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Major Article

Schistosomiasis in the Middle Paranapanema river region, state of São Paulo, Brazil: Does it matter today for public health?

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Abstract

Introduction: The Middle Paranapanema watershed is known for the transmission of schistosomiasis, and there have been autochthonous cases since 1952. This study aimed to describe this disease in space and time and evaluate its current importance as a public health problem. **Methods:** Thematic maps showing the risk areas for transmission of schistosomiasis, using scan statistics, and flow maps were created in the period 1978–2016. Incidence was calculated, and the existence of spatial dependence between autochthonous and imported cases was evaluated using Ripley's K12-function. Species of snails were identified in high-risk clusters. **Results:** A total of 1,511 autochthonous cases were reported in eight of the 25 municipalities in the study area, of which 92.8% occurred in Ourinhos. A total of 2,189 imported cases were reported (27% in Ourinhos and 20% in Assis), mainly originating in the states of Paraná and Minas Gerais. Clusters of autochthonous and imported cases with higher risk were identified in Ourinhos, Assis and Ipaussu. However, over the years, the cases began to occur in low density in Ourinhos and no longer in other municipalities in the region. The cluster detected in the period 2007–2016 in Ourinhos still has risk for the transmission of schistosomiasis. K12-function analysis indicated positive spatial dependence between autochthonous and imported cases. **Conclusions:** The study showed that, currently, schistosomiasis as a public health problem in Middle Paranapanema is restricted to Ourinhos. This fact may be related to the presence of *Biomphalaria glabrata* at a specific point and low coverage of basic sanitation.

Keywords: Schistosomiasis. Spatial analysis. Geocoding. Epidemiology. Brazil.

INTRODUCTION

Human schistosomiasis mansoni is a parasitic disease in which the etiological agent is the trematode *Schistosoma mansoni* Sambon, 1907. The disease occurs in areas where there is poor sanitation, the intermediate host (IH) of the genus *Biomphalaria* can be found, and where infected people with schistosomiasis migrate to non-endemic regions while healthy people to endemic regions, all of which are factors that favor the emergence of the disease[1,2]. It was reported that, in 2016, 12,411 adults were treated, and approximately 1.6 million individuals were infected with *S. mansoni* (*Sm*) in Brazil[3,4]. In 2012, positivity for *Sm* in Brazil was 4.5%[5]. In 2015, there was a decrease in positivity, to 1% in Brazil, with 2.4% in the southeast region and 0.04% in São Paulo (SP)[6].

Knowledge of spatial variation and geographical mapping of schistosomiasis cases allow identification of areas where there is a greater risk of infection and determination of priority areas for prevention measures[5]. Geographical information systems (GISs) have been used in public health studies since the 1990s and allow large quantities of data to be analyzed and disease transmission risks in a particular geographical area to be identified[7,8,9,10,11,12,13].

In Brazil, GISs have been used in studies to evaluate the occurrence of schistosomiasis, taking into account the geographical space, particularly in areas of high endemicity in Bahia[14,15], Pernambuco[16], Minas Gerais[17,18], Recife[19], and Sergipe[20]. Studies in areas with low endemicity of

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schistosomiasis, such as the state of SP, are rare. The studies by Anaruma Filho et al.[21] and Teles et al.[22] show an exception, relating to Bananal and Campinas, respectively, regions where it was possible to rate schistosomiasis transmission sites, map parasite foci, and identify those where intense surveillance and control would be required.

The Middle Paranapanema watershed, in SP, stands out as an important region for the transmission of schistosomiasis, with the occurrence of autochthonous cases since 1952.[23] Among the factors that could explain this autochthony would be the predominance and abundance of *Biomphalaria glabrata.*[24,25,26,27] This species was found naturally infected with *Sm* for the first time in 1952 in Ourinhos.[28,29] It has since been considered an important public health problem in this area of the state[30,31]. However, in this region, as in Brazil as a whole and several other countries of the world, recently, there has been a significant decrease in the incidence and prevalence of schistosomiasis, which has been attributed to the efficacy of the drugs used for treatment of infected individuals, increase in the coverage of basic sanitation services, and control of the IH[32,33,34,35].

Thus, this study aimed to describe the historical occurrence of schistosomiasis in the Middle Paranapanema region in space and time, characterize the presence of IH in areas at risk, and evaluate its current importance as a public health problem.

METHODS

The study area consists of 25 of 55 municipalities of the Hydrographic Unit Water of Resources Management of Middle Paranapanema (UGRHI–17)[36,37] (**Table 1**), including GeoSentinel sites that are priorities for the surveillance of schistosomiasis[38], which have a total estimated population of 488,955 inhabitants in 2018[39]. These municipalities include a significant part of the autochthonous occurrence of schistosomiasis in the Middle Paranapanema region[40]. The aforementioned region is located in the southeast of SP. It is characterized by a vast and complex hydrography in which the Paranapanema river predominates and flows into the west of SP in the direction of the Paraná River[41,42].

Information on schistosomiasis cases (notification date, home address, probable infection site [PIS], and epidemiological classification) in the period 1978–2016 was obtained from the National Notifiable Disease Information System (SINAN). Access to the necessary information was provided by the Alexandre Vranjak Center for Epidemiological Surveillance and the Superintendence for the Control of Endemic Diseases (SUCEN) of the Health Secretariat of the State of SP. Population data and cartographic material were obtained from the information supplied by the Brazilian Institute of Geography and Statistics (IBGE)[43,44,45,46,47] and the Secretariat for the Environment of the State of SP[48].

