Schistosomiasis in America

Oscar Noya, Naftale Katz, Jean Pierre Pointier, André Theron, and Belkisyolé Alarcón de Noya

Contents

O. Noya (✉)
Cátedra de Parasitología, Escuela de Medicina Luis Razetti, Facultad de Medicina, Universidad Central de Venezuela-UCV, Caracas, Venezuela

Sección de Biohelmintiasis, Instituto de Medicina Tropical, Facultad de Medicina, UCV, Caracas, Venezuela

Centro para Estudios Sobre Malaria, Instituto de Altos Estudios "Dr. Arnoldo Gabaldón" INH-MPPS, Caracas, Venezuela
e-mail: noyaoo@yahoo.com

N. Katz
Centro de Pesquisas René Rachou/CPqRR – Fundação Oswaldo Cruz, Minas Gerais, Brazil
e-mail: nkatz@cpqrr.fiocruz.br

J.P. Pointier
USR 3278 CNRS-EPHE-CRIOBE, Université de Perpignan, Perpignan, France
e-mail: pointier@univ-perp.fr

A. Theron
CNRS.UMR 5244 CNRS-UPVD. Ecologie et Evolutiondes Interactions (2EI) Université de Perpignan, Perpignan, France
e-mail: theron@univ-perp.fr

B.A. de Noya
Cátedra de Parasitología, Escuela de Medicina Luis Razetti, Facultad de Medicina, Universidad Central de Venezuela-UCV, Caracas, Venezuela

Sección de Inmunología, Instituto de Medicina Tropical, Facultad de Medicina UCV, Caracas, Venezuela
e-mail: belkisyole@yahoo.com.mx

C. Franco-Paredes, J.I. Santos-Preciado (eds.), *Neglected Tropical Diseases - Latin America and the Caribbean*, Neglected Tropical Diseases,
DOI 10.1007/978-3-7091-1422-3_2

Abstract Schistosomes are parasitic flatworms that cause schistosomiasis, a Neglected Tropical Disease affecting at least 249 million people worldwide. It is the most important waterborne disease in America introduced to this continent during the time of the African slave trade. Of the seven species that infect humans, only *Schistosoma mansoni* is present in America. Schistosomiasis is endemic in Brazil, Suriname, Venezuela, Dominican Republic, Guadeloupe, and St. Lucia. Around 1.8 million people in the region, mostly in Brazil, are thought to be infected, with 25 million living at risk of contracting the disease. The main risk factor for infection is skin exposure through household, work, or recreational activities in water bodies contaminated with cercariae, the infective larval stage of the parasite, released by freshwater mollusks of the genus *Biomphalaria*, that eventually enter the human skin. Adult worms in the porto-mesenteric venous system release hundreds of eggs which leave the body by stools or remain trapped in the intestine and liver, causing intestinal and hepatic pathology progressing to portal hypertension. Initially, schistosomiasis control was based on snail elimination with chemical moluscicides; since 1984 the strategy was reoriented to selective or mass chemotherapy and, since 2006, to preventive chemotherapy with praziquantel. Migration of rural populations, socioeconomic improvement, potable water supply, sanitation, increased exposure of flowing populations toward water bodies during weekends, invasion of exotic snails, chemotherapy program, and persistence of susceptible *Biomphalaria* species in endemic countries are factors that have modified the epidemiology in different ways in the six countries affected in America where prevalence varies.

Keywords Schistosomiasis • *Schistosoma mansoni* • *Biomphalaria* • Latin America • Caribbean • Venezuela • Dominican Republic • St. Lucia • Suriname • Brazil

1 Introduction

Schistosomiasis is a chronic parasitic disease caused by trematodes of the genus *Schistosoma* present in tropical and subtropical areas. Seven species: *Schistosoma mansoni, S. intercalatum, S. guineensis, S. japonicum, S. mekongi, S. malayensis,* and *S. haematobium* infect humans; the first six species cause the intestinal clinical form and the seventh causes the urogenital form of the disease.

Fig. 1 Distribution of schistosomiasis in America

Schistosomiasis is the most important waterborne disease in America that was introduced to this continent during the time of the African slave trade between the sixteenth and nineteenth centuries (Morgan et al. 2005), but only the African species *Schistosoma mansoni* (Sambon 1907a) was able to infect local snail species of the genus *Biomphalaria* (*B. glabrata*, *B. straminea*, *B. kuhniana, B. prona, and B. tenagophila*) (PAHO 1968; Malek 1980; De Jong et al. 2001). In America, schistosomiasis is endemic in Suriname, Venezuela, Dominican Republic, Guadeloupe, St. Lucia, and large areas of Brazil (Fig. 1). This trematode infection behaves

1. **Initial phase**:
Acute form
a. asymptomatic
b. symptomatic

2. **Late phase**
Chronic phases – according to the most affected organs:
a. Hepatic-intestinal
b. Hepatic: periportal fibrosis without splenomegaly
c. Hepatosplenic: periportal fibrosis with splenomegaly
d. Complicated forms: i. vasculopulmonary
ii. glomerulopathy
iii. neurological
iv. other localizations: eye. skin. urogenital. etc.
v. pseudoneoplasic
vi. lymphoprolific disease

3. **Associated diseases that modify the course of schistosomiasis**
a. prolonged salmonellosis
b. liver abscess
c. in immunosuppressed cases (SIDA. HTLV. use of immunosuppressive drugs. etc.)
d. other hepatic disorders : viral, alcoholic. etc.

This clinical classification was elaborated by a group of Brazilian specialists, who gathered in 2008, at the occasion of the 44th Congress of the Brazilian Society of Tropical Medicine, at the request of the Ministry of Health (Katz, 2014)

Chart 1 Classification of clinical forms of Schistosomiasis mansoni

as a real antroponosis having limited ability to maintain the infection only in wild reservoirs in southeast Brazil (*Nectomys squamites*) (D'Andrea et al. 2000) and Guadeloupe (*Rattus rattus*) (Théron and Pointier 1995; Alarcón de Noya et al. 1997). Around 1.8 million people in the region, mostly in the coastal states of Brazil, are thought to be infected, with 25 million living at risk of contracting the disease in America (PAHO 2010).

The main contributing factor to the maintenance of schistosomiasis transmission in a community is the contamination of water sources mainly with human feces from people suffering from schistosomiasis, containing parasite eggs that hatch in water. These eggs release ciliated miracidiae infecting freshwater snails that later on eliminate tailed larvae (cercariae) which penetrate the human skin during contact with infested water. In humans, larvae migrate through blood vessel to the lungs and the portal system where they mature to adult worms. Hundreds of eggs released daily by each female adult worm must either leave the body by stools or become trapped in nearby tissues causing pathology (WHO 2014a; Colley et al. 2014). Inflammatory response to eggs trapped in intestine and liver tissues results in pathology, associated with intestinal manifestations (intestinal form) and liver fibrosis that progress to portal hypertension (hepatointestinal and hepatosplenic forms). More explicit clinical forms are summarized in Chart 1. In consequence, infected individuals develop anemia, malnutrition, stunted growth, impaired cognitive development, and reduced capacity to work (Gryseels 2012).

The main risk factor for infection is skin exposure through household, work, or recreational activities in water bodies contaminated with feces from infected humans (WHO/PAHO 2014). In consequence, schistosomiasis is considered a disease of poverty, associated with the lack of basic health services (domestic potable water and wastewater treatment) and poor education for health.

Initially, schistosomiasis control was based on snail elimination with chemical moluscicides; since 1984 the strategy was reoriented to selective or mass chemotherapy with praziquantel (Pzq) and oxamniquine and, since 2006, to preventive chemotherapy with Pzq (WHO 2013). The preventive chemotherapy strategy for schistosomiasis control is based on the reduction of morbidity and transmission through periodic groups targeted for treatment with Pzq. These groups are school-aged children and adults at risk due to occupation or domestic tasks associated with water contact and entire communities living in highly endemic areas. The frequency of treatment is determined by the prevalence of infection in school-aged children (WHO 2006).

In recent decades, there have been significant epidemiological changes in America, such as socioeconomic improvement and increased health activities, which have conditioned disappearance of transmission in Puerto Rico; invasions of new competitor snail species (*Marisa cornuarietis* and *Melanoides tuberculata* (Pointier et al. 2011), management of the environment, and the migration of rural population to cities where there is limited water contact and pollution of the local rivers and other water bodies have decreased the possibility of water contact and transmission. This latter demographic factor adds to the fact that rural population has moved to urban places leaving the rural transmission foci of schistosomiasis and the numbers of reduced rural population have favored schistosomiasis control. The percentage of rural population decreased in Brazil from 70.5 % in 1950 to 15 % in 2013, from 59.5 to 1 % in Puerto Rico, and from 70.5 to 6 % in Venezuela, in the same period of time. (World Bank 2013; Negociado del Censo de los EE.UU. Puerto Rico 2010). This simple demographic factor has been underestimated and has quite possibly been one of the key factors in the decline of transmission in most countries of this continent. Noteworthy in contrast, in certain countries as Venezuela, is the increased exposure of urban tourist populations toward courses and water bodies in nearby endemic areas during weekends which is a risk for acquiring the infection and producing undetectable new cases, underestimating the true prevalence, and allowing maintenance and dispersion of the parasite.

This silent and chronic neglected tropical disease has become of secondary importance for Health Ministries due to the increasing relevance of other vector-borne diseases such as dengue, malaria, and chicungunya among others, in addition to administrative and political changes in most of the endemic countries of the region. However, ecological changes (pollution of infested rivers and water bodies), demographic changes (migrations from rural to urban areas), and improvement of socioeconomic standards (housing, domestic water supplies, and sanitation) might have had the most important impact on the control of schistosomiasis. The elimination of transmission in Puerto Rico and the almost disappearance in Antigua, Dominican Republic, Martinique, Guadeloupe, and Montserrat from the Caribbean islands, together with a similar trend of control in Brazil, indicate that when there is a proper political decision associated with socioeconomic amelioration, it is possible and realistic to carry out its elimination in America.

One of the important aspects that are usually not mentioned in the data provided by the surveillance control programs of different countries is the degree of morbidity. Partial data are provided in this chapter from Brazil and Venezuela. It is noticeable that because of the decreasing intensity of the disease, there is a progressive and sustained diminution in morbidity severity and consequently in mortality. Moreover, it is necessary to improve the diagnostic tests for schistosomiasis, since low parasite burden usually courses with asymptomatic or oligosymptomatic forms of the disease, limiting clinical and classical laboratory diagnosis, underestimating in this way the true prevalence from each country (Alarcón de Noya et al. 2000; Noya et al. 2002; Enk et al. 2008; Colley et al. 2013).

The main epidemiological aspects of schistosomiasis are described as follows in the Caribbean islands and the mainland countries, Brazil, Suriname, and Venezuela.

2 Schistosomiasis in Brazil

2.1 Historical Background

Schistosomiasis was introduced in Brazil due to the traffic of African slaves. Between 1550 and 1850, it is estimated that 3.5–4 million Africans disembarked in Brazil, coming from regions where today's Angola, Benin, Nigeria, Ivory Cost, Guinea, Mali, and Mozambique are situated. Initially, this slave labor was introduced in the northeast of Brazil (Pernambuco and Bahia) in the sixteenth century. In the eighteenth century, with the discovery of gold and diamond in Minas Gerais, the migration was intense and it is estimated that 1/5 of the country's population migrated to this region (Lambertucci et al. 1987).

The introduction and dissemination of schistosomiasis was always linked to the economic development in the country. Thus, in the middle of the nineteen and the twentieth centuries, the migration to São Paulo and to the north of Paraná was initiated, where several foci of schistosomiasis were created. The same occurred in Fordlândia (Amazonas State), a city created by Ford Company to explore gum during the Second World War, counted with the labor of northeastern migrants.

