes                       |
| Dois Unidos      | 01                   | 133                    | Yes                       |
| Engenho do Meio  | 03                   | 399                    | Yes                       |
| Gaubirá          | 01                   | 03                     | No                        |
| Hipódromo        | 01                   | 04                     | No                        |
| Ibirare          | 09                   | 954                    | Yes*                      |
| Imbiribéia       | 01                   | 62                     | Yes                       |
| Iputinga         | 01                   | 05                     | Yes                       |
| Jardim São Paulo | 03                   | 166                    | No                        |
| Joquiá           | 01                   | 76                     | No                        |
| Mangueira        | 01                   | 48                     | Yes                       |
| Prado            | 03                   | 370                    | Yes                       |
| San Martin       | 01                   | 237                    | No                        |
| Torróes          | 01                   | 526                    | Yes                       |
| Várzea           | 03                   | 38                     | No                        |
| Vasco da Gama    | 01                   | 70                     | No                        |
| Total            | 44                   | 3,800                  | 14 positives              |

*Two breeding sites were found in this NH and both were positive.*
Quartic KDE creates a smooth surface of the variation in the density of point events across an area and calculates weights for each point within the kernel’s radius, resulting in those points closer to the centre receive a higher weight and therefore contribute more to the cell’s total density value (Eck et al., 2020). The KDE is a non-parametric, interpolative, statistical technique that allows the estimation of the event intensity by counting all points within a region of influence across the entire area, even in regions where the process has not caused any actual occurrence. Weighting events by distance from each other and the location of interest provides visual recognition of hotspots without changing local characteristics (Barbosa et al., 2017).

To perform spatial scanning of the data of breeding sites and schistosomiasis cases, the SaTScan software (version 9.6.1) was applied using the discrete poisson model (positive cases/population) and relative risk. This approach analyzes spatial, temporal or...
spatiotemporal data to detect spatial clusters and verify if they are statistically significant, and the relative risk is used to determine whether a particular location and/or time has a greater or lesser risk of a known event occurring (Kulldorff, 2018).

To identify the risk in each NH, the Map Algebra methodology was used. This tool summarizes the values of ten variables, five variables surveyed in the field and five census sectors of the IBGE for each NH and the combination (sum = Risk, which is represented as R) of the total values of the variables selected for the creation of a choropleth map of risk situations for schistosomiasis transmission. The representations of the values of the classes varied from no risk (0) to very high risk (10) with different levels symbolized by different colours as seen in Figure 4. Map Algebra was performed using ArcGIS 10.3 software (version 10.3).

Results

Forty-four breeding sites were identified in the city of Recife, from which a total of 3,800 snails were collected (Table 1). These sites (waterhole, dam, ditch, canal, stream or natural lake) were located in the peri-domestic of the NHs, 93.3% of which lacked correct sewage for the disposal of human waste, which then results in faecal contamination of the environment.

All snails collected were examined by the classical light exposure technique for potential release of *S. mansoni* cercariae and found to be negative. Breeding sites were investigated in the NHs of Recife (94), identifying them in 24.5% of all (23).

Thus, all samples collected *Biomphalaria* specimens were also examined by Nested PCR to verify the presence of *S. mansoni* DNA at each site. Out of the 44 breeding sites identified in this study, 14 (31.8%) were found to be positive for *S. mansoni* and the lowest in DS II in Arruda/14,530 residents (0.6)

Table 2. Distribution of neighborhoods and number of residents in Sanitary Districts (Distrito Sanitário, DS) III, IV, V and VIII with the presence of snail breeding sites that transmit schistosomiasis in the municipality of Recife.