The data on autochthonous and imported cases and cases of unknown origin were analyzed for the periods 1978–1988, 1989–1999, 2000–2006, and 2007–2016. The first and second periods correspond to the time interval when reporting and investigation records were sent to SUCEN and organized manually. In the third and fourth periods, the data records were entered into the SINAN-W and SINAN-NET information systems, respectively. For the period 2000–2006, all cases were classified as those of unknown origin, probably due to the interruption of the epidemiological investigation of schistosomiasis in the region. The incidence rates of autochthonous and imported cases and those of unknown origin were calculated for municipalities with autochthonous occurrence of schistosomiasis according to the periods under consideration. The schistosomiasis cases were geocoded by home address using a batch geocoding tool[49], and the points corresponding to the geographical coordinates were imported in the format of latitude/longitude (datum WGS84) into the software QGIS version 2.14[50].

For each of these municipalities with autochthonous occurrence and after the geocoding, the imported and autochthonous cases were computed according to census tracts and periods considered. This was accomplished through the complement MMQGIS[51] in QGIS[50]. The areas at greatest risk for schistosomiasis were identified using the spatial scan statistics in SaTScan version 9.4[52]. For this, the populations in the middle of the period and centroid coordinates of the census tracts were also considered.

A spatial scan analysis was performed using the discrete Poisson model under the following conditions: maximum cluster size equal to 50% of the population and circular clusters[53,54]. The analysis identified clusters where there was a high risk of occurrence of infection and associated relative risk (RR), which corresponds to the ratio of the incidence rate inside the cluster to the incidence rate outside it. The respective P-values were also calculated, and a P-value $< 5\%$ was considered statistically significant. In water bodies, overlapped high-risk clusters of autochthonous cases were identified in the spatial scan analysis of this study. In these peculiar water bodies, planorbids of the genus *Biomphalaria* were collected between 2015 and 2017, using a standard ladle recommended by the Brazilian Ministry of Health[55]. The snails were identified by examination of the morphological characteristics of their reproductive apparatus as described in Paraense[56,57]. All snails were exposed to artificial light in the laboratory to induce shedding of trematode cercariae of *Sm*[55].

The relationship between the spatial distribution of autochthonous and imported cases in the period 1978–2016 of the GeoSentinel sites in UGRHI–17 of Middle Paranapanema was analyzed using Ripley's K12-function[58], in the R software version 3.2.2[59] with Splancs package[60]. This allowed the evaluation of the existence of spatial dependence between these two distributions and the radius of influence. The radius of influence data and geographical coordinates of the imported and autochthonous cases were subsequently used to estimate the kernel density to verify the lower and higher intensity probability of the occurrence of the cases in the geographical area. Red, green, and light blue colors were used to represent the areas where the densities of imported and autochthonous cases were mostly observed. This was achieved through Splancs package[60] in the R software[59].

Flow maps showing the origin of cases imported from other Brazilian states to the GeoSentinel sites and the internal flow

TABLE 1: Autochthonous, imported, and unknown origin cases of schistosomiasis in the eight autochthonous municipalities and the sum of the cases of the other municipalities* of the GeoSentinel sites of Middle Paranapanema, state of São Paulo, Brazil, according to the four study periods (1978–2016).

Municipalities	Epidemiological classification	Study periods							
		1º: 1978–1988		2º: 1989–1999		3º: 2000–2006		4º: 2007–2016	
		N	(%)	N	(%)	N	(%)	N	(%)
Ourinhos	Autochthonous	963	(61.7)	414	(67.1)		s.i.	25	(39.7)
	Imported	472	(30.2)	115	(18.6)		s.i.	5	(7.9)
	Unknown origin	126	(8.1)	88	(14.3)	61	(100)	33	(52.4)
Assis	Autochthonous	62	(13.1)	18	(29.5)		s.i.	0	(0)
	Imported	407	(86.2)	38	(62.3)		s.i.	2	(100)
	Unknown origin	3	(0.6)	5	(8.2)	1	(100)	0	(0)
Ipaussu	Autochthonous	3	(10.7)	10	(37.0)		s.i.	0	(0)
	Imported	25	(89.3)	16	(59.3)		s.i.	0	(0)
	Unknown origin	0	(0)	1	(3.7)	3	(100)	0	(0)
Candido Mota	Autochthonous	8	(4.6)	0	(0)		s.i.	0	(0)
	Imported	165	(94.3)	7	(87.5)		s.i.	3	(100)
	Unknown origin	2	(1.1)	1	(12.5)	7	(100)	0	(0)
Palmital	Autochthonous	1	(1.6)	1	(5.6)		s.i.	2	(66.7)
	Imported	54	(88.5)	14	(77.8)		s.i.	1	(33.3)
	Unknown origin	6	(9.8)	3	(16.7)	0	(0)	0	(0)
Chavantes	Autochthonous	0	(0)	1	(33.3)		s.i.	1	(100)
	Imported	54	(100)	2	(66.7)		s.i.	0	(0)
	Unknown origin	0	(0)	0	(0)	1	(100)	0	(0)
Canitar	Autochthonous	0	(0)	0	(0)		s.i.	1	(100)
	Imported	9	(100)	4	(80.0)		s.i.	0	(0)
	Unknown origin	0	(0)	1	(20.0)	0	(0)	0	(0)
São Pedro Turvo	Autochthonous	1	(2.4)	0	(0)		s.i.	0	(0)
	Imported	40	(97.6)	3	(100)		s.i.	0	(0)
	Unknown origin	0	(0)	0	(0)	2	(100)	0	(0)
***Others**	Autochthonous	0	(0)	0	(0)		s.i.	0	(0)
	Imported	656	(99.2)	95	(88.8)		s.i.	2	(33.3)
	Unknown origin	5	(0.8)	12	(11.2)	20	(100)	4	(66.7)
Total	Autochthonous	1038	(33.9)	444	(52.3)		s.i.	29	(36.7)
	Imported	1882	(61.5)	294	(34.6)		s.i.	13	(16.5)
	Unknown origin	142	(4.6)	111	(13.1)	95	(100)	37	(46.8)