A large number of the African slaves were certainly infected by *Schistosoma mansoni* and *Schistosoma haematobium*. *Schistosoma mansoni* found at least three species of snails of *Biomphalaria* genus as intermediate hosts: *B. glabrata, B. straminea,* and *B. tenaghophila.* It seems that these intermediate hosts were already in Brazil for over 1–2 million years, while the genus Bulinus was not present, not allowing the transmission of *S. haematobium* (Paraense 2008).

Otto Wucherer in 1866, who worked in Bahia, examined dozens of urine samples from patients at the request of Wilhelm Griesinger in 1866. Wucherer and Theodor Bilharz, who discovered the *Schistosoma haematobium* in Egypt, were classmates in the School of Medicine in Tubingen, Germany (Katz 2008). Wucherer did not find *S. haematobium* eggs in urine, although in August 4th 1866 he found microfilariae of a new species of parasite named later on as *Wuchereria bancrofti* (Coni 1952). The first cases of schistosomiasis mansoni in Brazil were reported in 1908 by Manoel Pirajá da Silva, with a description of 20 cases diagnosed by means of stool examination, where he found eggs with lateral spine (Pirajá da Silva 1909). Pirajá da Silva performed necropsies in three patients, and found 1 worm in the first two necropsies, in the third one he found 24 worms, describing adults and lateral-spined eggs in the female uterus. This description was decisive to differentiate *S. mansoni* from *S. haematobium* (Falcão 1959).

Although Sambon (1907a, b) named the new species as *S. mansoni* in honor of Patrick Manson, it was Pirajá da Silva who really described for the first time the worms of this species, since Sambon had examined a sole male worm incompletely in poor condition. Nevertheless, this important description by Pirajá da Silva was never recognized by Robert Leiper, when in 1915 he reproduced experimentally the life cycle of both parasites (Falcão 1953, 1959; Katz 2008). Lutz was responsible for the first description of Brazilian planorbids, intermediate hosts of schistosomiasis, and published a series on the life cycle of *Schistosoma mansoni* in *B. glabrata* and *B. straminea* snails, in Brazil (Lutz 1919). Brazilian researchers have contributed very much to the knowledge of schistosomiasis, in all fields, life cycle, treatment, clinical studies, pathology, diagnosis, epidemiology, control, genome, etc. (Katz 1992; Carvalho and Katz 2008).

The Integrated Program for Schistosomiasis (PIDE), at the Oswaldo Cruz Foundation, started in 1986, and 13 International Symposia on Schistosomiasis have been achieved every other year (Katz 2006).

2.2 Prevalence

To evaluate the prevalence of schistosomiasis in Brazil, two national surveys were previously conducted. The first one by Pellon and Teixeira (1950) and another one referring to the Special Program for Schistosomiasis Control "Programa Especial de Controle da Esquistossomose" (PECE 1976).

In the first survey, the prevalence of schistosomiasis was around 10 % in the states examined. The states of north, mid-west, south, and São Paulo were not included in this survey (Table 1) (Fig. 2). In PECE (1977) the prevalence was 6.6 %; all the states were examined, except the northern territories and Bahia (Table 1). In 2011, the Ministry of Health by means of the Oswaldo Cruz Foundation initiated the third National Survey on Prevalence of Schistosomiasis mansoni and Geo-helminthes ("Inquérito Nacional de Prevalência da Esquistossomose mansoni e Geo-helmintoses"), which is almost concluded. Approximately,

Table 1 National prevalence of schistosomiasis in Brazil between 1949 to 2014

		Pellon and Teixeira (1949)			PECE (1975–1977)			Katz et al. (2011–2014)		
Region	States	Examined	Positive	%	Examined	Positive	%	Examined	Positive	%
North	Acre	ND	ND	ND	ND	ND	ND	2,476	0	0.0
	Amazonas	ND	ND	ND	ND	ND	ND	2,857	0	0.0
	Amapá	ND	ND	ND	ND	ND	ND	1,686	0	0.0
	Pará	ND	ND	ND	28,227	124	0.35	2,558	8	0.23
	Rondônia	ND	ND	ND	ND	ND	ND	2,961	0	0.0
	Roraima	ND	ND	ND	ND	ND	ND	2,244	0	0.0
Northeast	Pernambuco	50,031	12,635	21.34	23,495	3,072	6.62	20,744	457	1.94
	Ceará	40,314	380	1.08	19,867	599	1.81	9,054	0	0.0
	Alagoas	14,966	3,065	19.17	70,040	14,712	19.06	12,735	307	2.66
	R.G. do Norte	18,662	433	2.19	11,870	70	0.6	9,648	5	0.04
	Bahia	74,015	12,237	15.38	ND	ND	ND	27,923	824	4.97
	Sergipe	14,675	4,423	27.46	6,085	1,926	31.49	11,735	740	6.55
	Paraíba	21,305	1,584	6.8	10,294	603	5.28	8,377	52	0.5
	Piauí	10,420	4	0.03	8,518	0	0.0	6,975	1	0.01
	Maranhão	12,716	59	0.45	13,754	446	2.82	9,415	21	0.24
South-East	Minas Gerais	162,176	7,953	6.51	55,605	5,656	6.98	34,606	850	0.89
	São Paulo	ND	ND	ND	ND	ND	ND	3,668	4	0.11
	E. Santo	12,822	209	2.39	11,057	290	1.37	7,084	61	0.86
	R. de Janeiro	ND	ND	ND	24,253	128	0.61	4,388	2	0.06
East-Center	Distrito Federal	ND	ND	ND	ND	ND	ND	2,722	0	0.0
	Goiás	ND	ND	ND	13,318	17	0.16	4,205	0	0.0
	Mato Grosso	ND	ND	ND	9,881	48	0.29	1,064	0	0.0
	Mato Grosso do Sul	ND	ND	ND	7,678	5	0.15	1,358	4	0.18
	Tocantins	ND	ND	ND	3,866	2	0.03	1,603	0	0.0

South	Paraná	ND	ND	ND	81,825	1,579	0.52	5,858	0	0.0
	Santa Catarina	ND	ND	ND	14,522	0	0.0	4,721	0	0.0
	Rio Grande do Sul	ND	ND	ND	29,222	1	0.0	2,127	0	0.0
	Brazil	432.102	42.982	9.94	443.377	29.278	6.60	204.153	3.336	1.63

ND, Not done

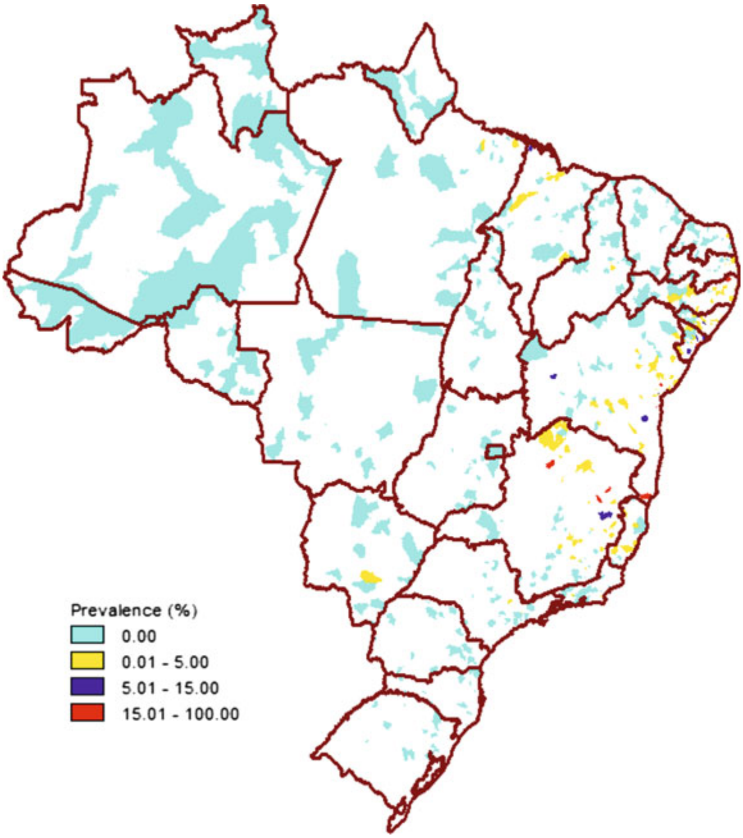

Fig. 2 Prevalence of Schistosomiasis mansoni in Brazil

200,000 school children (7–14-year old) have been examined by Kato Katz stool examination (Katz et al. 1972). This survey was conducted in 27 states of the Federation, including the Federal District and 540 municipalities. Schistosomiasis was found in 13 endemic states; since the cases from Mato Grosso do Sul were not autochthonous (Table 1) (Fig. 2). The states with higher prevalence were Sergipe (6.55 %), Bahia (4.97 %), Alagoas (2.66 %), and Pernambuco (1.94 %) (Katz et al. 2014).

Currently, the total prevalence in the country is 0.7 %, showing a significant decrease, when compared with the previous surveys (Table 1). When these numbers are extrapolated to the meso-regions for each state, an estimated number of 1.5 million people would be infected in the country. This kind of survey, although valid to show the prevalence in the country as a whole, does not allow the detection of isolated foci or areas that have not been selected. Some isolated foci with very low prevalence must be mentioned: one in the State of Rio Grande do Sul; two in the State of Santa Catarina; and several foci in Ceará, Paraná, and others (Fig. 2).

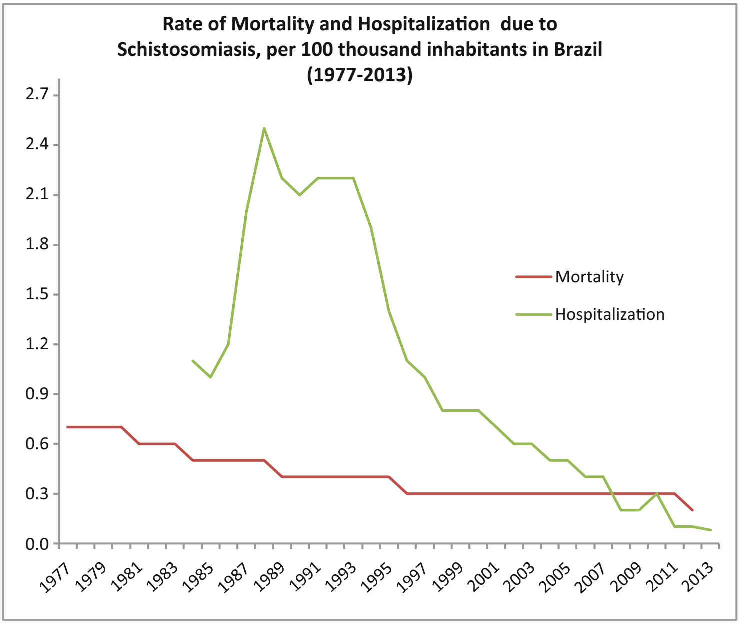

Fig. 3 Rate of mortality and hospitalization in Brazil due to schistosomiasis in Brazil 1977–2013 (*Source* Katz et al. 2014)

2.3 Morbidity, Mortality, and Treatment

The data of low prevalence are also corroborated by the intense decrease in the mortality rate, as well as in cases of hospitalization due to schistosomiasis, which occurred in the last decades Fig. 3. The hospitalization rate due to schistosomiasis was 2.5 % per 100,000 inhabitants in 1988 and 0.08 % in 2013. The mortality rate decreased from 0.5 % in 1987 to 0.2 % in 2012.

