Original article

Geographical distribution of intermediate hosts of *Schistosoma mansoni* in the states of Paraná, Minas Gerais, Bahia, Pernambuco and Rio Grande do Norte, Brazil, 2012-2014*

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Abstract

Objective: to describe the geographical distribution of intermediate hosts of Schistosoma mansoni in five Brazilian states. **Methods:** this was a descriptive cross-sectional study; municipalities were selected in the states of Paraná (78), Minas Gerais (120), Bahia (82), Pernambuco (51) , and Rio Grande do Norte (98), for the period 2012 to 2014; these municipalities were chosen because they did not have current records of the presence of snails vectores de S. mansoni. The molluscs were captured and taxonomically identified and examined for S. mansoni cercariae. **Results:** the work was carried out in 427 municipalities (99.5% of the 429 selected); the presence of mollusks was registered in 300 (70.2%) municipalities; Biomphalaria glabrata were found in 62 (21%) municipalities, B. straminea in 181 (60%), B. tenagophila in three (1%); B. glabrata/B. straminea association was found in 53 municipalities (18%) and B. glabrata/B. tenagophila association in one (0.3%) municipality. **Conclusion:** B. glabrata, B. straminea and B. tenagophila distribution records obtained in this study are consistent with previously known distribution.

Keywords: Schistosomiasis; Biomphalaria; Disease Vectors; Geographic Mapping.

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Introduction

Schistosomiasis mansoni is a parasitic infectious disease[1] the etiological agent of which is the *Schistosoma mansoni* trematode. It is endemic in approximately 49 countries of the Americas, Caribbean and Africa. In Brasil, from 1975 to 2012, the percentage of schistosomiasis positivity ranged from 4.5 to 23.3%, while the highest prevalences are found in the Northeast and Southeast regions of the country. From 1988 to 2013 the hospitalization rate ranged from 2.5 to 0.08/ 100,000 inhabitants and the mortality rate in the period from 1987 to 2012 ranged from 0.5 to 0.2/100,000 inhabitants.[1]

The invertebrate hosts are planorbidae mollusks of the *Biomphalaria* genus. Among the 11 species and one subspecies of mollusks of this genus recognized in Brazil, only *Biomphalaria glabrata*, *Biomphalaria tenagophila* and *Biomphalaria straminea* have been found naturally infected with *S. mansoni* so far. The most important intermediate host is *B. glabrata*, because of its high susceptibility to *S. mansoni* and wide distribution. In Brazil, its occurrence is almost always associated with the presence of schistosomiasis mansoni.[2]

> ***Biomphalaria straminea has the broadest geographical distribution and is present in almost all Brazilian river basins. Due to its extensive distribution, B. straminea is the species best adapted to all varieties of climates and ecological conditions of the country.***

Biomphalaria tenagophila has spread along the coastal strip from the south of the state of Bahia to Rio Grande do Sul. In the states of Minas Gerais, São Paulo, Paraná and Rio Grande do Sul, the species is moving west. *B. tenagophila* has epidemiological importance in the Paraíba Valley in São Paulo state.

Biomphalaria straminea has the broadest geographical distribution and is present in almost all Brazilian river basins. Due to its extensive distribution, *B. straminea* is the species best adapted to all varieties of climates and ecological conditions of the country. This species has importance in the epidemiology of schistosomiasis in some states of Northeast Brazil. The lack of malacological research in Brazil explains the shortage of data on the geographical distribution of these species of mollusks.[2]

A further three species, *Biomphalaria peregrina*, *Biomphalaria amazonica* and *Biomphalaria cousini*, and a hybrid of the latter two were experimentally infected and are considered potential hosts of the parasite.[3-5]

In 2008, the Ministry of Health, following the recommendation of the Technical Advisory Committee of Schistosomiasis Program, redefined the data on the geographical distribution of *S. mansoni* mollusk hosts of in the country's states, focusing on transmission as topic of relevance to the Schistosomiasis Surveillance and Control Program.