Source: SUCEN and SINAN. ***Other municipalities of GeoSentinel sites of Middle Paranapanema with cases** = Bernardino de Campos, Borá, Cruzália, Espírito Santo do Turvo, Florínia, Ibirarema, Lutécia, Maracaí, Óleo, Paraguaçu Paulista, Pedrinhas Paulista, Platina, Ribeirão do Sul, Salto Grande, Santa Cruz do Rio Pardo, Tarumã, and Timburi. s.i., no information.

of imported cases within the study area were obtained using information on PIS and the Flowmapper version 0.4.1[61] tool, an extension of QGIS[50].

RESULTS

In the period from 1978–2016, 4,085 schistosomiasis cases were noted in 25 municipalities (**Table 1**), 37.0% (1,511) of which were classified as autochthonous, 53.6% (2,189) as imported, and 9.4% (385) as being of unknown origin (i.e., cases that could not be classified because there was some uncertainty as to the municipality in which the infection had probably occurred or for which this information was not available).

During the study period, autochthonous cases were found in eight municipalities of this region (**Table 1**). Of these, 92.8% occurred in Ourinhos, 5.3% in Assis, and 0.9% in Ipaussu, totaling 99.0% of the total number of autochthonous cases. In the period 2000–2006, all cases were considered to be of unknown origin (**Table 1**, **Figure 1**). Throughout the entire period, 91.3% of the autochthonous cases were reported in urban areas.

Overall, there was a significant decrease in the number of schistosomiasis cases in the municipalities during the periods analyzed, with greater intensity in the three municipalities that have the greatest concentrations of autochthonous cases (**Figure 1**). Assis, Ipaussu, and São Pedro do Turvo only had autochthonous cases registered before the second study period (1989–1999), and Cândido Mota had autochthonous cases registered before the first period (1978–1988) (**Table 1**). However, it should be noted that only Ourinhos reported autochthonous cases before 2016 (three cases). The last autochthonous cases in Canitar, Chavantes, and Palmital were reported in 2008, 2009, and 2011, respectively. This decline was also observed in the number of imported cases and cases of unknown origin (**Table 1**). The last cases in both Ipaussu and Assis occurred in 2001 and 2008, respectively.

High-risk clusters were only recognized in the spatial analysis of the SatScan in the census tracts of Ourinhos, Assis, and Ipaussu. In Ourinhos, in the first and second study periods, two clusters in which there was a high risk of autochthonous cases were identified. The first was associated with the Christoni stream, and the second with the Furninhas stream (**Figure 2A1–2**). In the period 2007–2016, a single cluster (RR=14.7) was found. Both streams lay within this cluster (**Figure 2A3**). Spatial clusters in Ourinhos were identified for imported cases in three of the periods studied (**Figures 2A4–6**). Comparison of the results of the cluster analysis shows the similarity between the clusters of autochthonous and imported cases, as well as their proximity to the Furninhas and Christoni streams.

In the Christoni stream, the species *B. glabrata* and *B. occidentalis* were identified and in the Furninhas stream, *B. occidentalis* and *B. tenagophila* (**Table 2**). No snail eliminated cercariae of *Sm*.