In the parasite life cycle prepostural phase, the drug of choice is oxamniquine. After egg laying, praziquantel is the recommended drug (Coelho et al. 2009). The first clinical trial using praziquantel (the drug of choice) for *S. mansoni* infection was made in Brazil, by Katz et al. (1979). The recommended dose is 50 mg/kg for adults and 60 mg/kg for children (up to 15-year old), single dose and oral route. Brazilian researchers demonstrated that the specific clinical treatment prevents the appearance of hepatosplenic form, even if the patient is reinfected (Kloetzel 1963, 1967; Bina 1977). This finding led the World Health Organization to indicate morbidity control by means of specific clinical treatment, as a measure for the control of schistosomiasis in endemic areas (WHO 1985).

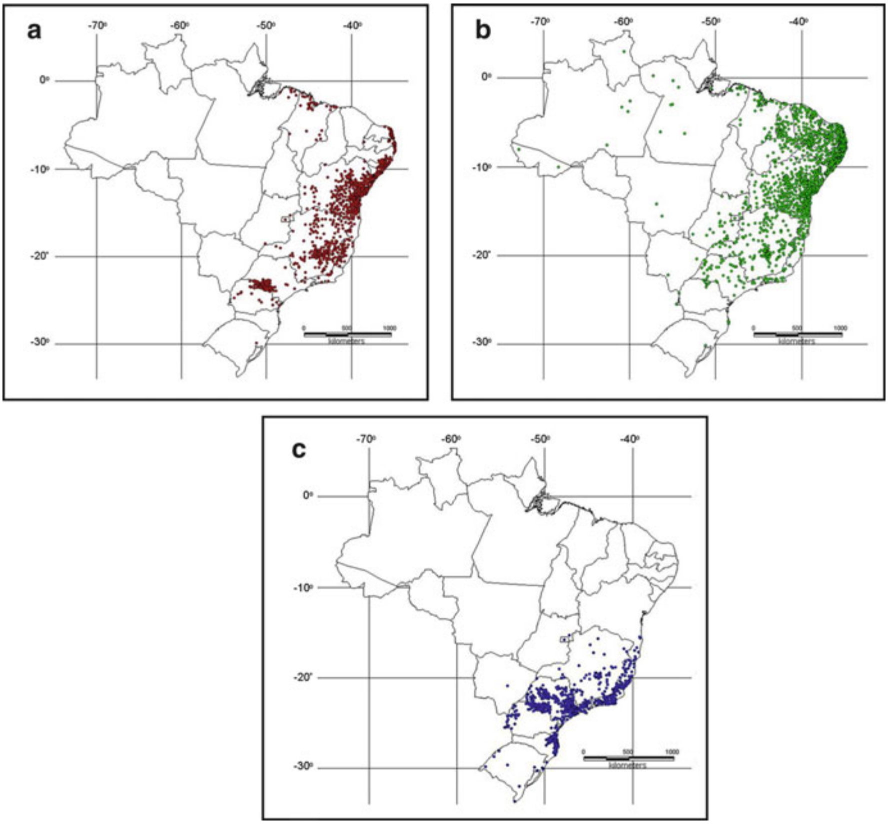

Fig. 4 Distribution of *B. glabrata* (**a**), *B. straminea* (**b**), *and B. tenagophila* (**c**) in Brazil (*Source* Carvalho et al. 2008)

2.4 Intermediate Hosts

Wladimir Lobato Paraense (1914–2012), the most important Brazilian malacologist and one of the best in the world, made the first map on the distribution of Schistosomiasis intermediate hosts in Brazil (Paraense 1970). Paraense is responsible for clarifying the classification and distribution of snail species in America and for the description of new snail species.

The data presented here are a summary of the Paraense publications, of Secretaria de Vigilância de Saúde do Ministério da Saúde do Brasil, and of the Laboratory of Intestinal Helminthosis, Research Center René Rachou/FIOCRUZ. Detailed information can be found at the review made by Carvalho et al. (2008). The three species, intermediate hosts of *S. mansoni* in Brazil, belong to the genus *Biomphalaria*: *B. glabrata, B. straminea,* and *B. tenagophila* (Fig. 4).

In recent decades, several malacological studies using molecular techniques have been carried out in Brazil in order to improve the knowledge on the genetic variability of *Biomphalaria* spp. For example Knight et al. (1991) showed that Southern blot analysis using ribosomal gene probes may be useful for the molecular differentiation of *B. glabrata* from other intermediate hosts. Other works also showed the interest in using the RLFP analysis of the internal transcribed spacer region of the rRNA gene for the identification of several species of *Biomphalaria* (Caldeira et al. 1998, 2000; Vidigal et al. 1998).

B. glabrata
The most important intermediate host is *B. glabrata.* It is axiomatically affirmed that where *B. glabrata* is present, schistosomiasis exists. This species has been observed in 16 states and in 806 municipalities from southeastern to the south region (Carvalho et al. 2008) (Fig. 4a). Graeff-Teixeira et al. (1999) described a new schistosomiasis focus at Esteio, at the Metropolitan Area of Porto Alegre, Capital of Rio Grande do Sul, maintained by *B. glabrata*. This is a serious problem since this area is near to Argentina, Paraguay, and Uruguay where schistosomiasis is absent.

B. straminea
This snail is the second one in importance as schistosomiasis intermediate host, with the largest distribution being present in 24 states and 1,325 municipalities including the Federal District (Brasília) (Carvalho et al. 2008) (Fig. 4b). *B. straminea* is the best adapted snail for all climate and ecological conditions (Paraense 1970, 1986).

B. tenagophila
This species has a more limited distribution, starting in the south of Bahia up to Rio Grande do Sul, including Brasília, Goiás, and Mato Grosso do Sul, in a total of 10 states and 63 municipalities (Carvalho et al. 2008) (Fig. 4c).

Two new species very similar to *B. tenagophila* were described: *B. occidentalis* (Paraense 1981) and *B. guaiabensis* (Paraense 1984). Both are resistant to schistosomiasis infection. Another species, *B. amazonica,* from the Amazon region was described and showed susceptibility to infection with miracidiae from northeastern or Minas Gerais regions (Corrêa and Paraense 1971).

2.5 Nonhuman Vertebrate Hosts

In Brazil, the first findings of natural rodent infection were made by Amorim (1953) in the state of Alagoas and Barbosa et al. (1953) in Pernambuco. A larger survey was made in two cities of the State of Minas Gerais. At Jaboticatubas city, only *Didelphis paraguayensis* and *Nectomys squamipes aquaticus* were found naturally infected, with 2.5 and 57.5 % prevalences, respectively. In Belo Horizonte five species were found: *Rattus norvegicus, Oryzomis mattogrossae, Zygodomys lasiurus, Cavia aperea aperea,* and *D. paraguayensis* (Vianna Martins et al. 1955). Infected wild rodents and marsupials were also captured in Bahia, Sergipe, Rio de Janeiro, São Paulo, and Paraná (Vianna Martins 1958).

In the wild rodent *Nectomys squamipes*, captured in Baldim, Minas Gerais, the *S. mansoni* strain (N) behaved similarly to the human strain (LE), and *Nectomys* is a good host for *S. mansoni*. The complete life cycle of *S. mansoni* could be achieved under seminatural conditions, using the system *Nectomys*—*B. glabrata*—*Nectomys* (Antunes et al. 1973). Similar results were also obtained with *Holochilus braziliensis* (Carvalho et al. 1976). Naturally infected rodents, captured in Belo Horizonte, Baldim, and Lapa Vermelha, State of Minas Gerais, and studied under experimental conditions, showed that *R. novergicus, Nectomys squamipes aquaticus, Zygodontomys lasirus, Orysomis subflavus, Oryzomis nigripes eliurus* and *Calomys expulsus* can be considered good *S. mansoni* hosts and may have some influence on the epidemiological chain (Borda 1972).

Holochilus, Zygodontomys, and *Nectomys* have been found in São Paulo (Rodrigues and Ferreira 1969; Dias (1972) similarly to that recorded for other Brazilian States (Bastos et al. 1978; Kawazoe and Pinto 1983). Studies on eco-epidemiology conducted in open areas prepared for these experiments seem to indicate that under special conditions, that is, when there is high population density of wild rodents, especially *Nectomys* and/or *Holochilus,* and when *B. glabrata* is the intermediate host, it is possible that the parasite's life cycle can exist without the presence of man (Dias 1976; Kawazoe and Pinto 1983).

In the State of Maranhão, *Holochilus brasiliensis nanus* was the only wild rodent captured throughout 1 year. At every month, infected animals were captured harboring a great number of *S. mansoni* worms and eggs (Veiga-Borgeaud et al. 1986). At Sumidouro area, in the State of Rio de Janeiro, *Nectomys squamipes* and *Akondon arviculoides* were found naturally infected. A strain isolated from one of those infected *Nectomys* was able to infect 75 % of *B. glabrata* and 100 % of albino *Mus musculus* under laboratory conditions (Rodrigues-Silva et al. 1992; D'Andrea et al. 2000; Gentile et al. 2006).

Cattle have been found infected with *S. mansoni* in Brazil (Barbosa et al. 1962; Piva and Barros 1966). Coelho et al. (1979) showed a prevalence of 3 % in cattle in an endemic area in Minas Gerais. The wild and domestic animals as reservoirs of *S. mansoni* in Brazil were recently reviewed (Modena et al. 2008).

The role of wild rodents and bovines, in the epidemiology of schistosomiasis at the endemic areas in Brazil, has not been proved. In fact, infected humans are essential for the maintenance of schistosomiasis. However, considering that the prevalence of schistosomiasis is sharply decreasing, it is possible that wild and domestic animals as reservoirs of *S. mansoni* could increase in importance.

2.6 Control

The first attempt for the control of schistosomiasis in Brazil was made by Jansen, when in the 1940s he began studying this subject in Catende, Pernambuco. In that urban community where about 7,000 people lived, the positivity rate for schistosomiasis was initially 53 %, and *B. straminea* was found infected in several foci. The approach for control was multiple: applying calcium hydroxide as moluscicide; treatment of the human population with different antimony salts; construction of public latrines, washing tanks, and sand filter in the water reservoirs of the community; and construction of urban and rural septic tanks and health education. Two years later, the prevalence rate decreased to 12 % (Jansen 1946). Sette (1953) carried out a reevaluation in the area, where more than 3,500 people had been treated from 1943 to 1947. When schistosome-induced lesions—detected by means of histological examination performed at liver fragments obtained by viscerothomy—were compared, from 1937 to 1941 and from 1942 to 1945, the percentage was from 16.5 % to 11.5 %, and when only "cirrhosis" was considered, the frequency was 32.6 and 11.1 %, respectively. At that time, cirrhosis and hepatic fibrosis were not differentiated. The differentiation was made only in the 1960s, especially due to the work of Luigi Bogliolo, carried out at the School of Medicine, Federal University of Minas Gerais (Bogliolo 1958, 1959). Kloetzel treated a group of 112 children infected by *S. mansoni* using antimonial salt, in Gameleira, Pernambuco. Evaluation performed 6–11 months and 4 years posttreatment revealed that schistosomiasis positivity was reduced to 43 and 55 %, respectively, and to 83 % at the last evaluation. Before treatment, 23 children presented splenomegaly. At the end of the evaluation (4 years post-treatment), the spleen growth diminished in 10 cases, increased in 2, and disappeared in 11 other ones. None of the 60 children who presented intestinal and/or hepatointestinal form at the beginning of the study developed splenomegaly (Kloetzel 1963). These results led the author to conclude that 7–10-year-old children, who presented more than 500 eggs per gram, should be treated, even at risk of reinfection (Kloetzel 1967). Bina treated a group of 115 children with hycanthone, keeping another group without treatment as control, in Caatinga do Moura, Bahia. He observed that 2 to 5 years post-treatment, although all children were practically reinfected, none of them developed the hepatosplenic form, whereas in the control group 35 new cases were detected (Bina 1977). These data clearly demonstrated that it is possible to control morbidity, when children are treated, since treatment prevents the emergence of the hepatosplenic form. Many other studies were conducted in Brazil, aiming at controlling this endemia in the States of Pernambuco, Bahia, Minas Gerais, and Rio de Janeiro (Paulini et al. 1972; Prata 1976; Katz 1980; Barbosa et al. 2008)