The geographical distribution of *S. mansoni* intermediate hosts by Brazilian municipalities has been progressively updated, on the basis of new records of the presence of the three host species.[6-24] Records of *B. glabrata* occurrence are delimited by the 0 53'S (Quatipuru, PA), 29 51'S (Esteio, RS), 53 44'S (Toledo, PR) parallels and the coastline; *B. straminea* is delimited by the 02º54'S and 31º00'S parallels, longitude 44º43'W and the coastline; and *B. tenagophila* is delimited by the quadrant between the 10º12°'S and 33º41'S parallels, longitude 57º05'W and the coastline.[9,12]

The objective of this study was to describe the geographical distribution of intermediate hosts of *S. mansoni* in five Brazilian states.

Methods

This is a descriptive ecological study, carried out in the period from September 2012 to October 2014. Quantitative and qualitative techniques (morphological identification) were used to survey intermediate hosts of *S. mansoni*, as well as information previously recorded on the collection of mollusks kept at the Oswaldo Cruz Institute/Oswaldo Cruz Foundation, Rio de Janeiro, RJ (Fiocruz/CMIOC). The study coverage area comprised 429 municipalities in states of Paraná (78), Minas Gerais (120), Bahia (82) Pernambuco (51) and Rio Grande do Norte (98). These municipalities were chosen because they did not have current records of the presence of intermediate hosts of *S. mansoni*. The samples were collected by a team composed of researchers and health professionals from the municipalities, previously trained at each state's reference laboratory.

Three water collections were selected by municipality, with priority being given to places where local populations have greater contact with water and where there are favorable conditions for the occurrence of planorbidae.[18]

Mollusks were collected at different water collection points. To achieve this, a perforated metal ladle (with holes around 2mm) or a riddle fixed to a handle approximately 1m in length were used. Submerged vegetation on the banks was scraped as was the bottom of the water collection points, in order to collect an adequate amount of specimens. There is no defined sampling technique for this kind of survey. All the specimens found were stored in plastic containers, labeled and taken to the laboratory.

The data on the geographic coordinates of all the places surveyed were obtained by means of GPS receivers and recorded using the decimal system.

The examination of *S. mansoni* larvae in the mollusks specimens[24] was performed at the Helminthology and Medical Malacology Laboratory of the René Rachou Institute/Oswaldo Cruz Foundation (IRR/Fiocruz) and at the Malacology Laboratory of the Oswaldo Cruz Institute/Fiocruz (IOC/Fiocruz). We used the technique of light stimulus or crushing between glass plates to detect the presence or absence of trematodes. Morphological identification was carried out at these two laboratories and also at the Laboratory of the Paraná State Health Department.

The dissection of the mollusks was done according to the Deslandes protocol;[25] specific identification was performed according to the protocols established by Paraense,[26] based on morphological characters. Molecular identification[27] was performed by the René Rachou Institute/Fiocruz Helminthology and Medical Malacology Laboratory, on at least one specimen from each catchment point in the states of Paraná, Minas Gerais and Pernambuco. The molecular profiles were compared to the standard profiles of the DNA extracted from snails tissue from the Medical Malacology Collection (Fiocruz/CMM).

Stata version 10.1 (Stata LP, College Station, TX, USA) was used for data analysis and the maps were drawn using ArcGIS software version 9.3 (Esri, Redlands, CA, USA).

The State Health Departments involved supported the study by making technical staff available for field work and also by providing transport to the collection sites. The formalization of their agreement was done by means of an official document.

The survey was conducted in accordance with Normative Instruction No. 141 of 19 December 2006, which regulates the environmental control and management of harmful synanthropic fauna.

Results

After checking with the state and municipal health authorities, the number of municipalities to be included was adjusted, since the state of Paraná had already done a survey in 172 municipalities. A further 93 municipalities were included in the other states, namely 52 in Minas Gerais, 6 in Bahia, 32 in Pernambuco and

Table 1 – Result of the capture of *Biomphalaria glabrata*, *Biomphalaria tenagophila* and *Biomphalaria straminea* in Paraná, Minas Gerais, Bahia, Pernambuco and Rio Grande do Norte, December 2012 - June 2014