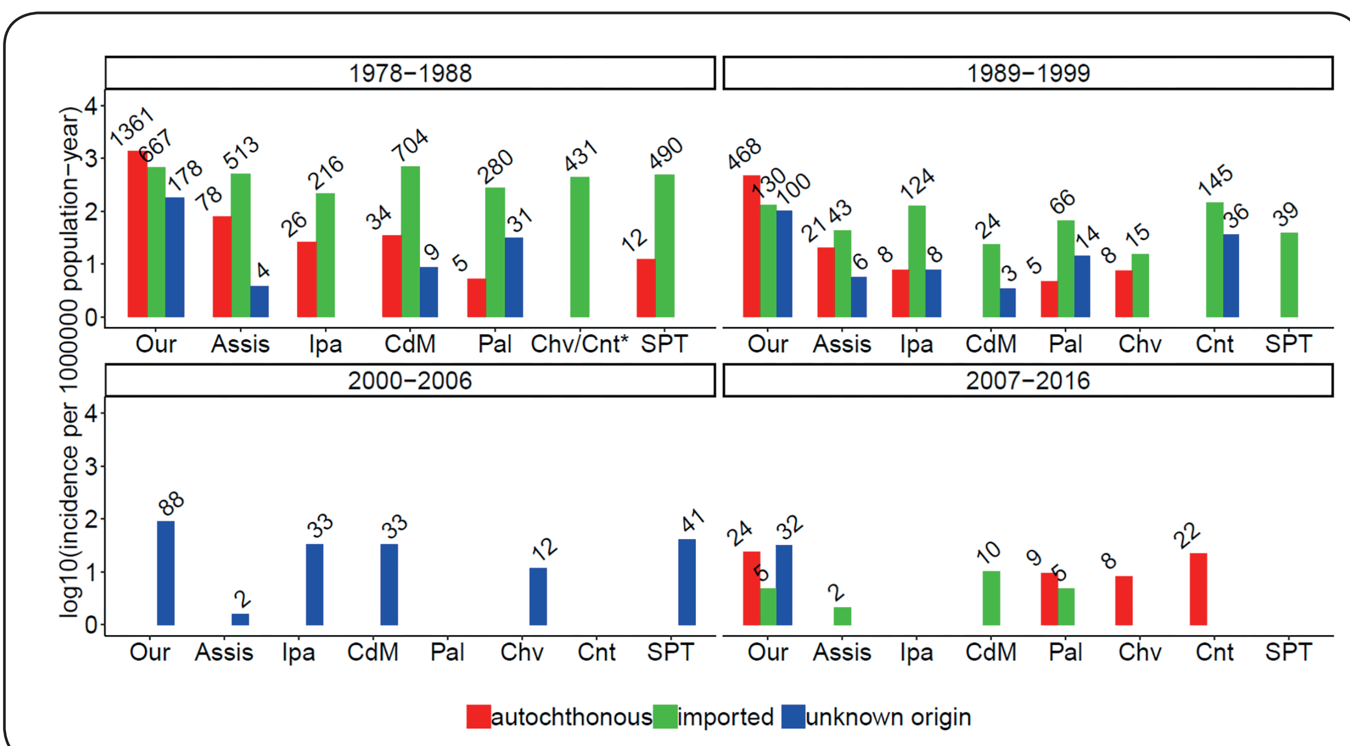
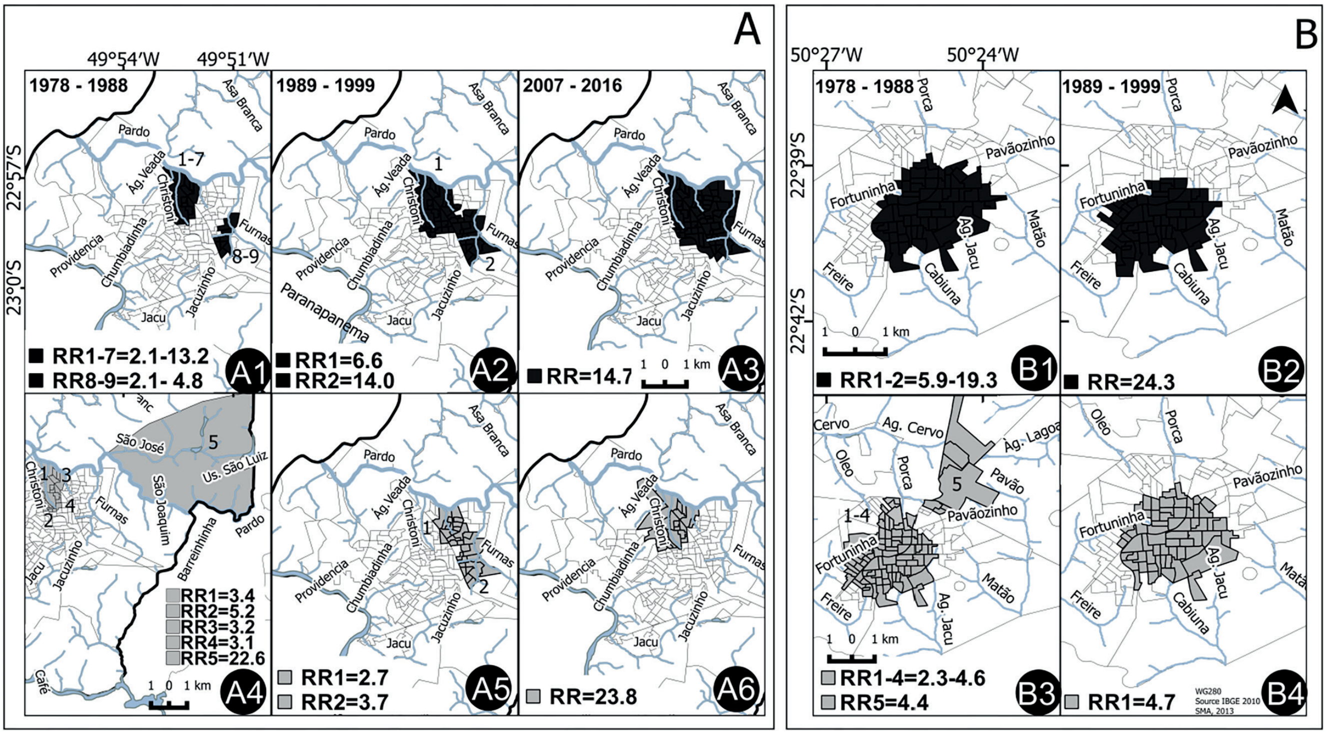


FIGURE 1: Incidence rates of autochthonous, imported, and unknown origin cases of the eight municipalities with autochthony of the GeoSentinel sites of Middle Paranapanema, São Paulo, Brazil, according to the four study periods (1978–2016). Incidence rate per 1 million inhabitants per year. (Our, Ourinhos; Ipa, Ipaussu; CdM, Candido Mota; Pal, Palmital; Chv, Chavantes; Cnt, Canitar; SPT, São Pedro do Turvo) *Chv/Cnt = Canitar belonged to Chavantes until 1991 (state law nº 7644, of December 30, 1991).