In 1975, the Ministry of Health Almeida Machado (1977) designed and initiated the Special Program of Schistosomiasis Control—"Programa Especial de Controle da Esquistossomose" (PECE). The strategy of PECE would be (1) elimination (90 %) of miracidiae using chemotherapy (oxamniquine); (2) density reduction of snails for limited periods, to less than 1 % of the preexisting density; (3) coordination of these two activities in time and space; (4) sanitary improvements in each rural housing, latrine, shower, and laundry sink; (5) supply of drinking water and construction of public sets of fountain, latrine, shower, and collective laundry; and (6) health education. At the end of the program, it privileged the diagnosis and treatment, with very few measures for sanitation. The criterion for treatment from 1975 to 1980 in areas with prevalence superior to 20 % was mass treatment for people over 2 years old;

with prevalence between 5 and 20 %, only individuals 5–35 years old were treated, and with prevalence less than 5 %, only the positive ones were treated. After that, there were some changes of criteria used for the treatment of the population, and mass treatment was administered only when the prevalence in 7–14-year-old children was more than 50 %; when the positivity detected was 25–50 %, a selective treatment (children) was administered; and when it was less than 25 % only the positive ones were treated. Later, the family members residing in the same household were also treated. Since the end of the 1990s, praziquantel was the substitute for oxamniquine as the drug of choice, mainly due to the high cost of oxamniquine

In the last few years in Brazil, the treatment in mass scale is administered when the prevalence in children is higher than 25 %.

Although the "Schistosomiasis Control Program (PECE)" was not evaluated in all its extension, some works demonstrated that the hospitalization rate, prevalence and mortality due to schistosomiasis decreased significantly in endemic areas (Costa et al. 1996; Katz 1980; Coura and Amaral 2004; Barbosa et al. 2008) (Figs. 2 and 3).

Currently, it is estimated that more than 15 million Brazilian people have been treated in the northeast and in Minas Gerais, which are the most important endemic regions for schistosomiasis in Brazil, in the last 30 years. In 2005, an evaluation was performed in an endemic area in Minas Gerais, which has been followed up since 1974. The initial population was of 1,500 with a schistosomiasis prevalence of 70 %. Between 1981 and 1992, five treatments were administered in patients excreting *S. mansoni* eggs in stools. At the same time, more than 95 % of the houses got drinking water supply and sewage. The results showed a marked reduction of the prevalence from 70 to 1.7 % and of hepatosplenic forms from 7 to 1.3 % (Sarvel et al. 2011). Barbosa et al. (1971) in Potezinha, Pernambuco, showed for the first time that it is possible to control this parasitosis by the construction of water supply and sewage.

The significant prevalence reduction must be ascribed not only to the treatment of millions of people, but mainly to the great increase of housing water supply and sewage. As seen in Fig. 5, in 2010, more than 85 % of the housings in Brazil had water supply and about 55 % got sewage. If this action persists, perhaps in 10 or 20 years, schistosomiasis can be eliminated from the country, that is, to be no more a disease of Public Health importance.

3 Schistosomiasis in the Caribbean Islands

The Caribbean region commonly named as Antilles is composed of the Lucayan Archipelago, the West Indies, and a chain of islands surrounding the Caribbean Sea and composed of more than 700 islands, islets, reefs, and cays. The Caribbean islands are divided into the Greater Antilles on the north (Cuba, the Cayman Islands, Hispaniola (containing the Dominican Republic and Haiti), Puerto Rico, and Jamaica), and the Lesser Antilles on the south and east (Saint Kitts, Antigua and Barbuda, Montserrat, Guadeloupe, Dominica, Martinique, St. Lucia, Saint Vincent and the Grenadines, Barbados, Grenada, and Trinidad and Tobago) (Fig. 6).

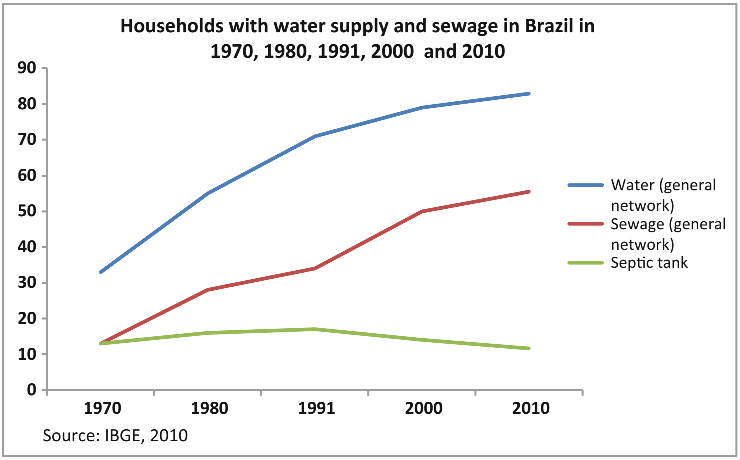

Fig. 5 Household with water supply and sewage in Brazil, 1970, 1980, 1991, 2000, and 2010

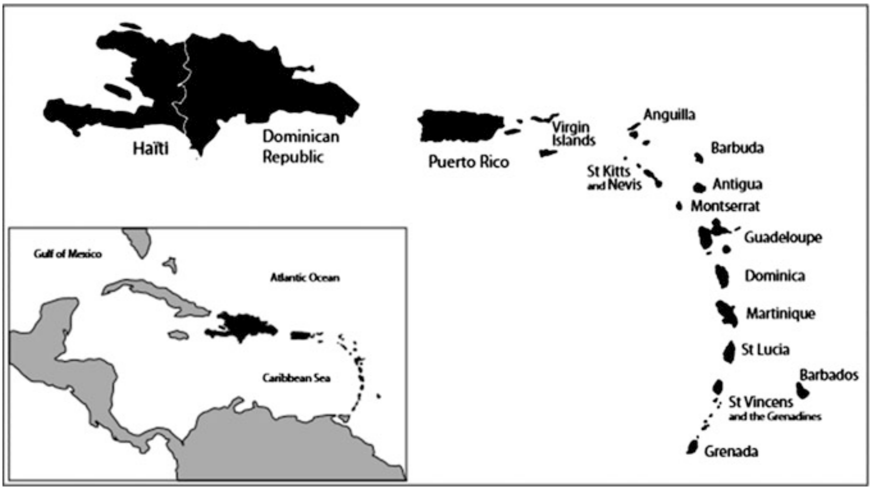

Fig. 6 Map of the Caribbean area

Historically, it is from the stool of a patient who had previously lived in Saint Kitts and Antigua that lateral-spined schistosome eggs were identified for the first time by Sir Patrick Manson (Seamen's Hospital in Greenwich) in 1902 and distinguished from *S. haematobium* with terminal-spined eggs in the urines. This new schistosome species was later described as *Schistosoma mansoni* by Luigi Sambon of the London School of Tropical Medicine in 1907 in honor of P. Manson.

The distribution of human intestinal schistosomiasis in this Caribbean region and its transmission was conditioned to the presence of freshwater habitats (rivers, pools, canals, reservoirs, and swamps) housing populations of the unique intermediate snail host species *Biomphalaria glabrata*. Dominican Republic, Puerto Rico, St. Kitts, Antigua and Barbuda, Montserrat, Guadeloupe, Martinique, and St. Lucia were the main endemic areas of schistosomiasis *mansoni* (Doumenge et al. 1987). In spite of *B. glabrata* is present in Haiti and Dominica, no autochthonous infections with *S. mansoni* have been reported in these two islands.

For most of these countries, intestinal schistosomiasis was first diagnosed between the beginning and the half of the twentieth century. The disease appears very irregularly distributed throughout the islands, according to the geography, the freshwater environments, the agricultural activities, the population density, and the socioeconomic level of the areas (Doumenge et al. 1987). In Puerto Rico and St. Lucia, the large-scale irrigation system for sugarcane has played an important role as favorable habitat for the snail hosts and the spread of the disease (Jobin 1980). In Guadeloupe, the mean prevalence detected by stool examination was very much higher in the valleys of the mountainous volcanic part of the Basse Terre (49 % in Baillif) than in the lowlands of the calcareous dry part of the Grande Terre (1 % in Anse-Bertrand) (Fig. 7) (INSERM 1980). In Martinique, it was the multiple very small transmission foci constituted by water cress beds that were considered as important sites of infection for numerous families (INSERM 1979; Pointier et al. 1984). In this island, during the 1970s, *B. glabrata* was gradually replaced by another species, *Biomphalaria kuhniana*, best adapted to the irregular water courses encountered in Martinique (Guyard et al. 1982) and fortunately few compatible to the local strain of *S. mansoni*, contributing to the decline of the disease. Contrasting with all other islands, the epidemiology of the schistosomiasis in Guadeloupe was characterized by the presence of a murine reservoir host (*Rattus rattus*) heavily infected (Alarcón de Noya et al. 1997). In the mangrove swamp focus of Grande Terre, murine prevalence could reach locally 100 % and parasite intensities more than 500 worms per rat (Théron et al. 2004). All around the Grand Etang lake in a rain forest of the south of the Basse Terre island, the rats were able to maintain alone the life cycle of the parasite in the absence of human infection. Adaptative genetic variations were demonstrated between murine and human schistosome populations (Théron 1984). While the cercariae from the human parasite showed the typical emergence pattern with a middle-day peak shedding time adapted to the water contact period of these populations, cercariae of the murine schistosome showed a late shedding pattern with a crepuscular emergence peak adapted to the nocturnal activities of the rodent.