Federative Unit	Municipalities agreed on	Municipalities added	Municipalities worked in	Municipalities surveyed		Mollusks caught per species and municipalities				
				Total (%)	With mollusks (%)	*B. glabrata*	*B. tenagophila*	*B. straminea*	*B. glabrata* + *B. straminea*	*B. glabrata* + *B. tenagophila*
Paraná	250	–	78[a]	78 (100)	18 (23)	–	2	16	–	–
Minas Gerais	68	52	120	120 (100)	79 (66)	33	1	28	16	1
Bahia	76	6	82	82 (100)	74 (90)	28[b]	–	14	32	–
Pernambuco	19	32	51	51 (100)	40 (78)	–	–	38	2	–
Rio Grande do Norte	95	3	98[c]	96 (98)	89 (93)	1	–	85	3	–
Total	508	93	429	427 (99)	300 (70)	62	3	181	53	1

a) When the project was started, the Paraná State Health Department had already studied 172 municipalities.
b) 18 specimens positive for *S. mansoni* were found in the following municipalities: Itororó (eight), Arataca (one) and Teolândia (nine).
c) In two municipalities, there was no capture due to drought.

3 in Rio Grande do Norte. In the latter state, it was not possible to perform collection in two municipalities (Grossos and Galinhos) due to the most severe drought in the last 100 years and consequent absence of environments propitious to freshwater mollusks.

Of the 429 municipalities selected for the study data were obtained from 427 municipalities (99.5%) (Table 1), mollusks of the *Biomphalaria* genus were found in 300 (70.2%). These snails were found in 120 municipalities in the state of Minas Gerais and 78 municipalities in the state of Paraná (Figure 1), these being in the country's Southeast and Southern regions, and in 82 municipalities in the state of Bahia, 51 in Pernambuco and 98 in Rio Grande do Norte, these being in the country's Northeast region (Figure 2). Data on 61 of these municipalities had already been already recorded as part of collection of mollusks kept at the Oswaldo Cruz Institute. The presence of *B. glabrata* was recorded in 62 municipalities, *B. straminea* in 181 and *B. tenagophila* in three municipalities. In 53 municipalities, *B. glabrata* was associated with *B. straminea*; and in one municipality, *B. glabrata* was found associated with *B. tenagophila* (Table 1).

Mollusks were infected with *S. mansoni* in three (1%) of the 300 municipalities where mollusks were present, all three of them being in the state of Bahia: Itororó (eight), Arataca (one) and Teolândia (nine). The results of collection per municipality, in the five states surveyed (Figure 1A), are presented below:

Minas Gerais (Figure 1B)

Biomphalaria glabrata (33): Aricanduva, Cachoeira de Pajeú, Capelinha, Carmésia, Catas Altas, Crisólita, Cristiano Otoni, Diogo de Vasconcelos, Divisópolis, Frei Gaspar, Itaverava, Jeceaba, Lamim, Mato Verde, Monte Formoso, Ouro Verde de Minas, Palmópolis, Piranga, Presidente Bernardes, Queluzita, Rio do Prado, Rio Espera, Rubim, Santa Helena de Minas, Santana dos Montes, Santo Antônio do Itambé, São Brás do Suaçuí, São Gonçalo do Rio Preto, Senhora de Oliveira, Senhora do Porto, Senhora dos Remédios, Serra Azul de Minas and Serro.