Ourinhos **(A)** and Assis **(B).** With spatial clusters of autochthonous cases of schistosomiasis (■), for the periods of 1978–1988 **(A1, B1)**, 1989–1999 **(A2, B2)**, and 2007–2016 **(A3)**, and clusters of imported cases (■) for the periods 1978–1988 **(A4, B3)**, 1989–1999 **(A5, B4)**, and 2007–2016 **(A6)**. The main water bodies and census area[44,45] are also shown.

FIGURE 2: Maps of the municipalities of Ourinhos and Assis, São Paulo, Brazil, with spatial clusters of cases of schistosomiasis.

In Assis, one high-risk cluster was found for the occurrence of autochthonous and imported cases in the period 1978–1988 and another in 1989–1999, near the Fortuninha and Jacu streams (**Figure 2B1–4**). The collection of snails in Assis to identify IH in clusters that were considered of high risk resulted in the following: *B. glabrata* was identified in the Fortuninha stream, while *B. tenagophila* and *B. occidentalis* were identified in the Jacu stream (**Table 2**).

In Ipaussu, a high-risk cluster was identified relating to the São Luiz stream, with autochthonous cases for the period 1989–1999 (RR=19.2), and another cluster with imported cases in the period 1978–1988 (RR=20.2). Both clusters were located in the urban areas. The São Luiz stream is currently colonized by *B. tenagophila*, *B. occidentalis*, and *B. peregrina* (**Table 2**).

Moreover, there was agreement between these clusters and the PIS identified in the databases. The PIS identified the greatest frequency of autochthonous cases in the following streams in Ourinhos: Christoni, in 43.4% (608); Furninhas, in 35.8% (503); Furnas, in 5.7% (80); and other water bodies (Turvo, Paranapanema, Pardo rivers and others), in 8.2% (115). However, in 6.8% (96) of the survey records, we observed a complete lack of information.

In Assis, there was agreement between PIS and cluster in the following water bodies: Jacu, in 35.0% (28); Fortuninha (Buracão park), in 20.0% (16); Aldeia stream, in 7.5% (6); and *Canada* farm lakes (Jacu neighborhood), in 5.0% (4). However, in 32.5% (26) of the records, no information was included. In Candido Mota, 50% (4) were identified in the Jacu stream (headwater in Assis[62]), whereas others lacked any identification. In Ipaussu, a higher frequency of autochthonous cases was identified in the following water bodies: São Luiz stream, in 76.9% (10), *Municipal* lake, in 15.4% (2); and Paranapanema river reservoir, in 8% (1).

The graph of the K12-function analysis (**Figure 3A**) indicates the existence of positive spatial dependence to a distance of approximately 3,900 m between the imported and autochthonous cases, corroborated by the kernel density map analysis (**Figure 3BC**), where a higher concentration of cases may be seen in Ourinhos and Assis, for both autochthonous and imported cases.

Figure 4A shows the origin of cases imported from other Brazilian states for the GeoSentinel sites of Middle Paranapanema: Paraná (34.6%), Minas Gerais (16.8%), Alagoas (9.3%), Pernambuco (9.0%), Bahia (8.3%), and Sergipe (4.5%). Of the total number of imported cases, 27.0% belonged to the municipality of Ourinhos and 20.4% to Assis. In relation to the internal flow of cases of the study area, Ourinhos was the municipality that provided most imported cases to others (**Figure 4B**).

DISCUSSION

The use of GIS and spatial analysis techniques in the study of schistosomiasis allowed us to specify in great detail, within

TABLE 2: Geographic coordinates and number of *Biomphalaria* Preston, 1910 species collected in water bodies in the municipality of Ourinhos, Assis, and Ipaussu, SP, Brazil, between 2015 and 2017.

Municipalities	Water Bodies	*Bgl	*Btt	Boc	Bpe	N° snails collected	Latitude	Longitude	Collection date
Ourinhos	Christoni	x				212	-22.967600	-49.874683	2015–2016
		x				46	-22.967117	-49.875167	2015–2017
				x		146	-22.964467	-49.875633	2015–2016
		x		x		147	-22.952833	-49.876333	2015–2016
		x		x		77	-22.950050	-49.875850	2015–2016
	Furninhas		x	x		175	-22.985556	-49.849972	2015–2016
				x		109	-22.977056	-49.851667	2015–2017
			x			32	-22.976766	-49.851745	2015
Assis	Fortuninha	x				20	-22.660240	-50.437510	2017
	Jacu		x	x		24	-22.670850	-50.406117	2017
Ipaussu	São Luiz (Sapo)		x	x		149	-23.064750	-49.630250	2015–2016
			x	x		114	-23.060083	-49.628333	2015–2016
			x			23	-23.047528	-49.630250	2015–2016
			x		x	113	-23.046556	-49.627528	2015–2016
					x	86	-23.045750	-49.625250	2015–2016

*All specimens of IH were negative for the elimination of *S. mansoni* cercariae. *Bgl*, *B. glabrata* (Say, 1818)*; Btt, B. tenagophila* (d'Orbigny, 1835)*; Boc, B. occidentalis* (Paraense, 1981)*; Bpe, B. peregrina* (d'Orbigny, 1835).