Human schistosomiasis was an important health problem for all of these islands particularly between 1950 and 1980. Numerous stool or serological surveys showed that human prevalence higher than 70 % were common in several parts of these islands (Doumenge et al. 1987). Puerto Rico initiated in 1953 the first control program by the Puerto Rico Health Department, using limited chemotherapy and snail control by environmental, biological, and chemical means (Negro-Aponte and Jobin 1979) (Fig. 8). At the same time, extensive programs of water supply, health education, and free latrine distribution were implanted across the island (Hillyer 2005). The St. Lucia Research and Control project was developed between the years 1965 and 1981 (Jordan 1985). If chemotherapy was an effective way to reduce the prevalence, incidence, and transmission potential of the disease, the

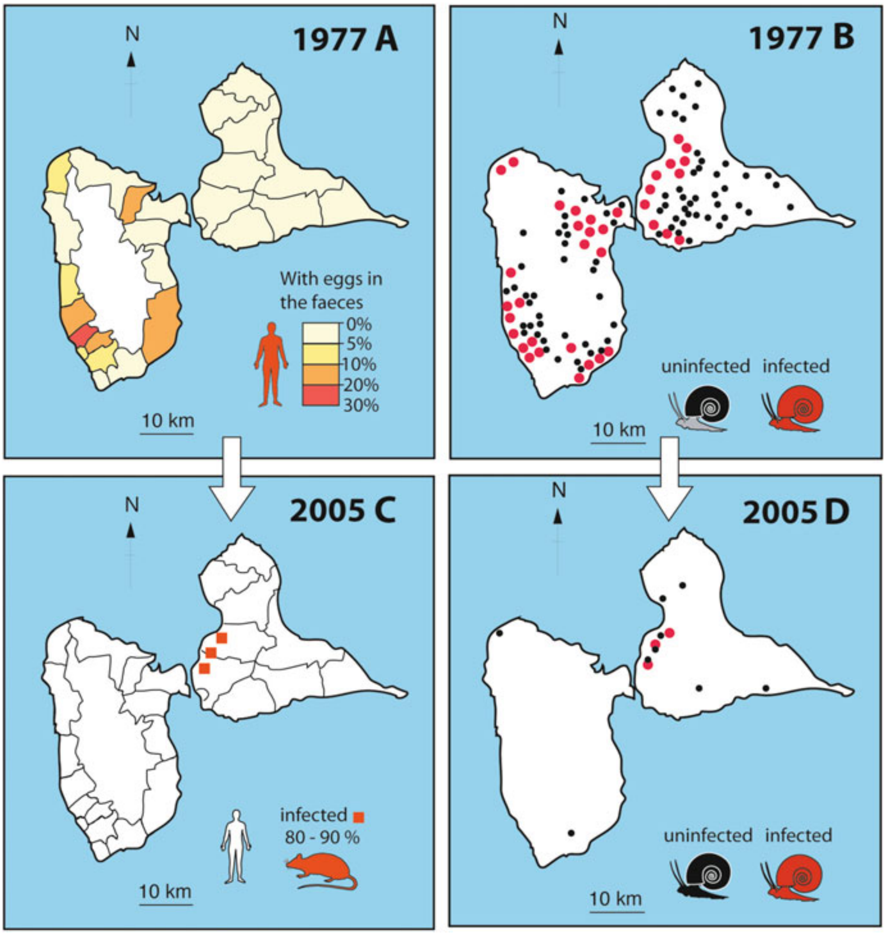

Fig. 7 Distribution and decrease of human intestinal schistosomiasis' prevalences and *Biomphalaria glabrata* snail populations in the island of Guadeloupe between 1977 and 2005

effect of snail control, the introduction of water supplies, and health education were also of importance. In Guadeloupe and Martinique, an integrated control program (chemotherapy, management of the environment, control of intermediate hosts) was initiated in 1978, and most of the transmission sites were eliminated in the1990s except the mangrove swamp foci of Guadeloupe where murine schistosomiasis was still present in 2005 (Pointier and Théron 2006).

Following the different control programs that have played an important role in the decline of the disease, other various factors have later contributed to achieve elimination (Rollinson et al. 2013). Indeed, most of these islands have experienced a rapid socioeconomic development with an improvement in housing, use of domestic water supplies and sanitation, healthcare facilities that have been essential to reduce infection level, and preventing reemergence of schistosomiasis. On another side, ecological changes, unassisted invasions of new competitor snail

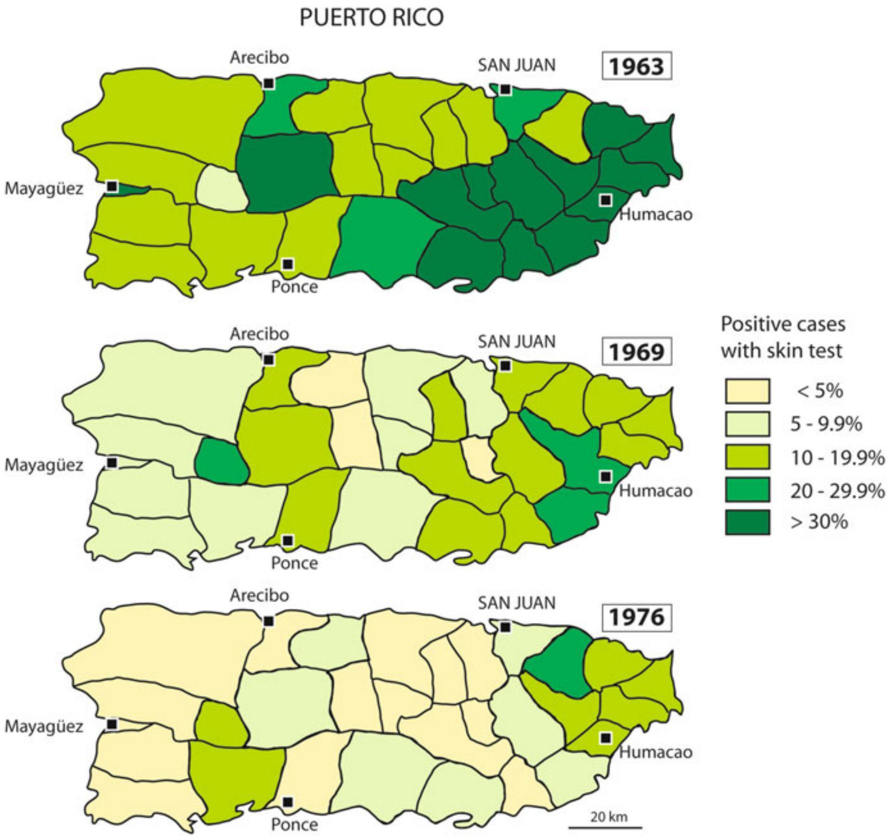

Fig. 8 Distribution and decrease of intestinal schistosomiasis between 1963 and 1976, as determined by intradermal test in 5th grade children in Puerto Rico

species, management of the environment, modification of fresh water milieu, and chemical pollution contributed to the decline and disappearance of snail host populations (Pointier et al. 2011).

All the Caribbean islands are now areas of no or very low transmission since the incidence of schistosomiasis has been dramatically reduced, making it possible for the disease to be eliminated (Schneider et al. 2011; Rollinson et al. 2013). St. Lucia seems to be the only country that has recently reported schistosomiasis infections. In 2010, a school-based study (550 children in three villages) revealed four active infections (prevalence, 0.6 %) (Kurup and Hunjan 2010). All recent trends suggest that human schistosomiasis is disappearing from Antigua, Dominican Republic, Martinique, Guadeloupe, Monserrat, and Puerto Rico. However, these countries require updating evaluation in order to verify if interruption of transmission has been achieved (WHO 2013). Vigilance remains always necessary to avoid the reemergence of the disease as recently observed in southern Europe where autochthonous transmission of the urinary schistosomiasis occurred in the Mediterranean French island of Corsica in 2012 and 2013 (Berry et al. 2014).

Fig. 9 Distribution of schistosomiasis in Suriname

4 Schistosomiasis in Suriname

Schistosomiasis mansoni is still present in Suriname, with an estimated general prevalence of 0.89 % in a country with a population of 529,000 persons. This prevalence varies between different areas and age groups. Highest prevalence is related to some occupational activities (fishing and agriculture) and to certain ethnic groups, Javanese and Hindustani, who live in rural areas of all the districts of the coastal plain (PAHO 2010; Rebollo 2010) (Fig. 9). The only available information about schistosomiasis in Suriname has been provided by a document elaborated by PAHO (2010), which is transcribed as follows: "The endemic areas comprise the territory from Commewijne district in the east to the settlement of Wagenigen in the west. It is thought that the establishment of an irrigation scheme for rice cultivation in Wagenigen introduced schistosomiasis transmission to the west of the coastal plain. The most recent data on schistosomiasis are from surveys conducted by the Ministry of Health in Commewijne and Saramacca districts in 1997 and 1998. The overall prevalence of infection in the samples taken was 3.1 % in Commewijne and 4.7 % in Saramacca district. In none of the communities surveyed was the prevalence of infection higher than 9 %. In Saramacca district, prevalence of infection was highest in those over 39 years of age, although 17 cases in children under 15 years, including 2 cases in under 5 s, were found. In Meerzorg, Commewijne district, prevalence of infection was highest among those over 19 years of age although 12 children below this age were infected. Studies conducted in the 1990s showed that schistosomiasis was a major cause of morbidity and mortality, with hematemesis, and pulmonary hypertension being the major consequences of infection. Two districts not previously reported as endemic for schistosomiasis—Nickerie (West) and Brokopondo should be surveyed in order to confirm the autochthonous transmission" (PAHO 2010).

5 Schistosomiasis in Venezuela

In Venezuela, a country of a surface area of 912,000 km^2, transmission persists in two distinct areas, the north central coastal region of the country (Valencia lake basin) covering an area of approximately 13,000 km^2, where 15,299,729 inhabitants live, representing 52.9 % of the population, with six major cities and a total of 27 populations above 50,000 persons. There is a secondary focus in a small rural area in the Andean region (Chabasquen basin) (Fig. 10). Schistosomiasis in Venezuela was initially discovered in Caracas by Vicente Raúl Soto (Soto 1906) in a patient at the Vargas Hospital in 26th October, 1905. The initial epidemiological studies using parasitological methods revealed a general prevalence of 14.6 % between 1943 and 1960 in the Northern Central region (Balzan 1988). A vertical control program of the Ministry of Health started in 1943. It was based on snail elimination with chemical moluscicides, improving housing, extensive programs of water supply and sewage, health education, and latrine construction. These measures, together with other factors such as pollution of rivers in major cities where the prevalence of transmission was high such as Caracas, Guarenas, Guatire, Cua, Charallave, Santa Teresa del Tuy, La Victoria, Maracay and Valencia, make parasitological prevalence of 14.6 % (Scott 1942; Balzan 1988; Alarcón de Noya et al. 2006) decreased to 0.7 % in 2012 (DGSSA-MPPS 2012; (Fig. 11).

Recent data provided by the Ministry of Health suggest that there is a progressive increase on the transmission, coincident with a decade of progressive diminution of epidemiological surveillance and control activities. The estimated average prevalence for the decade 2002–2011 was 0.93 % by Kato-Katz and 6.76 % by COPT (DGSSA 2012).

Fig. 10 Map of endemic areas in Venezuela

In relation to the parasite burden, field investigations between 2002 and 2010 in the endemic area using the Kato-Katz technique (Katz et al. 1972) have found that 74 % eliminates less than 100 eggs per gram of feces (egf) (light infection), 27.6 % between 100 and 400 egf (moderate infection), and none (0 %) eliminated more than 400 egf. In concordance with that data, the majority of the population exhibited moderate clinical form as follows: Asymptomatic 48.6 %, hepatointestinal 48.6 %,

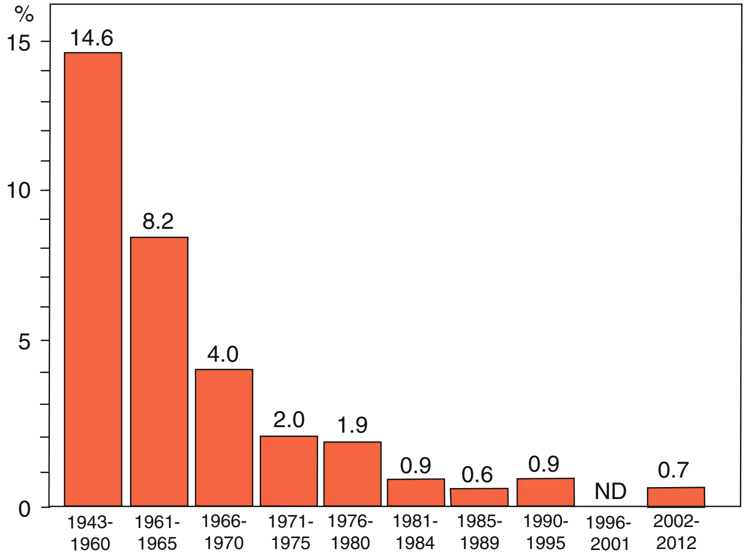

Fig. 11 Prevalence of schistosomiasis in Venezuela 1943–2012 (*ND* No Data, From Balzan (1988) and Dirección General Sectorial de Salud Ambiental, Ministerio del Poder Popular para la Salud, Venezuela, 2012)

and hepatosplenic only 2.8 % (Sección de Biohelmintiasis, IMT-UCV 2011, unpublished data). Nevertheless, since the mid-1990s, the control program was reduced, decreasing notably the epidemiological surveillance on the human population, as well as on the rivers and water bodies and its mollusk fauna. In contrast, important achievements were reached in sanitation: the increase of domestic water supply from 80 to 85 %, as well as the availability of sewage from 42 to 91 % in Venezuela, between 1970 and 2011 (INE 2011).