| DS III (municipality/no. of residents) | DS IV and DS V (municipality/no. of residents) | DS VIII (municipality/no. of residents) |
|----------------------------------------|-----------------------------------------------|----------------------------------------|
| Alto do Mandaí/4,655                   | Cidade Universitária/818                      | Iburá/50,617                           |
| Parnamirim/7,636                       | Cordeiro/41,104                               | Curado/16,418                          |
| Monteiro/5,917                         | Engenho do Meio/10,211                       | Mustardinha/12,429                     |
|                                        | Prado/11,684                                  | San Martin/25,414                      |
|                                        | Torrões/32,015                                | Jardim São Paulo/31,648                |

Table 3. Distribution of neighborhoods and number of residents in the Sanitary Districts (Distrito Sanitário, DS) IV, V and VIII with the presence of snail breeding sites that transmit schistosomiasis in the municipality of Recife.

| DS IV (municipality/no. of residents) | DS V (municipality/no. of residents) | DS VIII (municipality/no. of residents) |
|---------------------------------------|--------------------------------------|----------------------------------------|
| Cidade Universitária/818              | Curado/16,418                        | Cohab/67,283                           |
| Engenho do Meio/10,211                | San Martin/25,414                    | Iburá/50,617                           |
| Torrões/32,015                        |                                      |                                        |

Table 4. Distribution of neighborhood and number of residents in the Sanitary Districts (Distrito Sanitário, DS) IV, V and VIII with the presence of snail breeding sites that transmit schistosomiasis in the municipality of Recife.

| DS IV (municipality/no. of residents) | DS V (municipality/no. of residents) | DS VIII (municipality/no. of residents) |
|---------------------------------------|--------------------------------------|----------------------------------------|
| Torrões/32,015                        | Curado/16,418                        | Cohab/67,283                           |
|                                      |                                      | Iburá/50,617                           |
cases/100,000 inhabitants). Curado/16,418 residents in DS V also had a low prevalence. No cases were registered in the 19 districts covered by DS I, II, III, V and VII.

With respect to the case prevalence presented by by KDE (Figure 3D), two high-risk clusters in DS I (Santo Amaro/27,939 residents, Santo Antônio/285 residents and São José/8,688 residents) were identified. In addition, two medium-risk clusters in DS IV (Várzea/70,453 residents and Caxangá/9,634 residents) and DS VIII (Ibura/50,617 residents) were noted. For these DSs (I, IV and VIII), spatial analysis using SaTScan software identified a significant cluster in each.

A purely spatial analysis of the distribution of schistosomiasis cases by SaTScan and the Discrete Poisson model identified 3 clusters (marked with blue circles in Figures 3D and 4C), which had significant P-values, with the following Relative Risk (RR): 2.39 in the largest cluster; 3.18 in the smallest cluster and 5.00 in...
the medium sized cluster. These three significant clusters encompassed 14 NHs in six DSs as shown in Table 6. The results in this analysis indicate that the risk for schistosomiasis was 2.39; 3.18 and 5.0 times higher for those living in the respective areas identified by the clusters (blue circles in the Figures 3D and 4C) compared to residents of other areas in the municipalities.

The application of Map Algebra with the variables of the census sectors of IBGE (waste water discharge and income as well as presence of paving, manholes and open sewage) and the information obtained in the field by the LRE-IAM/Fiocruz (vegetal cover, presence of faeces, flooding, number of snails, number of infected snails) as seen in Figure 4. The outcome of these investigations resulted in maps showing the variables of the census sectors of IBGE (Figure 4A); information obtained in the field by LRE-IAM/Fiocruz (Figure 4B); summation of the data from Figures 4A and 4B (Figure 4C), the latter also highlighting the three statistically significant agglomerations identified by SaTScan.

The map with the IBGE data (Figure 4A) is relatively homogeneous, generally with the low-risk NHs in West (green) and the medium-risk ones in the East (yellow) for most of the eastern NHs in the city of Recife. Only the Recife NH (DS I) showed no transmission risk (white). The risk distribution according to the LRE-IAM/Fiocruz (Figure 4B) showed eight medium risk NHs (yellow); three high risk NHs (orange); and eight very high risk NHs (red), (Table 7). Only one NH (Vasco da Gama/31.025 residents - DS VII showed low risk (green) while all remaining NHs were without risk (white).