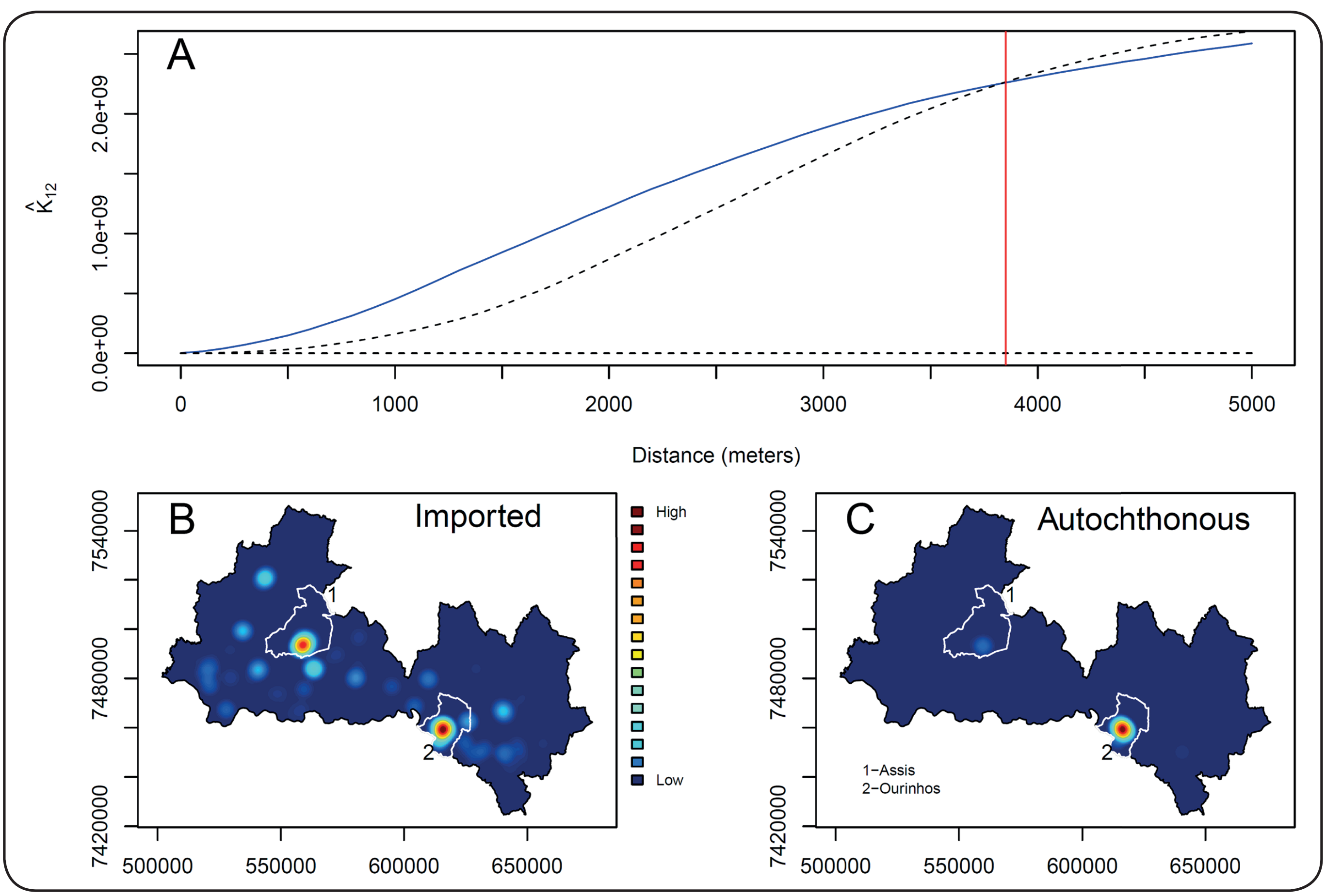


FIGURE 3: Graph of bivariate K12-function analysis **(A).** The blue curve that continues above the envelope shows a positive spatial dependence between imported and autochthonous cases of schistosomiasis, and Kernel density with radius of influence of ~ 3,900 m maps shows the distribution of imported **(B)** and autochthonous **(C)** cases in GeoSentinel sites of Middle Paranapanema, SP, Brazil.