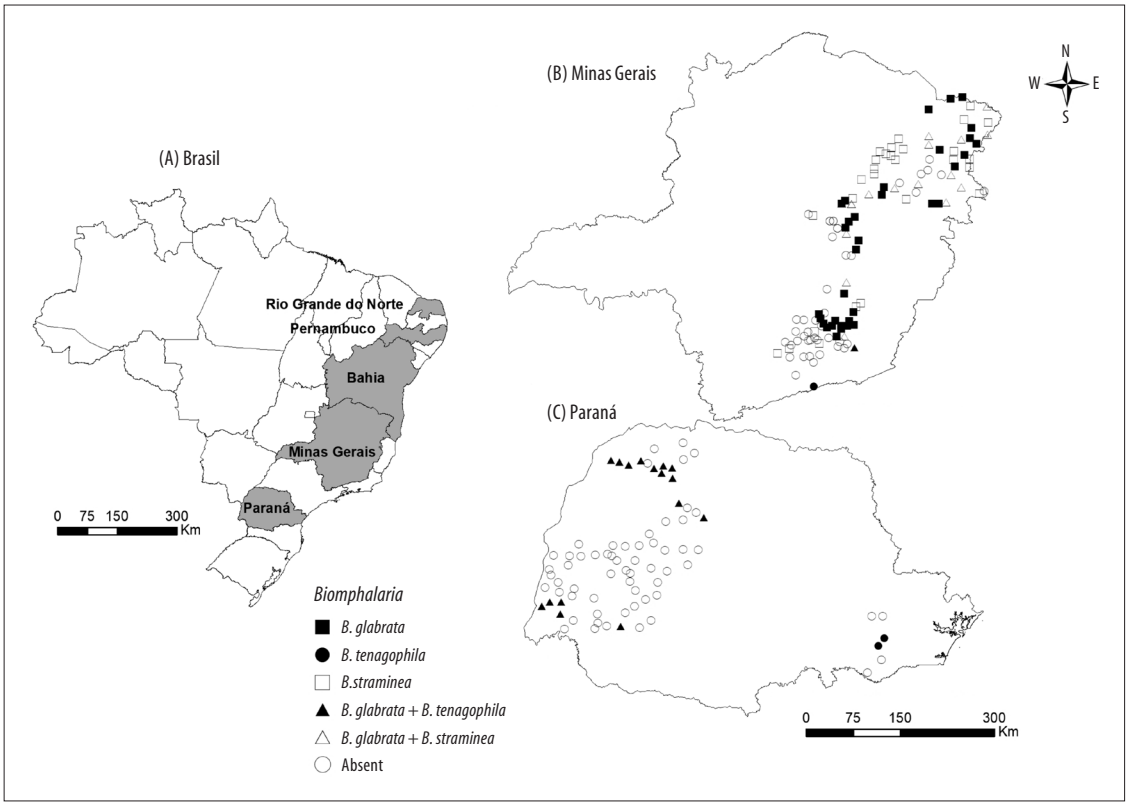

Figure 1 – Map of Brazil highlighting the states surveyed (A) and distribution of *Schistosoma mansoni* intermediate hosts in Minas Gerais (B) and Paraná (C), December 2012 - June 2014

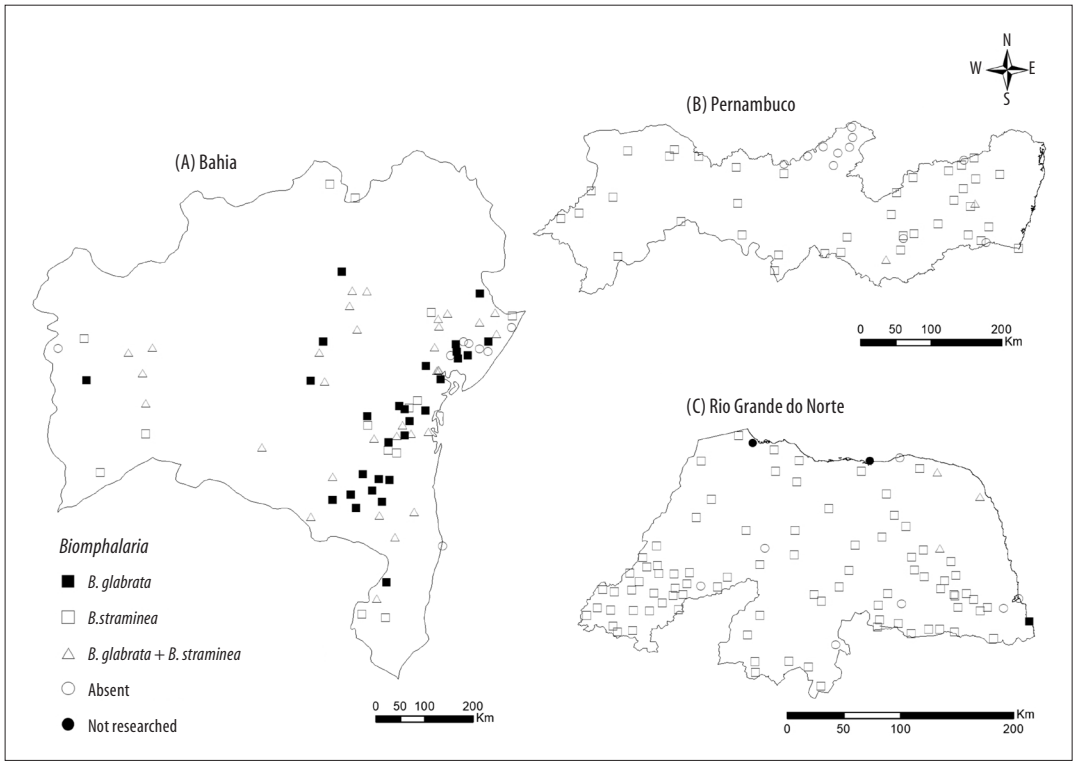

Figure 2 – Distribution of *Schistosoma mansoni* intermediate hosts in Bahia (A) Pernambuco (B) and Rio Grande do Norte (C), December 2012 - June 2014