Currently, Venezuela is still considered an area of low transmission of schistosomiasis based on the limited epidemiological data provided by the Minister of Health, but it is susceptible to be eliminated from its territory if it is recovered the strategy of an integrated and sustained program of control. The true epidemiological situation of schistosomiasis in Venezuela is not known: When studies are done in rural populations, relatively low prevalence is achieved. However, the Ministry of Health does not know the actual percentage of infected people who are mobilized by thousands during weekends and holidays to the rivers and water bodies in the endemic area, due to the ease of movement of the inhabitants from large populations' neighbors, propitiated by the availability of vehicles and motorcycles and the low cost of gasoline.

6 The Snail Hosts of Schistosomiasis in the Caribbean

Biomphalaria is the single genus belonging to the Planorbidae family involved in the transmission of schistosomiasis in America (PAHO 1968). The correct identification of the species acting as intermediate hosts for the parasite and the ecology of the snail hosts are a key aspect for understanding snail–schistosome relationships, as well as for building control programs of the disease.

6.1 Taxonomical Aspects

Shell characters can be used to distinguish groups of planorbids, but are of limited use for separating closely allied species because of wide ecophenotypic variation. The anatomy of reproductive tracts (e.g., shape and size of penial complex) is more informative, but still not fully diagnostic. Reproductive isolation has unfortunately been little used for clarifying species' boundaries and that some species of *Biomphalaria* mainly reproduce through self-fertilization certainly sets a practical limit to such investigation. Molecular phylogenies have also been developed in the last decade and clarified the relationships among most extant species.

In the Caribbean area, including Greater and Lesser Antilles, Venezuela, and Suriname, the main snail host responsible for schistosome transmission is *Biomphalaria glabrata* (PAHO 1968). Its morphology, including shell, radula, and anatomical characters of its soft parts, has been extensively studied and details are given in Paraense and Deslandes (1955). More recently, molecular markers helped to shed some light on the phylogeny of *Biomphalaria glabrata*. Two phylogenetic analyses, both using nuclear and mitochondrial markers, have addressed this question (Mavárez et al. 2002; De Jong et al. 2003), the first focusing more on the northern part of the distribution (Venezuela and the Lesser Antilles), and the second considering samples mainly from Brazil. These studies indicated that *B. glabrata* is structured into five, rather deeply separated, main clades. Snails from the Greater Antilles form a clade perhaps basal to other clades. As these clades are partially reproductively isolated from one another, *B. glabrata* might well be a species complex (Jarne et al. 2011).

Two other species have been found sometimes infected in the field: (1) *B. kuhniana* (under the name of *B. straminea*) in Venezuela (Balzán, personal communication) and Martinique (Paraense, personal communication; Pointier 2015) and (2) *B. prona* in Venezuela (Balzán personal communication; Pointier 2015). However, the epidemiological importance of these two species is presently negligible in this area, in spite of the wide distribution in some countries as Venezuela (Fig. 12)

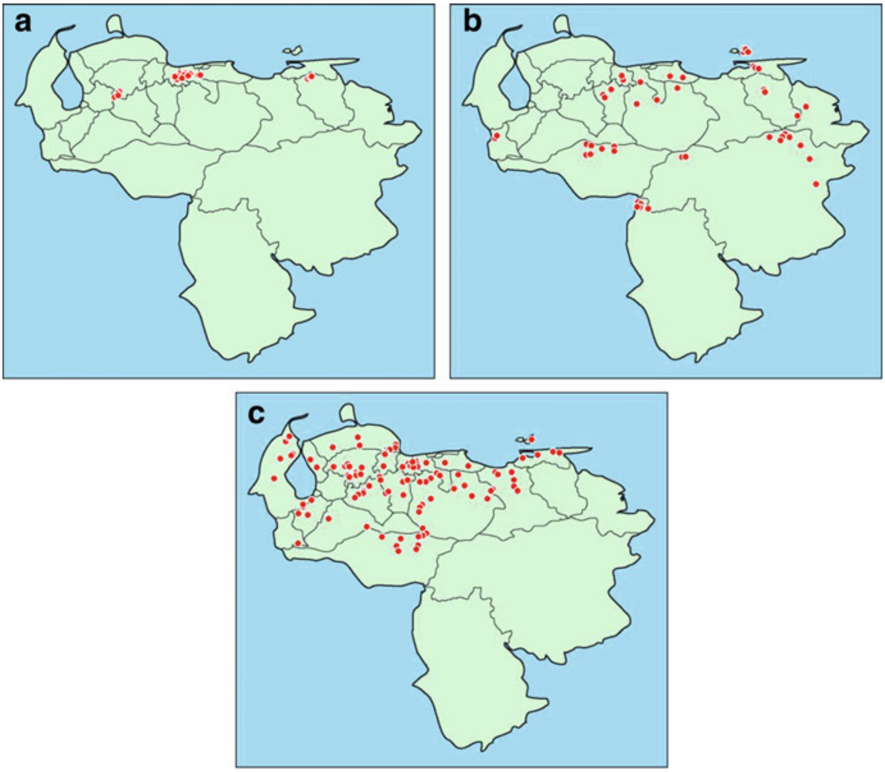

Fig. 12 Distribution of *B. glabrata* (**a**), B. *kuhniana* (**b**), *and B. prona* (**c**) in Venezuela (*Source*: Pointier & Noya, unpublished data)

6.2 Ecological Aspects and Control Measures

Biomphalaria glabrata has a very wide range extending from the Greater Antilles (Dominican Republic and Haïti) to the Southern part of Brazil (Fig. 13). In the Greater and Lesser Antilles, this species was reported from Haïti, Dominican Republic, Puerto Rico, St Marteen, St Kitts, Antigua, Montserrat, Guadeloupe, Dominica, and Martinique (PAHO 1968; Pointier 1974; Prentice 1980). However, in the last few decades, *B. glabrata* populations have strongly diminished and even disappeared following the improvement of control measures (chemical, physical, and biological control programs), the economical development, and the invasion of exotic mollusks (see Fig. 13).

Long-term studies carried out in the Caribbean area have demonstrated that two main species belonging to the Ampullariidae (*Marisa cornuarietis*) and Thiaridae (*Melanoides tuberculata*) families have succeeded in eliminating or reducing populations of the snail hosts of schistosomes, especially *B. glabrata* in several different habitats in St. Lucia, Martinique, Guadeloupe, and Venezuela (Pointier

Fig. 13 Distribution of *Biomphalaria glabrata* in America

et al. 2011). However, their efficiency is context dependent. Ampullarids and thiarids are good competitors in relatively stable habitats only when long-term resource exploitation rather than colonization is the limiting factor. At the same time, unassisted invasions by these species and by other fresh water snails, including numerous pulmonates, were detected in the 1950s, followed by rapid spread in the following decades to most Neotropical areas. These invasions were largely responsible for the general decline of *B. glabrata* in islands such as Martinique and Guadeloupe, replicating at a larger scale the results of biological control programs. No extinctions of local snail species occurred following the invasion of exotic snails, except for *B. glabrata* in Martinique (Pointier and Théron 2006). Thus, biological invasions could qualify as efficient *unintentional biological control* agents. However, the downside of biological invasions is that snail hosts can be invasive and establish new sites of parasite transmission in formerly parasite-free areas.

References

Alarcón de Noya B, Pointier JP, Colmenares C, Théron A, Balzan C, Cesari IM, Gonzalez S, Noya O (1997) Natural *Schistosoma mansoni* infection in wild rats from Guadeloupe: parasitologic and immunologic aspects. Acta Tropica 68:11–21

Alarcón de Noya B, Colmenares C, Lanz H, Caracciolo MA, Losada S, Noya O (2000) *Schistosoma mansoni:* immunodiagnosis is improved by sodium metaperiodate which reduces cross-reactivity due to glycosylated epitopes of soluble egg antigen. Exp Parasitol 95 (2):106–112

Alarcón de Noya B, Ruiz-Guevara R, Colmenares C, Losada S, Noya O (2006) Low transmission areas of schistosomiasis in Venezuela: consequences on the diagnosis, treatment, and control. Memorias Institute Oswaldo Cruz 101(suppl 1):29–35

Amorim JP (1953) Infestação experimental e natural de murídeos pelo *Schistosoma mansoni*. Nota Prévia. Revista Brasileira de Malariologia e Doenças Tropicais 5:219–222

Antunes CMF, Milward AR, Katz N, Coelho PMZ, Pellegrino J (1973) Role of *Nectomys squamipes* in the epidemiology of *Schistosoma mansoni* infection. Exp Parasitol 34:181–188

Balzan C (1988) Programma de lucha contra la esquistosomiasis en Venezuela. Dirección General Sectorial de Malariología y Saneamiento Ambiental. Dirección de Endemias Rurales, 36 p

Barbosa F, Dobbin JE Jr, Coelho MV (1953) Infecção natural de *Rattus rattus frugivorus* por *Schistosoma mansoni* em Pernambuco. Publicações avulsas do Instituto Aggeu Magalhães 2:43–46

Barbosa FS, Barbosa L, Arruda F (1962) *Schistosoma mansoni*: natural infection of cattle in Brazil. Science 138:831

Barbosa FS, Pinto R, Souza OA (1971) Control os schistosomiasis mansoni in a small north east Brazilian community. Trans R Soc Trop Med Hyg 65:206–217

Barbosa CSB, Favre TC, Amaral RS, Pieri OS (2008) Epidemiologia e Controle da Esquistossomose mansoni. In: Carvalho OS, Coelho PMZ, Lenzi HL (Org.): *Schistosoma mansoni* e esquistossomose: uma visão multidisciplinar. Rio de Janeiro, Editora Fiocruz, 1.124 p

Bastos OC, Magalhães LA, Rangel HA, Piedrabuena AE (1978) Alguns dados sobre o comportamento parasitológico das linhagens humana e silvestre do *Schistosoma mansoni*, no vale do Rio Paraíba do Sul. SP (Brasil) Revista de Saúde Pública, São Paulo 12:184–199

Berry A, Moné H, Iriart X, Mouahid G, Abbo O, Boissier J, Fillaux J, Cassaing S, Debuisson C, Mitta G, Théron A, Magnaval JF (2014) Schistosmiasis haematobium in Corsica, France. Emerg Infect Dis. doi:10.3201/eid2009.140928

Bina JC (1977) Influência da terapêutica especifica na evolução da esquistossomose mansônica. Tese de Doutorado. Universidade Federal da Bahia, Salvador, 58 p

Bogliolo L (1958) Subsídios para o conhecimento da forma hépato-esplênica e da forma toxêmica da esquistossomose mansônica. Serviço Nacional Educação Sanitário do Ministério da Saúde, Rio de Janeiro

Bogliolo L (1959) Esquistossomose: patologia. Revista Brasileira de Malariologia e Doenças Tropicais 54:357–368