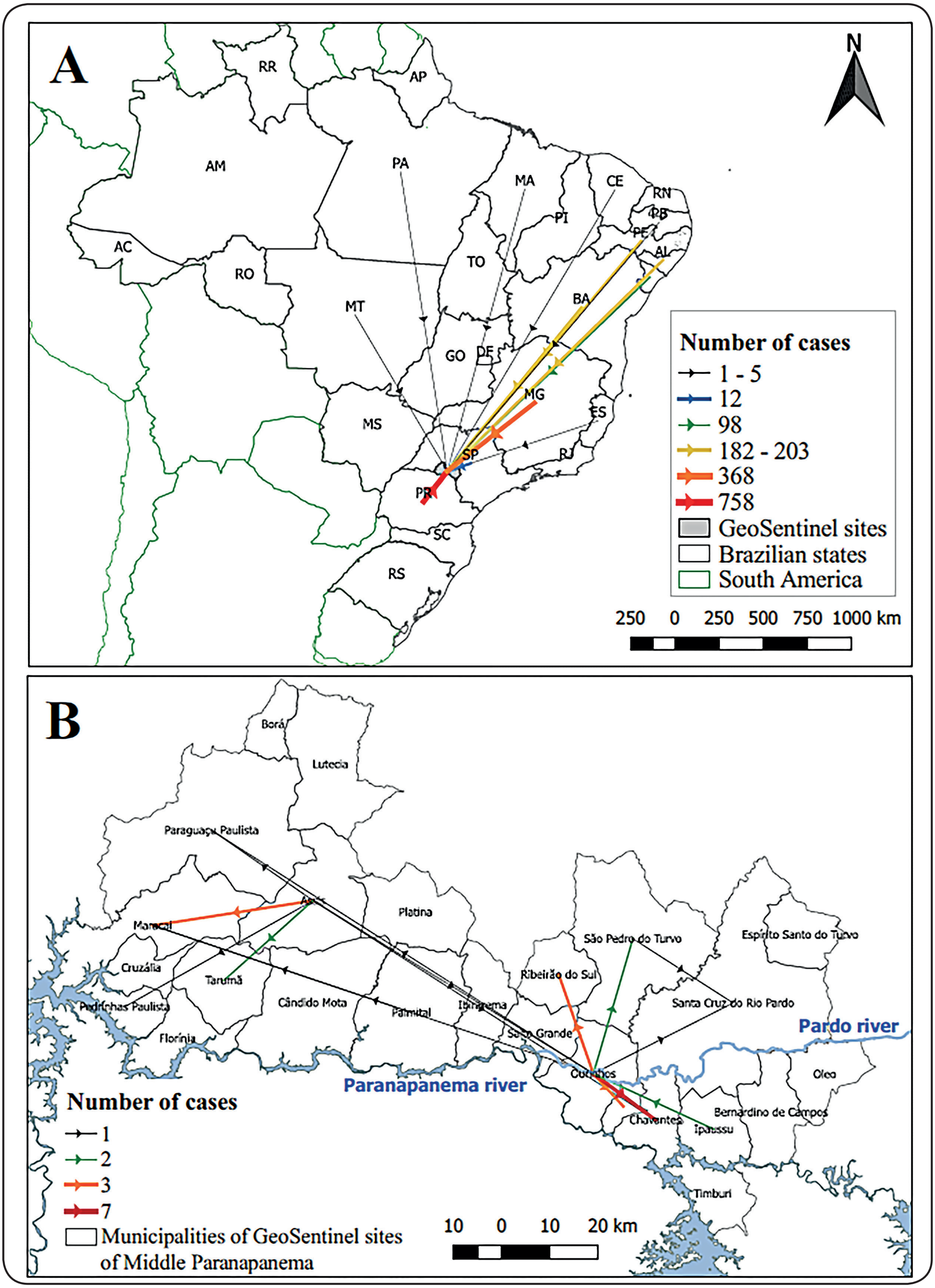


FIGURE 4: Localization of GeoSentinel sites of Middle Paranapanema in the state of São Paulo, Brazil, South America; flow map of imported cases of schistosomiasis from other Brazilian states to the study area **(A)**. Municipalities that compose the GeoSentinel sites; flow map with the internal flow of imported cases in the GeoSentinel sites **(B)** in the period 1978–2016.

the space occupied by the municipalities and their water bodies in the GeoSentinel sites of Middle Paranapanema, the areas with the highest risk for the transmission of schistosomiasis in different periods and map the origin of the imported cases. In delimiting risk areas, the GIS allows the orientation of the malacological surveillance to specific points, being fundamental tools for the improvement of the surveillance and control activities that may result in the elimination of schistosomiasis in the study region.

The results indicate a progressive decline in the incidence of schistosomiasis cases in the study region between 1978 and 2016. Only Ourinhos continued to be a significant area of autochthonous occurrence of the disease. In Cândido Mota, Assis, and Ipaussu, the last autochthonous cases of schistosomiasis occurred in the 1980s and 1990s. This reduction may be related to the process of urban development of the municipalities[6,63,64] and/or the appropriate treatment of patients[34]. It is important to bear in mind that the dynamics of the colonization and adaptation of IH species of *Sm* may affect the risk of disease transmission[19].

The detection of the high-risk spatial cluster of schistosomiasis in the Christoni stream and the fact that this stream is still colonized by *B. glabrata*[27,65,66,67], may characterize this stream as a transmission hotspot in Ourinhos. It is known that this IH species is best adapted to the development and propagation of the parasite[29,68]. The flow map of imported cases demonstrates that Ourinhos is also an important nucleus for the regional dispersion of the disease.

The Christoni stream defines an area subject to flooding[70], with vegetable gardens in meadows[71] that seem to constitute an ideal ecosystem for the breeding of *B. glabrata*, which allows us to hypothesize that this stream is an important site for the transmission of the species and, consequently, the disease.

In addition to the Christoni stream, a high-risk cluster was identified in the Furninhas stream in Ourinhos, previously colonized by *B. glabrata*[27,66] but currently by *B. tenagophila*. The Furninhas stream has recently been the target of a significant intervention, not only along the urban stretch of the stream (reduction in tree coverage and canalization) but also in the rural stretch (replacement of pasture and annual crops by sugarcane plantations)[72], favoring the substitution of native species by *B. tenagophila*. This hypothesis might explain the decrease in the number of cases observed in this municipality. *B. tenagophila* has reproductive and physiological characteristics that enable it to proliferate in modified environments[73] and has a limited capacity to act as an IH of *Sm*[74,75].