Biomphalaria tenagophila (1): Santa Rita de Jacutinga.

Biomphalaria straminea (28): Acaiaca, Águas Formosas, Almenara, Araçuaí, Bandeira, Barra Longa, Barroso, Berilo, Bertópolis, Carbonita, Coronel Murta, Francisco Badaró, Franciscópolis, Fronteira dos Vales, Ingaí, Itutinga, Jenipapo de Minas, José Gonçalves de Minas, Lagoa Dourada, Leme do Prado, Monjolos, Nanuque, Santa Maria do Salto, Senador Modestino Gonçalves, Turmalina, Veredinha, Virgem da Lapa and Umburatiba.

B. glabrata/B. straminea (16): Alto Rio Doce, Alvorada de Minas, Ataléia, Carlos Chagas, Couto Magalhães de Minas, Felício dos Santos, Felisburgo, Itamarandiba, Itaobim, Jordânia, Ladainha, Pavão, Ponto dos Volantes, Santo Antônio do Jacinto, São Gonçalo do Rio Abaixo and Setubinha.

B. glabrata/B. tenagophila (1): Rio Pomba.

Negative municipalities (41): Angelândia, Carrancas, Casa Grande, Catuji, Conceição da Barra de Minas, Congonhas, Congonhas do Norte, Datas, Desterro de Entre Rios, Desterro do Melo, Dores de Campos, Entre Rios de Minas, Gouvea, Ibertioga, Ibituruna, Itaipé, Madre de Deus de Minas, Mercês, Morro do Pilar, Nazareno, Novo Oriente de Minas, Padre Paraíso, Paiva, Passa Tempo, Piedade do Rio Grande, Poté, Prados, Presidente Kubitschek, Raposos, Resende Costa, Ressaquinha, Ritápolis, Santa Barbara do Tugurio, Santa Cruz de Minas, Santana do Garambéu, Santo Antônio do Rio Abaixo, Santo Hipólito, São Tiago, Serra dos Aimorés, Serranos and Tiradentes.

Paraná (Figure 1C).

Biomphalaria tenagophila (2): Araucária and Contenda.

Biomphalaria straminea (16): Fênix, Itaipulândia, Medianeira, Mirador, Missal, Nova Aliança do Ivaí, Paraíso do Norte, Planaltina do Paraná, Ramilândia, Santa Cruz de Monte Castelo, Santa Isabel do Ivaí, Santa Mônica, São Carlos do Ivaí, Tamboara, Terra Boa and Três Barras do Paraná.

Negative municipalities (60): Altamira do Paraná, Alto Paraná, Amaporã, Anahy, Araruna, Assis Chateaubriand, Boa Esperança, Boa Vista da Aparecida, Braganey, Cafelândia, Campina da Lagoa, Campo Bonito, Campo

Largo, Campo Magro, Capitão Leônidas Marques, Catanduvas, Cruzeiro do Sul, Diamante D'Oeste, Diamante do Sul, Engenheiro Beltrão, Entre Rios do Oeste, Espigão Alto do Iguaçu, Formosa do Oeste, Guairaçá, Guaraniaçu, Ibema, Iguatu, Iracema do Oeste, Iretama, Janiópolis, Jesuítas, Lindoeste, Luiziana, Mamborê, Maripá, Matelândia, Mercedes, Nova Aurora, Nova Cantu, Nova Santa Rosa, Palotina, Pato Bragado, Peabiru, Quarto Centenário, Quatro Pontes, Quedas do Iguaçu, Quinta do Sol, Quitandinha, Rancho Alegre D'Oeste, Rio Negro, Roncador, Santa Helena, Santa Lúcia, Santa Tereza do Oeste, São João do Caiuá, São José das Palmeiras, São Pedro do Iguaçu, Serranópolis do Iguaçu, Ubiratã and Vera Cruz do Oeste.