Borda CE (1972) Infecção natural e experimental de alguns roedores pelo *Schistosoma mansoni* (Sambon, 1907). Belo Horizonte, Instituto de Ciências Biológicas da Universidade Federal de Minas Gerais. Dissertação (Mestrado), 43 p

Caldeira RL, Vidigal THDA, Paulinelli ST, Simpson AJG, Carvalho OS (1998) Molecular identification of similar species of the genus *Biomphalaria* (Mollusca: Planorbidae) determined by a polymerase chain reaction-restriction fragment length polymorphism. Memorias do Instituto Oswaldo Cruz 93(1):219–225

Caldeira RL, Vidigal THDA, Matinella L, Simpson AJG, Carvalho OS (2000) Identification of planorbids from Venezuela by polymerase chain reaction amplification and restriction fragment length polymorphism of internal transcriber spacer of the RNA ribosomal gene. Memorias do Instituto Oswaldo Cruz 95(2):171–177

Carvalho OS, Katz N (2008) Bibliografia Brasileira de Esquistossomose, Série Esquistossomose 1908–2007. Série Esquistossomose n°9. Centro de Pesquisas René Rachou/FIOCRUZ, Belo Horizonte, 86p

Carvalho OS, Andrade RM, Cortês MIN (1976) Ciclo vital de *Schistosoma mansoni* através de *Holochilus brasiliensis* (Desmarest, 1818), em ambiente semi-natural (Trematoda: Schistosomatidae; Rodentia; Cricetidae). Revista da Sociedade Brasileira de Medicina Tropical 10:235–247

Carvalho OS, Amaral RS, Dutra LV, Scholte RGC, Guerra MAM (2008) Distribuição espacial de *Biomphalaria glabrata*, *B. straminea* e *B. tenagophila*, hospedeiros intermediários de *Schistosoma mansoni* no Brasil. In: Carvalho OS, Coelho PMZ, Lenzi HL (Org.): *Schistosoma mans*oni e esquistossomose: uma visão multidisciplinar. Editora Fiocruz, Rio de Janeiro, 1.124p

Coelho PMZ, Dias M, Mayrink W, Magalhães P, Mello MN, Costa CA (1979) Wild reservoirs of *Schistosoma mansoni* from Caratinga, an endemic area of Minas Gerais State. Brazil. Am J Trop Med Hyg 28:163–164

Coelho PMZ, Enk MJ, Katz N (2009) Treatment of clinical schistosomiasis at the prepatent phase: an option? Trends in Parasitol 25:299–300

Colley DG, Binder S, Campbell C, King CH, Tchuem Tchuente LA, Eliezer K, N'Goran EK, Berhanu Erko B, Karanja DMS, Kabatereine NB, van Lieshout L, Rathbun S (2013) A five-country evaluation of a point-of-care circulating cathodic antigen urine assay for the prevalence of Schistosoma mansoni. Am J Trop Med Hyg 88(3):426–432

Colley DG, Bustinduy AL, Secor WE, King CH (2014) Human schistosomiasis. Lancet 383:2253–2264

Coni AC (1952) A Escola Tropicalista Bahiana. Tipografia Beneditina Ltda., Bahia, 82 p

Corrêa LR, Paraense WL (1971) Susceptibility of *Biomphalaria amazonica* to infection with two strains of *Schistosoma mansoni*. Revista do Instituto Medicina Tropical de São Paulo 13:387–390

Costa MFFL, Guerra HL, Pimenta FG Jr, Firmo JOA, Uchoa E (1996) Avaliação do Programa de Controle da Esquistossomose (PCE/PCDEN) em municípios situados na Bacia do Rio São Francisco, Minas Gerais, Brasil. Revista da Sociedade Brasileira de Medicina Tropical 29:117–126

Coura JR, Amaral RS (2004) Epidemiological and control aspects of schistosomiasis in Brazilian endemic areas. Mem Inst Oswaldo Cruz 99(suppl I):13–19

D'Andrea PS, Maroja LS, Gentile R, Cerqueira R, Maldonado A Jr, Rey L (2000) The parasitism of *Schistosoma mansoni* (*Digenea–Trematoda*) in a naturaly infected population of water rats, *Nectomys squamipes* (Rodentia–Sigmodontinae) in Brazil. Parasitology 120:573–582

De Jong RJ, Morgan JA, Paraense WL, Pointier JP, Amarista M, Ayeh-Kumi PF, Babiker A, Barbosa CS, Brémond P, Canese PA, De Souza CP, Dominguez C, File S, Gutierrez A, Incani RN, Kawano T, Kazibwe F, Kpikpi J, Lwambo NJ, Mimpfoundi R, Njiokou F, Noël Poda J, Sene M, Velásquez LE, Yong M, Adema CM, Hofkin BV, Mkoji GM, Loker ES (2001)

Evolutionary relationships and biogeography of *Biomphalaria* (Gastropoda: Planorbidae) with implications regarding its role as host of the human bloodfluke, *Schistosoma mansoni*. Mol Biol Evol 18(12):2225–2239

De Jong RJ, Morgan JAT, Wilson WD, Al-Jaser MH, Appleton CC, Coulibaly G, D'Andrea PS, Doenhoff MJ, Haas W, Idris MA, Magalhães LA, Moné H, Mouahid G, Mubila L, Pointier JP, Webster JP, Zanotti-Magalhães EM, Paraense WL, Mkoji GM, Loker ES (2003) Phylogeography of *Biomphalaria glabrata* and *B. pfeifferi*, important intermediate hosts of *Schistosoma mansoni* in the new and old World tropics. Mol Ecol 12:3041–3056

INSERM-Institut National de la Santé et de la Recherche Médicale (1979) Etude de l'endémie parasitaire intestinale dans les Départements d'Outre-Mer. 1. La Martinique. Le Vésinet, Unité 165-I.N.S.E.R.M., 53p

INSERM-Institut National de la Santé et de la Recherche Médicale (1980) Etude de l'endémie parasitaire intestinale dans les Départements d'Outre-Mer. 2. La Guadeloupe. Le Vésinet, Unité 165-I.N.S.E.R.M., 53p

DGSSA, Dirección General Sectorial de Salud Ambiental. Ministerio del Poder Popular para la Salud, Venezuela (2012) Re-emergencia de esquistosomosis mansoni en Venezuela, 1–18

Dias LCS (1972) Pequenos mamíferos silvestres naturalmente infectados por *Schistosoma mansoni* (Nota prévia). Revista de Saúde Pública de São Paulo 6:233

Dias LCS (1976) Aspectos parasitológicos e ecológicos da esquistossomose mansônica no Vale do Rio Paraíba do Sul e na Represa de Americana, São Paulo, Brasil. Tese de Doutorado. Instituto de Biologia da Universidade Estadual de Campinas

Doumenge JP, Mott KE, Cheung C, Villenave D, Chapuis O, Perrin MF, Reaud-Thomas G (1987) Atlas of the global distribution of schistosomiasis. CRGET-CNRS, Talence; OMS/WHO, Genève; Presses Universitaires de Bordeaux, Talence, 400p

Enk MJ, Lima ACL, Drummond SC, Schall VT, Coelho PMZ (2008) The effect of the number of stool samples on the observed prevalence and the infection intensity with Schistosoma mansoni among a population in an area of low trasnmission. Acta Tropica 108:222–228

Falcão EC (1953) Estudos sobre o "*Schistosoma mansoni*" (1908-1916). Author Edition. São Paulo, 123p

Falcão EC (1959) Pirajá da Silva, o incontestável descobridor do *Schistosoma mansoni*. São Paulo, 314p

Gentile R, Costa-Neto SF, Gonçalves MML, Bonecker FAF, Garcia JS, Barreto MGM, Soares M, D'Andrea PS, Peralta JM, Rey L (2006) An ecological field study of the water-rat *Nectomys squamipes* as wild reservoir indicator of *Schistosoma mansoni* transmission in an endemic area. Memórias do Instituto Oswaldo Cruz 101(Supl. I):111–117

Graeff-Teixeira C, Anjos CB, Oliveira VC, Velloso CFP, Fonseca MBS, Valar C, Moraes C, Garrido CT, Amaral RS (1999) Identification of a transmission focus of *Schistosoma mansoni* in the Southernmost Brazilian State, Rio Grande do Sul. Memórias do Instituto Oswaldo Cruz 94:9–10

Gryseels B (2012) Schistosomiasis. Infect Dis Clin N Am 26:383–397

Guyard A, Pointier JP, Théron A, Gilles A (1982) Mollusques hôtes intermédiaires de la Schistosomose intestinale dans les Petites Antilles: Hypothèses sur le rôle de *Biomphalaria glabrata* et *B. straminea* en Martinique. Malacologia 22:103–107

Hillyer GV (2005) The rise and fall of Bilharzia in Puerto Rico: its centennial 1904-2004. P R Health Sci J 24:225–235

INE, Instituto Nacional de Estadística, Venezuela Censo (2011) http://www.ine.gov.ve

Jansen G (1946) Profilaxia experimental da esquistossomose mansoni. Memórias do Instituto Oswaldo Cruz 44:549–578

Jarne P, Pointier JP, David P (2011) Biosystematics of *Biomphalaria* spp. with an emphasis on *Biomphalaria glabrata*. In: Toledo R, Fried B (eds) *Biomphalaria* snails and larval trematodes. Springer, New York, pp 1–32

Jobin WR (1980) Sugar and snail: the ecology of bilharziasis related to agriculture in Puerto Rico. Am J Trop Med Hyg 29:86–94

Jordan P (1985) Schistosomiasis: the Saint Lucia project. Cambridge University Press, Cambridge, 456p

Katz N (1980) Experiências com quimioterapia em grande escala no controle da esquistossomose no Brasil. Revista do Instituto de Medicina Tropical de São Paulo 22:40–51

Katz N (1992) Brazilian contributions to epidemiological aspects of schistosomiasis mansoni. Mem Inst Oswaldo Cruz 87(Suppl 4):1–9

Katz N (2006) Twenty years of the Schistosomiasis programme at Fiocruz. Memórias do Instituto Oswaldo Cruz 101(suppl I):9–11

Katz N (2008) The discovery of schistosomiasis mansoni in Brazil. Acta Tropica 108:69–71

Katz N, Chaves A, Pellegrino J (1972) A simple device for quantitative stool thick-smear technique in schistosomiasis mansoni. Rev Inst Med Trop Sao Paulo 14:397–400

Katz N, Rocha RS, Chaves A (1979) Preliminary trials with praziquantel in human infection due to *Schistosoma mansoni*. Bull World Health Organ 57:781–785

Katz N, Rocha RS, Barbosa CS, Bezerra FSM, Coelho PMZ, Carvalho OS, Teixeira CG, Fazito D, Marcelino JM (2014) National survey on Schistosomiasis mansoni and Geohelminths in Brazil (2011-2014). XIII international congress of parasitology–ICOPA, Mexico

Kawazoe U, Pinto AC (1983) Importância epidemiológica de alguns animais silvestres na esquistossomose mansônica. Revista de Saúde Pública de São Paulo 17:345–366

Kloetzel K (1963) Sobre a conveniência da quimioterapia da esquistossomose em população em continuo contato com os focos. Revista do Instituto de Medicina Tropical de São Paulo 5:106–110

Kloetzel K (1967) A rationale for the treatment of schistosomiasis mansoni, even when reinfection is expected. Trans R Soc Trop Med Hyg 61:609–610

Knight M, Brindley PJ, Richards CS, Lewis FA (1991) Use of a cloned ribosomal RNA gene probe to detect restriction fragment length polymorphisms in the intermediate hosts biomphalaria glabrata. Exp Parasitol 73:285–294

