Ecological Aspects of *Biomphalaria* in Endemic Areas for Schistosomiasis in Brazil

Marco Antônio Andrade de Souza[1] and Alan Lane de Melo[2]
[1]*Departamento de Ciências da Saúde, Centro Universitário Norte do Espírito Santo, Universidade Federal do Espírito Santo*
[2]*Departamento de Parasitologia, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais*
Brazil

1. Introduction

Schistosomiasis is a disease caused by trematodes belonging to family Schistosomatidae. Within this family, only genus *Schistosoma* has species that parasitize humans. It is accepted that the genus *Schistosoma* was brought to the Americas during the Atlantic slave trade and with Eastern and Asian immigrants. However, only *Schistosoma mansoni* Sambon, 1907, settled here certainly due to the presence of susceptible intermediate hosts, freshwater planorbid snails belonging to the genus *Biomphalaria* and to environmental conditions similar to the region of origin (Morgan et al., 2001). Of the major endemic diseases that occur in Brazil, schistosomiasis is widely distributed, being considered as a serious medical and socio-economic problem. Brazil is considered one of the endemic foci of the disease, with active transmission in at least 16 states, despite the variability of data regarding its prevalence in different regions of the country (Cunha, 1970; Katz & Peixoto, 2000). Since human activity plays a significant role in expanding the territory colonized by hosts of *S. mansoni*, human migration has contributed to the expansion of schistosomiasis to developing regions. In Brazil, the first centuries of territory occupation were marked by the presence of scattered populations in coastal areas, increased by the first expeditions, called colonial exploratory expedition, in the seventeenth century. The discovery of gold and precious stones in the eighteenth century in the current states of Minas Gerais, Mato Grosso, Goiás and Bahia contributed to the increase in population, and encouraged the opening of roads, which significantly strengthened the relationships of these areas with the sources of supplies. Many cities that emerged in function of these and other activities have become more important with the intensification of trade, such as port cities. The nineteenth century opened up new perspectives for the settlement of the Brazilian territory, also marked by the beginning of the territory mechanization with the construction of railroads, telegraph and the first shipping companies, resulting in urbanization process in the country (Ferreira, 1959; L.A. Souza, 2004). The phenomenon of urbanization itself only emerged in the mid twentieth century. After the 50s, as a result of industrialization, economic ties and the urban factor became correlated. A new logic in the organization of Brazilian society was established. Economic and social innovations are enormous as they are associated, in this context, to the demographic revolution, the rural exodus and the integration of the territory by transport and communications. Cities of all kinds and with different functional levels emerged (Chiavenato, 1999). Industrialization, agriculture mechanization and the rural exodus are also responsible for the fact that some Brazilian cities received enormous population contingents in search of jobs and access to various services, people without qualification and perspectives. The phenomenon of *favelizações* (social phenomenon that occurs in urban centers where there is growth and proliferation of slums) was intensified during this period, where population clusters settled without any technical and administrative control in the suburbs of metropolitan areas. The 1970s was also marked by the construction and expansion of roads and by the creation of a modern telecommunications system, which enabled a greater fluidity in the territory, besides allowing the unification of the market nationwide (Brazilian Institute of Geography and Statistics [IBGE], 2000). The effects of the urbanization process and the deployment of large urban centers could be perceived by the shortage of spaces favorable to the territorial occupation and the increasing difficulty of exploitation of natural resources. The disordered growth led to major environmental disturbances, which can be evidenced by the spread of diseases, initially restricted to certain areas, for different regions of Brazil. In this context, schistosomiasis stands out, which is a disease associated to the livelihood of people, and has advanced in the country by human migrations into different directions. Although the first record of human infection with *S. mansoni* in Brazil has been reported by Pirajá da Silva (1908), the importance of schistosomiasis in the country was only evidenced when Pellon & Teixeira (1950, 1953), conducting the first major national parasitological survey, showed the prevalence of the disease in 612 of 877 localities surveyed in Northeastern Brazil and state of Minas Gerais. The presence of schistosomiasis was later reported in Northern Brazil and in other states in Southern and Southeastern Brazil. Until today, schistosomiasis is increasingly spreading to new regions of the country (Araújo et al., 2007; Barbosa et al., 1996, 2010; Graeff-Teixeira et al., 1999, Paredes et al., 2010). The disease is a major public health problem in Brazil, and it is estimated that schistosomiasis affects 4.6% of the population, approximately 8,000,000 individuals, and in the states of Minas Gerais, Pernambuco and Espírito Santo, approximately 2.9 million people are infected (Katz & Peixoto, 2000; Paraense et al., 1983). The country's tropical climate allows, in most Brazilian states, the development of ecological conditions necessary for its transmission. The enormous variety of aquatic habitats, which play the role of nurseries for transmitter snails, high temperatures and intense lighting contribute to the maintenance and spread of this disease. In addition, the concentration of susceptible human hosts, living in unsanitary conditions, lack of health education and public sanitation, are key factors for the establishment of transmission foci, providing the contamination of sites, where susceptible snails reproduce, by feces containing viable eggs of *S. mansoni* and thus contributing to the maintenance of schistosomiasis and the expansion of its area of occurrence. Men become infected when in contact with contaminated water during their normal daily or leisure activities (Figure 1). When in contact with the host's skin, cercariae, which are infective larvae, adhere to it through mucoprotein substance secreted by their acetabular glands. After penetration, the resulting larvae known as schistosomula, adapt to the physiological conditions of the internal environment, and are carried from the skin to the lungs primarily by the blood vascular system, with likely participation of the lymphatic system (Wilson et al., 1978, 1986). Thus, progressively and regardless of route, these larvae pass through the pulmonary arteries and veins and when they reach the portal venous system, either by blood or transtecidual route, the parasites complete their development and sexual maturation. This