In Ourinhos, there are still areas where there is no piped wastewater system and some of the sewage is disposed of untreated. According to the National Sanitation Information System data, 78.6% of the water consumed by the municipality in 2015 was collected as sewage, and only 68.0% of this was treated[76]. Sewage that is neither collected nor treated can contaminate watercourses as it may contain feces from infected individuals, allowing the disease cycle to be completed when IHs are present[55]. In Ourinhos, as many of these water bodies are near residential areas, they can be readily accessed by the local community, leading to the continued occurrence of infection[69]. Our results corroborate the findings of other authors[69,85,86] who have shown that most infection sites were close to dwellings, i.e., transmission was peri-domiciliary.

In Assis, between 1978 and 1999, clusters were found around the Fortuninha and the Jacú streams. In contrast with Ourinhos, in Assis, the sanitation has recently improved, and in 2015, 83.7% of the volume of water consumed was collected as sewage and treated[76]. The increased coverage of sewage collection and water treatment may explain the elimination of the disease in the city. Other authors have also correlated the sewage collection coverage with the decrease in the number of cases of this disease and other intestinal parasite diseases in Assis[77,78], demonstrating the impact of basic sanitation on intestinal infectious diseases[6,79]. Although the Fortuninha stream is still colonized by *B. glabrata*[66,80], it has been channeled, and lakes have been constructed, making it a public park[81]. The same has happened to the Jacu stream, that has undergone changes in width and depth, recomposition of the gallery forest[82], and channeling in its urban stretch[83], conditions that must have favored the replacement of *B. glabrata*[66,80] by *B. tenagophila* and *B. occidentalis.*

Another example of the influence of anthropic alterations on the transmission dynamics of schistosomiasis is found in the observation, in Ipaussu, of the limitation of schistosomiasis to the first two periods analyzed in this study. This coincides with the colonization of the main stream of Ipaussu (São Luiz) by *B. glabrata*[66], sometimes found infected with *Sm*[31,66]. Currently, the levels of fecal coliforms in the São Luiz stream are within the levels allowed by law[84], indicating that there has been a significant improvement in freshwater quality, which in theory may have favored the replacement of *B. glabrata* by *B. tenagophila*, as has been observed since 2003[27,67], resulting in a reduction in the risk of the transmission of schistosomiasis.

The results of the scan statistics show that the clusters of imported cases coincide with the clusters of autochthonous cases in Ourinhos, Assis, and Ipaussu. These areas had already been identified by Figueiredo[69] as having significant numbers of autochthonous cases and therefore qualifying for consideration as important potential transmission areas. This result is consistent with that obtained by Ripley's K12-function, which showed that there is a positive spatial dependence between autochthonous and imported cases, with the result that both the addresses of the imported and autochthonous cases provide important information about the transmission sites.

The vast majority of cases imported into the study region came from Paraná and Minas Gerais states. The municipality of Jacarezinho in Paraná, which borders Ourinhos, has been a focus of schistosomiasis since 1948[87] and has the presence of *B. glabrata*[88] and *B. tenagophila*[55,89]. The presence of an economic pole in Ourinhos may be a determining factor accounting for the human migratory flow from northern Paraná. The migratory movement from Minas Gerais merits the attention of epidemiological research services because this state has highly endemic areas for schistosomiasis related to *B. glabrata*[5,30,85,90]. Possibly, this disease was introduced in SP, just as in Paraná, by infected immigrants from Minas Gerais and the Northeastern region of the country[85].

The limitations of this study are its use of secondary data on the occurrence of schistosomiasis underlying which are two important components: failures in the classification of cases and identification of the respective PIS and the underreporting of cases. If we consider that, according to Eduardo et al.[91], 30% of cases of unknown origin should in fact be classified as autochthonous, it follows that the schistosomiasis in the study area has been underestimated. This problem had already been noted by Bezerra[92], who stressed the importance of training staff to reduce the number of mistakes in the reporting and investigation of the records relating to the disease.

The failure to undertake surveillance and control of schistosomiasis may be associated with the decentralization of these actions that was officially sanctioned in 1999[5,93]. From that year on, reporting became the responsibility of the municipalities, and many cases ceased to be classified or investigated. The problem was solved in 2003, with the resumption of schistosomiasis surveillance and control activities[5,94,95,96]. Underreporting contributes to the characterization of schistosomiasis as a neglected tropical disease, which is not accorded priority by public health policies[34,97,98].

In contrast, the strength of this study is the association of geoprocessing techniques with epidemiological studies so that the objectives of the study could be achieved. Moreover, these tools are useful for the elaboration of strategies of action and have the potential to improve the system of surveillance and control of schistosomiasis.

Finally, this study shows that there has been a general decrease in the incidence of schistosomiasis in the GeoSentinel sites, in UGRHI-17 of Middle Paranapanema. In Ourinhos, schistosomiasis persists but has low incidence, though it still represents a public health problem. In this municipality, the health services should invest in the early detection of the disease, adequate notification and classification of autochthonous cases, malacological surveillance of the water bodies containing *B. glabrata*, and improvements in basic sanitation. These are measures that would make the elimination of schistosomiasis on the short term conceivable with a resulting impact throughout the region.

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Ethical Approval

The project was approved by the School of Public Health Committee for Ethics in Research (COEP) of USP. Approval was granted through the Plataforma Brasil system (Ministry of Health, National Health Council) under reference number 53559816.0.0000.5421.

Conflict of Interest

The authors declare that there is no conflict of interest.

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