Kurup R, Hunjan GS (2010) Epidemiology and control of schistosomiasis and other intestinal parasitic infections among school children in three rural villages of south Saint Lucia. J Vector Borne Dis 47:228–234

Lambertucci JR, Rocha RS, Carvalho OS, Katz N (1987) A esquistossomose mansoni em Minas Gerais. Revista da Sociedade Brasileira de Medicina Tropical 20:47–52

Lutz A (1919) O *Schistosoma mansoni* e a schistosomatose segundo observações, feitas no Brazil. Memórias do Instituto Oswaldo Cruz 11:121–155

Machado AP (1977) O Modelo. In: Painel Programa Especial de Controle da Esquistossomose, pp 1–19

Malek E (1980) Snail-transmitted parasitic diseases, vol 1. CRC, Boca Raton, pp 179–307

Mavárez J, Steiner C, Pointier JP, Jarne P (2002) Evolutionary history and phylogeography of the schistosome-vector fresh water snail biomphalaria glabrata based on nuclear and mitochondrial DNA sequences. Heredity 89:266–272

Modena CM, Lima W, Coelho PMZ (2008) Wild and domesticated animals as reservoirs of Schistosoma mansoni in Brazil. Acta Tropica 108:242–244

Morgan J, Dejong R, Adeoye G, Ansa E, Barbosa C, Brémond P, Cesari I, Charbonell N, Correa L, Coulibaly G, D'Andrea P, De Souza C, Doenhoff M, File S, Idris M, Incani N, Jarne P, Karanja D, Kazibwe F, Kpiki J, Lwambo N, Mabaye A, Magalhaes L, Makundi A, Moné H, Mouahid G, Muchemi G, Mungai B, Séne M, Southgate V, Tchuente L, Therón A, Yousif F, Zanotti-Magalhaes E, Mkoji G, Loker E (2005) Origin and diversification of the human parasite *Schistosoma mansoni*. Mol Ecol 14:3889–3902

Negro-Aponte H, Jobin WR (1979) Schistosomiasis control in Puerto Rico. Twenty-five years of operational experience. Am J Trop Med Hyg 28:515–525

Noya O, Alarcón de Noya B, Losada S, Colmenares C, Guzmán C, Lorenzo MA, Bermúdez H (2002) Laboratory diagnosis of schistosomiasis in areas of low transmission. A review of a line of research. Memorias Instituto Oswaldo Cruz 97(Suppl 1):167–169

PAHO (1968) A guide for the identification of the snail intermediate hosts of schistosomiasis in the Americas. Pan American HealthOrganization, Scientific Publication, Washington, DC, 168, 122pp

PAHO (2010) Control and elimination of five neglected diseases in Latin America and the Caribbean, 2010-2015: analysis of progress, priorities and lines of action for Lymphatic filariasis, Schistosomiasis, Onchocerciasis, Trachoma and Soil-transmitted helminthiases. Washington, DC

PAHO (2014) Small bites, big threats. http://www.paho.org/schistosomiasis

Paraense WL (1970) Planorbídeos hospedeiros intermediários do *Schistosoma mansoni*. In: Cunha AS (ed) Esquistossomose Mansônica. Sarvier, Edusp, São Paulo

Paraense WL (1981) *Biomphalaria occidentalis* sp.N. from South América (Mollusca, Basomatophora, Pulmonata). Memórias do Instituto Oswaldo Cruz 79:199–211

Paraense WL (1984) *Biomphalaria tenagophila guaiabensis* ssp.n from Southern Brazil and Uruguay (Pulmonata: Planorbidae). I–Morphology. Memórias do Instituto Oswaldo Cruz 79:465–469

Paraense WL (1986) Distribuição dos caramujos no Brasil. In: Reis FA, Faria I, Katz N (Orgs). Modernos Conhecimentos sobre Esquistossomose Mansônica. Academia Mineira de Medicina, Belo Horizonte

Paraense WL (2008) História do *Schistosoma mansoni*. In: Carvalho OS, Coelho PMZ, Lenzi HL (Org): *Schistosoma mansoni* equistossomose: uma visão multidisciplinar. Editora Fiocruz, Rio de Janeiro, 1.124p

Paraense WL, Deslandes N (1955) Observations on the morphology of *Australorbis glabratus*. Memorias do Instituto Oswaldo Cruz 53:87–103

Paulini E, Freitas CA, Aguirre GH (1972) Control of schistosomiasis in Brazil. In: Miller MJ (ed) Proceeding of a symposium on the future of schistosomiasis control. Tulane University, New Orleans, pp 104–110

PECE - Programa Especial de Controle da Esquistossomose no Brasil (1976) Publicação do Conselho de Desenvolvimento Social. Brasília, 41p

PECE (1977) Painel Programa Especial de Controle da Esquistossomose. Ministério da Saúde, Brasília, 92p

Pellon AB, Teixeira I (1950) Distribuição geográfica da esquistossomose mansônica no Brasil. Ministério da Educação e Saúde (Divisão da Organização Sanitária), Rio de Janeiro, 103p

Pirajá da Silva MA (1909) Contribution to the study os schistosomiases in Bahia, Brazil. J Trop Med Hyg 12:159–164

Piva N, Barros PRC (1966) Infecção natural de animais silvestres e domésticos pelo *Schistosoma mansoni* em Sergipe. Rev Bras Malariol Doencas Trop 18:221–223

Pointier JP (1974) Faune malacologique dulçaquicole de l'île de la Guadeloupe (Antilles françaises). Bulletin du Museum National d'Histoire Naturelle de Paris 3(159):905–933

Pointier JP (2015) Freshwater mollusks of Venezuela and their medical and veterinary importance. Conchbooks, Hackenheim

Pointier JP, Guyard A, Théron A, Dumoutier A (1984) Le fonctionnement d'un site de transmission à *Schistosoma mansoni* en Martinique (Antilles françaises). Ann Parasitol 59:589–595

Pointier JP, Théron A (2006) Transmission de la bilharziose intestinale aux Antilles Guyane. Bulletin d'Alerte et de Surveillance Antilles Guyane 1:1–4

Pointier JP, David P, Jarne P (2011) The biological control of the snail hosts of schistosomes: the role of competitor snails and biological invasions. In: Toledo R, Fried B (eds) *Biomphalaria* snails and larval trematodes. Springer, New York, pp 215–238

Prata A (1976) Experience in Brazil with the use of available schistosomicides in mass treatment campaigns. Revista da Sociedade Brasileira de Medicina Tropical 10:354–360

Prentice MA (1980) Schistosomiasis and its intermediate hosts in the lesser antilles and islands of the Caribbean. Bull Pan Am Health Organ 14(3):258–268

NEGOCIADO DEL CENSO DE LOS EE.UU. Puerto Rico (2010) Recuentos de Población y Unidades de Vivienda. Censo de Población y Vivienda del 2010. Departamento de Comercio de los EE.UU. Administración de Economía y Estadísticas census.gov, p 1

Rebollo M (2010) Inter-American Development Bank. Neglected tropical diseases in Suriname: integrated strategy towards schistosomiasis eliminations

Rodrigues DC, Ferreira CS (1969) Primeiro encontro de roedor (Nectomys squamipes) naturalmente infectado pelo *S. mansoni* no Estado de São Paulo (Brasil). Revista do Instituto de Medicina Tropical de São Paulo 11:306–308

Rodrigues-Silva R, Machado-Silva RR, Faerstein NF, Lenzi HL, Rey L (1992) Natural infection of wild rodents by *Schistosoma mansoni*: parasitological aspects. Memórias do Instituto Oswaldo Cruz 87(1):271–276

Rollinson D, Knopp S, Levitz S, Stothard JR, Tchuem Tchuenté LA, Garba A, Mohammed KA, Schur N, Person B, Colley DG, Utzinger J (2013) Time to set the agenda for schistosomiasis elimination. Acta Tropica 128:423–440

Sambon LW (1907a) New or little known African Entozoa. J Trop Med Hyg 10:117

Sambon LW (1907b) Remarks on *Schistosoma mansoni*. J Trop Med Hyg 10:303–304

Sarvel AK, Oliveira AA, Silva RA, Lima ACL, Katz N (2011) Evaluation of 25-year-program for the control of schistosomiasis mansoni in an endemic area in Brazil. PLoS Negl Trop Dis 6: e990

Schneider MC, Aguilera XP, da Silva B, Junior J, Ault SK, Najera P, Martinez J, Requejo R, Nicholls RS, Yadon Z, Silva JC, Leanes LF, Periago MR (2011) Elimination of neglected diseases in Latin America and the Caribbean: a mapping of selected diseases. PLoS Negl Trop Dis 5(2):e964. doi:10.1371/journal.pntd.0000964

Scott A (1942) The epidemiology of schistosomiasis in Venezuela. Am J Epidemiol 35:337–366

Sette H (1953) O tratamento da esquistossomose mansoni à luz da patologia hepática (Estudo clínico). Tese, Recife, Universidade Federal de Pernambuco, 220p

Soto V (1906) Naturaleza de la disenteria en Caracas. Tesis de Doctorado, Facultad de Medicina, Universidad Central de Venezuela, 63p

Théron A (1984) Early and late shedding patterns of *Schistosoma mansoni* cercariae: ecological significance in transmission to human and murine hosts. J Parasitol 70:652–655

Théron A, Pointier JP (1995) Ecology, dynamics, genetics and divergence of trematode populations in heterogeneous environments: the model of *Schistosoma mansoni* in the insular focus of Guadeloupe. Res Rev Parasitol 55(1):49–64

Théron A, Sire C, Rognon A, Prugnolle F, Durand P (2004) Molecular ecology of *Schistosoma mansoni* transmission infered from the genetic composition of larval and adult infrapopulations within intermediate and definitive hosts. Parasitology 126:1–15

Veiga-Borgeaud T, Lemos Neto RC, Peter F, Bastos OC (1986) Constatações sobre a importância dos roedores silvestres (*Holochilus brasiliensis nanus*. Thomas, 1897) na epidemiologia da esquistossomose mansônica própria da Pré-Amazonia, Maranhão–Brasil. Caderno de Pesquisa de São Luiz 2:86–89

Vianna Martins A (1958) Non-human vertebrate and *Schistosoma mansoni*. Bull World Health Organ 18:931–944

Vianna Martins A, Martins G, Siebra de Brito R (1955) Reservatórios silvestres do *Schistosoma mansoni* no Estado de Minas Gerais. Revista Brasileira de Malariologia e Doenças Tropicais 7:259–265

Vidigal THDA, Spatz L, Nunes DN, Simpson AJG, Carvalho OS, Neto ED (1998) Biomphalaria spp: identification of the intermediate snail hosts of *Schistosoma mansoni* by polymerase chain reaction amplification and restriction enzyme digestion of the ribosomal RNA gene intergenic spacer. Exp Parasitol 89:180–187

WHO (World Health Organization) (1985) Schistosomiasis control. Technical report series, Geneva, p 728

WHO (2006) Preventive in human helminthiasis. Coordinated use of anthelminthic drugs in control interventions: a manual for health professionals and programme managers. ISBN 92 4 154710 3, 63p

WHO (2013) Schistosomiasis: progress report 2001-2011 and strategic plan 2012-2020

WHO (2014a) Schistosomiasis. Fact sheet N°115. WHO/DCO/WHD/b2014.1, pp 26–27

World Bank (2013) http://data.worldbank.org

http://www.springer.com/978-3-7091-1421-6

Neglected Tropical Diseases - Latin America and the Caribbean
Franco-Paredes, C.; Santos-Preciado, J.I. (Eds.)
2015, VIII, 243 p. 52 illus., 42 illus. in color., Hardcover
ISBN: 978-3-7091-1421-6