Bahia (Figure 2A)

Biomphalaria glabrata (28): Andaraí, Barra do Choça, Cabaceiras do Paraguaçu, Catu, Entre Rios, Guaratinga, Ibicuí, Iguaí, Itambé, Itapicuru, Itororó, Jiquiriçá, Jitaúna, Lajedo do Tabocal, Maragogipe, Mirangaba, Nova Canaã, Nova Ibiá, Pedrão, Poções, São Desidério, Teodoro Sampaio, Teolândia, Terra Nova, Ubaíra, Utinga, Valença and Vitória da Conquista.

Biomphalaria straminea (14): Aiquara, Barreiras, Barrocas, Casa Nova, Cocos, Coribe, Ipuaú, Itanhém, Jandaira, Juazeiro, Lafaiete Coutinho, Laje, Mutuípe and Vereda.

B. glabrata/B. straminea (32): Anagé, Aporá, Apuarema, Arataca, Baianópolis, Biritinga, Cachoeira, Caem, Cândido Sales, Catolândia, Crisópolis, Esplanada, Feira de Santana, Gandu, Itapetininga, Ituberá, Jacobina, Jequié, Jucuruçu, Lagoa Real, Lamarão, Miguel Calmon, Mundo Novo, Muritiba, Nova Redenção, Potiraguá, Rio Real, Santa Maria da Vitória, São Felix, Serrinha, Wagner and Wenceslau Guimarães.

Negative municipalities (8): Alagoinhas, Araçás, Aramari, Belmonte, Conceição do Jacuípe, Conde, Itanagra and Luiz Eduardo Magalhães.

Pernambuco (Figure 2B)

Biomphalaria straminea (38): Afrânio, Alagoinha, Calumbi, Camocim de São Félix, Capoeiras, Carnaubeira da Penha, Caruaru, Casinhas, Cedro, Cumaru, Dormentes, Feira Nova, Granito, Ibirajuba, Ipubi, Itacuruba, Itaiba, Jaqueira, Jataúba, Jatobá, Joaquim Nabuco, Jucati, Lagoa Grande, Manari, Moreilândia, Orocó, Paranatama, Petrolândia, Poção, Riacho das Almas, Santa Cruz, Santa Filomena, Santa Maria Cambucá, São José da Coroa Grande, São José do Belmonte, Taquaritinga do Norte, Tupanatinga and Xexéu.

B. glabrata/B. straminea (2): Iati and Saire.

Negative municipalities (11): Brejinho, Caetés, Iguaraci, Ingazeira, Quixaba, Santa Cruz da Baixa Verde, Santa Terezinha, São José do Egito, Solidão, Tuparetama and Vertente do Lério.

Rio Grande do Norte (Figure 2C).

Biomphalaria glabrata (1): Baia Formosa.

Biomphalaria straminea (85): Afonso Bezerra, Almino Afonso, Antônio Martins, Areia Branca, Baraúnas, Barcelona, Boa Saúde, Bodó, Bom Jesus, Campo Redondo, Carnaúbas, Coronel Ezequiel, Coronel João Pessoa, Doutor Severiano, Encanto, Equador, Felipe Guerra, Fernando Pedrosa, Francisco Dantas, Frutuoso Gomes, Governador Dix-Sept Rosado, Guamaré, Ipueira, Itajá, Jaçanã, Jandaíra, Janúário Cicco, Japi, Jardim de Angicos, João Dias, Judiá, Janduís, Lagoa de Pedras, Lagoa de Velhos, Lagoa Nova, Lagoa Salgada, Lajes, Lajes Pintadas, Lucrécia, Major Sales, Marcelino Vieira, Messias Targino, Montanhas, Monte das Gameleiras, Olho-d'Água dos Borges, Ouro Branco, Paraná, Passa e Fica, Passagem, Pau dos Ferros, Pedra Grande, Pedra Preta, Pilões, Porto do Mangue, Rafael Godeiro, Riacho da Cruz, Riacho de Santana, Riachuelo, Rodolfo Fernandes, Ruy Barbosa, Santana do Seridó, São Bento do Trairi, São Fernando, São Francisco do Oeste, São João do Sabugi, São Pedro, São Rafael, São Vicente, Senador Eloi de Souza, Serra Caiada, Serra de São Bento, Serra do Mel, Serrinha, Serrinha dos Pintos, Severiano Melo, Taboleiro Grande, Tenente Ananias, Tenente Laurentino, Tibau, Timbaúba dos Batistas, Triunfo Potiguar, Umarizal, Upanema, Venha-Ver and Viçosa.