Fig. 1. Human activities on water collections: Work and leisure

cycle takes approximately 28 days. After mating, they migrate against the current towards the branches of the inferior mesenteric vein. Around the 35th day (which may occur between the 27th and 48th day of infection), they begin to lay about 300 or more eggs per day for each pair of parasites, depending on the vertebrate host, starting up a new cycle (Melo & Coelho, 2000). Among the planorbid snails that occur in Brazil, main species of *Biomphalaria* (*B. glabrata, B. tenagophila* and *B. straminea*) are considered natural vectors of *S. mansoni*, whose distribution varies according to each region. According to Paraense (1984), in Northeastern and Southeastern Brazil, the most important species is *Biomphalaria glabrata* (Say, 1818), due to its distribution amplitude and transmission efficiency, being responsible for much of outbreaks in the states of Minas Gerais and Espírito Santo (Giemsa & Nauck, 1950a, 1950b; Lambertucci et al., 1987; C.P. Souza et al., 2001). On the other hand, it is important to emphasize that in part of Southeastern and Southern Brazil, the main intermediate host species is *B. tenagophila* (Orbigny, 1835) (Paraense, 1972, 1984; Telles et al., 1991). *B. straminea* (Dunker, 1848), despite being the species found in almost all watersheds of Brazil and adapted to climate variations, its natural infection occurs predominantly in the Northeastern states (Barbosa et al., 1996). Distribution and infection rates of these planorbid snails are correlated to disease distribution, and the presence of aquatic habitats suitable for the survival of these snails is governed by climatic and environmental factors such as vegetation, temperature, precipitation, characteristics of water bodies, topography and soil use. Any change in one of these factors may change the distribution of snails and therefore the dynamics of schistosomiasis transmission. Since the environment plays an important role in this dynamics, the assessment of habitat diversity provides an opportunity to examine the levels of human impacts on watershed areas (Galdean et al., 2000), constituting an important tool in environmental monitoring programs (Callisto et al., 2001). Thus, this study aims to examine some ecological aspects relevant for the identification of risk areas for schistosomiasis transmission in Brazil, using impact assessment protocols that enable determining and classifying sites for collection of *Biomphalaria*, such as areas under natural conditions, altered or impacted.

2. Study areas

The studies were conducted in 147 sites of the municipality of Mariana, located in the central region of Minas Gerais, about 110 Km distant from Belo Horizonte, in 9 sampling stations in the Carne de Vaca beach, municipality of Goiana (Pernambuco), distant about 70 km from Recife and in 41 sites in seven municipalities from northern state of Espírito Santo as follows: Boa Esperança, Conceição da Barra, Montanha, Mucurici, Ponto Belo, Pedro Canário and Pinheiros (Figure 2), taking into account, for the determination of sampling sites, the human presence and the existence of water collections, with antropogenic impact or not. Freshwater environments occurring in the localities and their systems were characterized as lotic (consisting of collections of running water, streams, waterfalls and rivers) and lentic (consisting of collections of waters with little flow, such as lakes, ponds, puddles, artificial ponds and swamps). Thus, uses and conservation conditions were identified and a protocol for assessing the habitat diversity (Callisto et al., 2002), with modifications (Table 1), which allows evaluating the impact of human action on aquatic environment through a specific score for the study areas (Galdean et al., 2000), was used. In all sites selected, geographic coordinates were obtained with the aid of a GPS device.