By combining the information provided by IBGE and that provided by LRE-IAM/Fiocruz, a new risk map (Figure 4C) was generated, which shows a decrease in the environmental risk for schistosomiasis with very high risk NHs now had moved to only high risk; while Prado - DS IV moved even further - from very high to medium risk.

Discussion

The findings of this study identified the existence of a large number of breeding sites with the presence of B. straminea (n=44), many of which included infected snails (n=14) that were therefore considered potential schistosomiasis transmission foci. Indeed, research transmission of schistosomiasis in urban areas is reported to have become more frequent (Santos et al., 2016), particularly after the rainy season when flooded streets provide expansion of the breeding sites to also other locations favouring the emergence of new transmission foci (Leal-Neto et al., 2013; Gomes et al., 2016). These flood situations, which are common in the city of Recife, thus expose the population to a higher risk of schistosomiasis transmission than before (Barbosa et al., 2013).

The geoprocessing tools used in this research were fundamental to determine the risk areas for schistosomiasis transmission in the capital of Pernambuco. For example, as seen in Figures 2 and 3, the spatial analysis based on KDE not only showed high-intensity clusters of snail breeding sites in DS VIII but also indicated a high number of schistosomal cases. This corroborates the risk of ongoing disease transmission in Recife, which has been shown in Lauro de Freitas in Bahia by Cardim et al. (2011) and in the locality of Nova Tiúma Municipality of São Lourenço da Mata, Pernambuco by Galvão et al. (2010) in a similar way.

In the analysis of the environmental data of the breeding sites obtained by the LRE/IAM-Fiocruz (Figure 4B), it was observed...
that districts found to be classified as of high risk for schistosomiasis transmission are low-income housing settlement areas partly belonging to the special zones of social interest (Zonas Especiais de Interesse Social, ZEIS), (Prefeitura do Recife, 2019). Schistosomiasis is a disease determined by environmental and behavioural factors related to vulnerable population and as Recife generally has low rates of sanitary conditions, with 65% of the population lacking access to a sewage system (ITB, 2013), the high risk for schistosomiasis is understandable.

In the analysis of the situation with the Map Algebra methodology, it was observed that the risk map of Recife became more heterogeneous compared to the IBGE map with the sociodemographic data (Figure 4A) when the malacological and abiotic data obtained in the field research were added (Figure 4B). We noted the greater risk for schistosomiasis transmission in the NHs of Torrões, Prado, Curado, Jiquiá, Barro, Iputinga, Dois Irmãos, Casa Forte, Cidade Universitária and Jardim São Paulo, which demonstrates the importance of collecting environmental data in the snail breeding sites in order to determine the risk more accurately.

When analyzing IBGE and LRE-IAM/Fiocruz data together (Figure 4C) most NHs located in these areas the risk was shown to have decreased with regard to environmental influence in the transmission of the disease from very high (LRE-IAM/Fiocruz) to only high (IBGE variables). The combination of these data visualized a more realistic environmental situation as it analyzed the global sanitation data by NH and the environmental conditions found in the breeding sites. In addition, as we were working with census data by NH (average of data from the IBGE census sectors), it became less pronounced. IBGE data are important for the study, as they are standardized throughout Brazil and makes it possible to reproduce the study in other areas (municipalities, states) without the cost of field work. By overlapping the combined IBGE and LRE-IAM/Fiocruz data with statistically significant cases obtained through cluster analysis by SaTScan (Figure 4C), it was observed that the cluster with the highest RR (5,0) was located in the Iputinga NH (DS VIII), a place that presented high environmental, sociodemographic and malacological risk. Based on these findings, the need for greater attention for surveillance and control actions of

Table 5. Distribution of schistosomiasis cases by neighborhood and number of residents in the Sanitary Districts (Distrito Sanitário, DS) I, II, IV, V, VI, VII and VIII in the municipality of Recife.