B. glabrata/B. straminea (3): Rio do Fogo, Santa Maria and São Miguel do Gostoso.

Negative municipalities (7): Caiçara do Norte, Carnaúba dos Dantas, Goianinha, Paraú, Patu, Santa Cruz and Tibau do Sul.

Discussion

The results of our study show that the presence of intermediate hosts was recorded in 70.2% of the municipalities studied. The data collected provide

additional information – which had been scarce until then - for the archives of the health surveillance teams (http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sinan/pce/cnv/pcebr.def). Notwithstanding, the records provided by this study are in keeping with the known distribution of the three intermediate host species.[9] It is important to emphasize the simultaneous occurrence of two intermediate *S. mansoni* host species, namely B *straminea* and *B. glabrata*, in 53 municipalities of the five states under analysis. In the case of the state of Rio Grande do Norte, 62% of the information was obtained from the records on the collection of mollusks kept at the Oswaldo Cruz Institute (Fiocruz/CMIOC), reinforcing the importance of the Fiocruz policy of preservation and maintenance of biological collections. On the other hand, mollusks (*B. glabrata*) infected with *S. mansoni* were found in only three municipalities out of the 427 studied. Our research confirms: the geographic distribution of these mollusks has been slow, progressively reaching new locations, and corroborates the data obtained by numerous researchers, as well as the data obtained by the National Health Foundation, State Departments of Health and the Ministry of Health Department of Health Surveillance, provided by the managers of the Schistosomiasis Surveillance and Control Program. These databases have been fed by numerous sources and publications.[6-24]

In spite of the efforts made, data about the actual geographic distribution of these mollusks throughout all the national territory are subject both to the difficulty of access to certain regions of the country and the lack of financial resources and limited number of researchers working in this specific area. Another major limitation lies in the capacity of intermediate hosts of *S. mansoni* to adapt to inappropriate environmental conditions, such as drought in their habitats, thus imposing the need of conducting periodic searches in freshwater biotopes.[28] These mollusks are able to bury themselves as the environment becomes drier; while after the rainy season, they quickly repopulate the habitat thanks to their great reproductive capacity. According to Paraense,[28] a single *B. glabrata* specimen is capable of cumulatively producing ten million descendants in three months. Besides burying themselves, these mollusks can survive even if they are infected with *S. mansoni*, by reducing their metabolism and remaining in diapause or anhydrobiosis.[29] The geographical distribution of *S. mansoni* intermediate hosts in Brazil provides schistosomiasis with the ability to spread, including to areas considered to be unaffected.[6,9,30]

The geographical distribution and the correct identification of three intermediate *S. mansoni* host species are important to guide health care workers and the surveillance and environmental control measures in each locality, allowing the interruption of the disease's epidemiological chain. Studies like this one contribute to health services in terms of improving or more appropriate structuring of schistosomiasis control and surveillance activities, directing actions toward areas of risk and streamlining the application of resources available. *S. mansoni* intermediate host mollusk monitoring activities and research into of larval forms of *S. mansoni* need to be permanent activities, as preventive measures to prevention the spread or outbreaks of schistosomiasis in Brazil.

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Authors' contributions

Carvalho OS, Thiengo SC, Caldeira RL, Fernandez MA and Marcelino JMR contributed substantially to the conception, data analysis and interpretation, preparation of the preliminary versions and writing final version of the manuscript. Scholte RGC contributed with the interpretation of the results, preparation of the preliminary versions, revision of the final version, processing the data and construction of maps. Jannotti-Passos LK, Mendonça CLF, Carmo EH, Mesquita SG and Leal RS participated in data analysis and interpretation, writing and revising the manuscript. All the authors have approved the final version and declared themselves responsible for all aspects of the study, ensuring its accuracy and integrity.

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