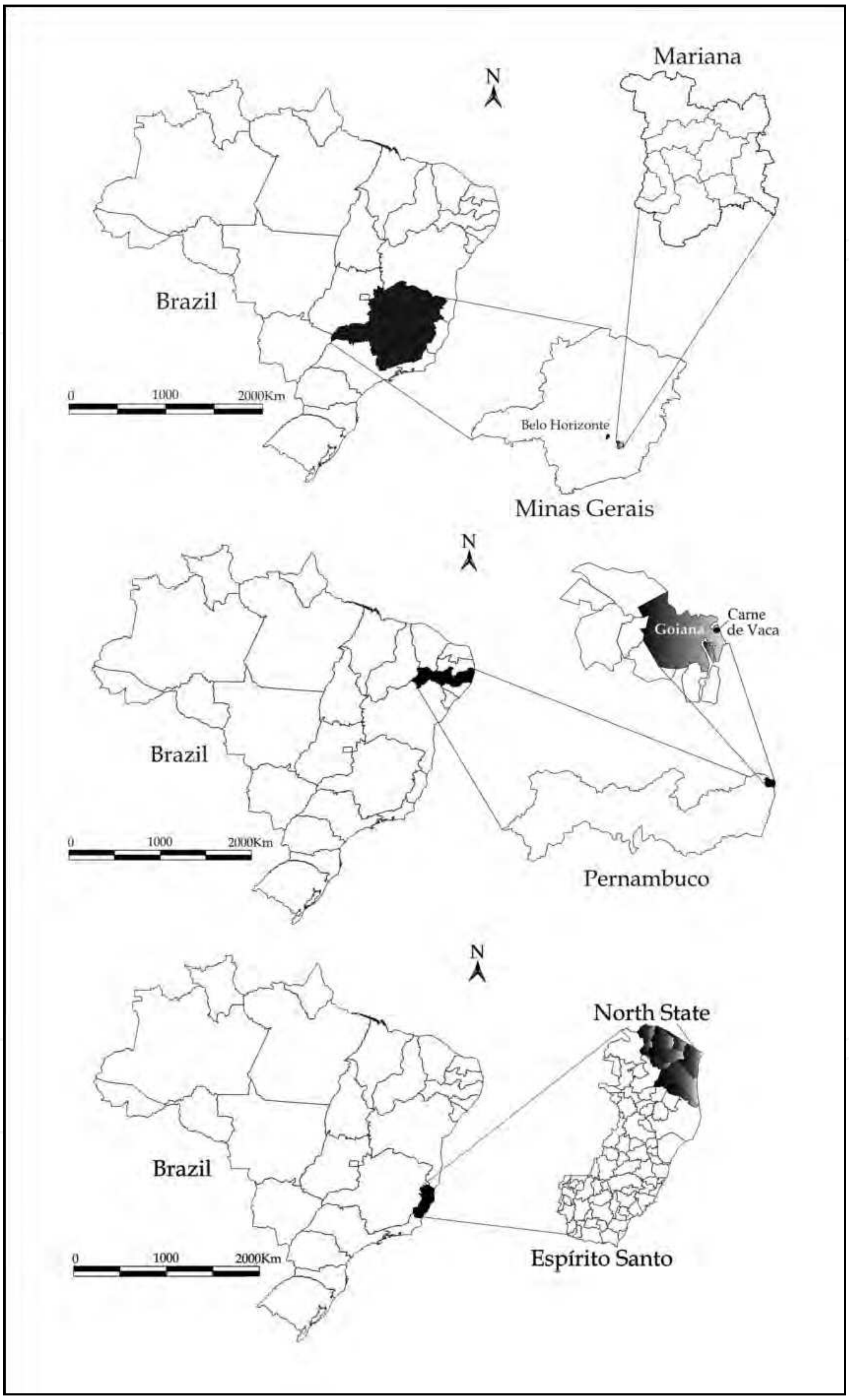

Fig. 2. Study areas: Mariana, Carne de Vaca beach and municipalities in northern state of Espírito Santo

Location:	Date of collection:
Time of collection:	Time (situation of the day):
Collection mode (Collector):	Water pH:

Type of environment:
Stream ( ) River ( ) Lake ( ) Pond ( ) Waterfall ( )

Parameters	Score		
	4 points	*2 points*	*0 point*
1- Type of occupation at the margin of water bodies (main activity)	*Native vegetation*	*Pasture/ Agriculture/ Monoculture/ Reforestation*	*Residential/ Commercial/ Industrial*
2- Erosion near the margin of rivers and silting of the riverbed	*Absent*	*Moderate*	*Accentuated*
3-Anthropic alterations	*Absent*	*Alterations of domestic origin (sewage, garbage)*	*Alterations of industrial / urban origin (factories, iron and steel industry, canalization, reuse of the river course)*
4- Vegetal coverage in the riverbed	*Partial*	*Total*	*Absent*
5- Water odor	*None*	*Sewage (rotten egg)*	*Oil / Industrial*
6- Water oiliness	*Absent*	*Moderate*	*Abundant*
7- Water transparency	*Transparent*	*Turbid*	*Opaque or colorful*
8- Odor of the sediment (bottom)	*None*	*Sewage (rotten egg)*	*Oil / Industrial*
9- Bottom oiliness	*Absent*	*Moderate*	*Abundant*
10- Type of bottom	*Rocks/rubble*	*Mud/sand*	*Cement / canalized*

Note: 4 points (natural situation), 2 and 0 points (slightly or deeply altered).