| DS I (municipality/no. of residents) | DS II (municipality/no. of residents) | DS IV (municipality/no. of residents) | DS V (municipality/no. of residents) | DS VI (municipality/no. of residents) | DS VII (municipality/no. of residents) | DS VIII (municipality/no. of residents) |
|-------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|---------------------------------------|---------------------------------------|
| Santo Amaro/27,939                  | Campo Grande/32,149                  | Engenhoc de Meio/10,211              | Barro/31,847                         | Boa Viagem/122,922                   | Iputinga/52,200                      | Macaé/20,313                         |
| Torrões/1,083                       | Iputinga/52,200                      | Várzea/70,453                        | Nova Descoberta/24,122               | Coelho/87,283                       | Maceió/20,777                        |                                                                                     |
| Água Fria/43,529                    | Iputinga/52,200                      | Várzea/70,453                        | Nova Descoberta/24,122               | Coelho/87,283                       | Maceió/20,777                        |                                                                                     |
| Bomba do Hemetério/8,472            | Torrões/32,015                       | Vaso da Cama/31,025                  |                                                                                     |                                      |                                                                                     |

Table 6. Distribution of neighborhoods and number of residents in Sanitary Districts (Distrito Sanitário, DS) I, II, IV, V, VII and VIII with the presence of a relative risk for schistosomiasis in the municipality of Recife.

| DS I (municipality/no. of residents) | DS II (municipality/no. of residents) | DS IV (municipality/no. of residents) | DS V (municipality/no. of residents) | DS VII (municipality/no. of residents) | DS VIII (municipality/no. of residents) |
|-------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|---------------------------------------|---------------------------------------|
| Santo Amaro/27,939                  | Dois Irmãos/2,566                    | Caxangá/9,634                        | Curado/16,418                        | Guabirá/6,330                        | Iputinga/52,200                      |
| Parnamirim/7,636                    | Cidade Universitária/818             |                                      |                                      |                                      |                                      |
| Sítio dos Pontos/7,276               |                                     |                                      |                                      |                                      |                                      |
| Engenhoc de Meio/10,211              |                                      |                                      |                                      |                                      |                                      |
| Iputinga/52,200                      |                                      |                                      |                                      |                                      |                                      |
| Várzea/70,453                        |                                      |                                      |                                      |                                      |                                      |

Table 7. Risk classification for schistosomiasis in the neighborhoods and number of residents by Health Districts (Distrito Sanitário, DS) of the municipality of Recife.

| Medium risk NHs (municipality/no. of residents) | High risk NHs (municipality/no. of residents) | Very high risk (municipality/no. of residents) |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Arruda/14,530                                 | DS II                                         | Parnamirim/7,636                              |
| Hipódromo/2,658                               | DS II                                         | DS III                                        |
| Casa Forte/6,750                              | DS III                                        | DS IV                                         |
| Cordeiro/41,164                               | DS IV                                         | DS V                                          |
| Engenhoc de Meio/10,211                       | DS IV                                         | DS VI                                         |
| Várzea/70,453                                 | DS IV                                         | DS VIII                                       |
| San Martin/25,144                             | DS V                                          |                                               |
| Guabirá/6,330                                 | DS VII                                        |                                               |
The presence of Biomphalaria snails are prerequisites for the transmission of S. mansoni, increasing the risk factors for its occurrence. The Map Algebra analysis technique turned out to be fundamentally important as it demonstrated places with a high probability of schistosomiasis transmission. Such findings may assist managers in the elaboration of health planning in disease control actions.

Conclusions

As demonstrated in this paper, both primary and secondary data as well as the use of spatial analysis tools are of fundamental importance to locate high-risk areas for transmission of schistosomiasis when considering the environmental, human and malacological aspects. These tools provide facts that are necessary for the planning of control actions in a timely manner, enabling the expansion of disease surveillance in areas where populations are vulnerable in different regions and environments where

The lack of basic sanitation, faecal contamination of water and

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