Table 1. Rapid assessment of habitat diversity in watershed areas, modified from the protocol of the Environmental Protection Agency (EPA), USA, 1987 (Callisto et al. 2002;)

3. Collection of snails

Two monthly snail collections were performed between 2004 and 2010 using a hand net (netting), made with nylon (50 cm of width, 40 cm in height, 30 cm of opening, with mesh of 1 mm^2), adapted to wooden or steel end of 150 cm in length (Figure 3). An individual sampling effort of 30 minutes per scanning, was applied at each 10 (ten) meters in each of the selected sampling stations (Souza et al., 2006). All material collected was packed in plastic bags, labeled and transported to the laboratory, where the snails were sorted, macroscopically observed for preliminary analysis of the species, counted, measuring the diameter of the shells and placed in small plastic containers with 10 ml capacity containing 5 ml of water free of chlorine. Then, they were left overnight to be evaluated before and after direct artificial photostimulation (60 W lamp), to verify the occurrence of cercarial emergence. On the next day, after examination without photostimulation, they were examined after exposure to light for two hours (Figure 4). This procedure was repeated weekly for 90 days. After this period, the snails that were negative were crushed between glass plates for the detection of possible larval stages (Coutinho, 1950). From each batch of snails collected, about 10% of live individuals were removed and sacrificed in water at 70°C. The soft tissues were fixed in Railliet - Henry and dissected under a stereomicroscope (Paraense & Deslandes, 1955). For the identification of species, conchological and morphological parameters were considered according to Paraense (1975).

Fig. 3. Hand net (netting) used for the collection of snails (left); Procedures for the collection of snails through scanning (right)

Fig. 4. Direct artificial photostimulation (left); analysis of cercarial emergence in stereomicroscope (right)

4. Remarks and discussion

The assessment of habitat diversity provides an opportunity to examine the levels of human impacts on watershed areas (Galdean et al., 2000), and constitutes an important tool in environmental monitoring programs (Callisto et al., 2001). Residential occupation on banks of water courses (leading to moderate and severe erosion processes and silting of the riverbed), alterations of domestic origin such as garbage and sewage (an important source of organic matter for the development of snails) and the presence of vegetation cover on the river bed, very favorable to the fixing of snails in the freshwater environment stand out as the most relevant (Figures 5 and 6). The use of assessment protocols in each location allowed analyzing the collection sites with the determination of areas in natural conditions, altered or impacted. Impacted areas were considered as those whose scores achieved by the protocol for the assessment of habitat diversity reached up to 20 points. Altered areas scored between 20 and 36 points, and over 36 points, areas in natural conditions (Figures 7a, b, c). Among the sampling stations established in the municipality of Mariana, MG, Carne de Vaca beach, PE, and municipalities in northern state of Espírito Santo, the presence of *Biomphalaria* was directly related to sites with anthropogenic changes (Figure 8). Approximately 5928 snails from Mariana were analyzed, all *B. glabrata* with positivity rate of 2.19%. In this municipality, *B. tenagophila* and *B straminea* were not found. In Carne de Vaca beach, Pernambuco, 4435 *B. glabrata* were analyzed, with an infection rate of 0.44%. On the other hand, in municipalities from northern state of Espírito Santo, 732 *B. glabrata* and 921 *B. straminea* were analyzed, and so far none of them were positive for *S. mansoni*. The collection of snails was performed using a hand net (netting), adapted to wooden or steel end according to Souza et al. (2006). This procedure was proposed as an alternative to traditional metal scoop (WHO, 1965), keeping in mind that in some areas, quantifying is not feasible and in another area, qualitative study fits well to the work objectives. The use of netting consists of scanning previously established collection waters, providing better coverage of the study area, in less time. Associating positive sites with the protocol for rapid assessment of habitat diversity, it was observed that the presence of snails infected by *S. mansoni* is

Fig. 5. Sampling stations in the city of Mariana, MG. Anthropic disturbances

Fig. 6. Sampling stations in Carne de Vaca beach, PE (left) and northern state of Espírito Santo (right). Anthropic disturbances

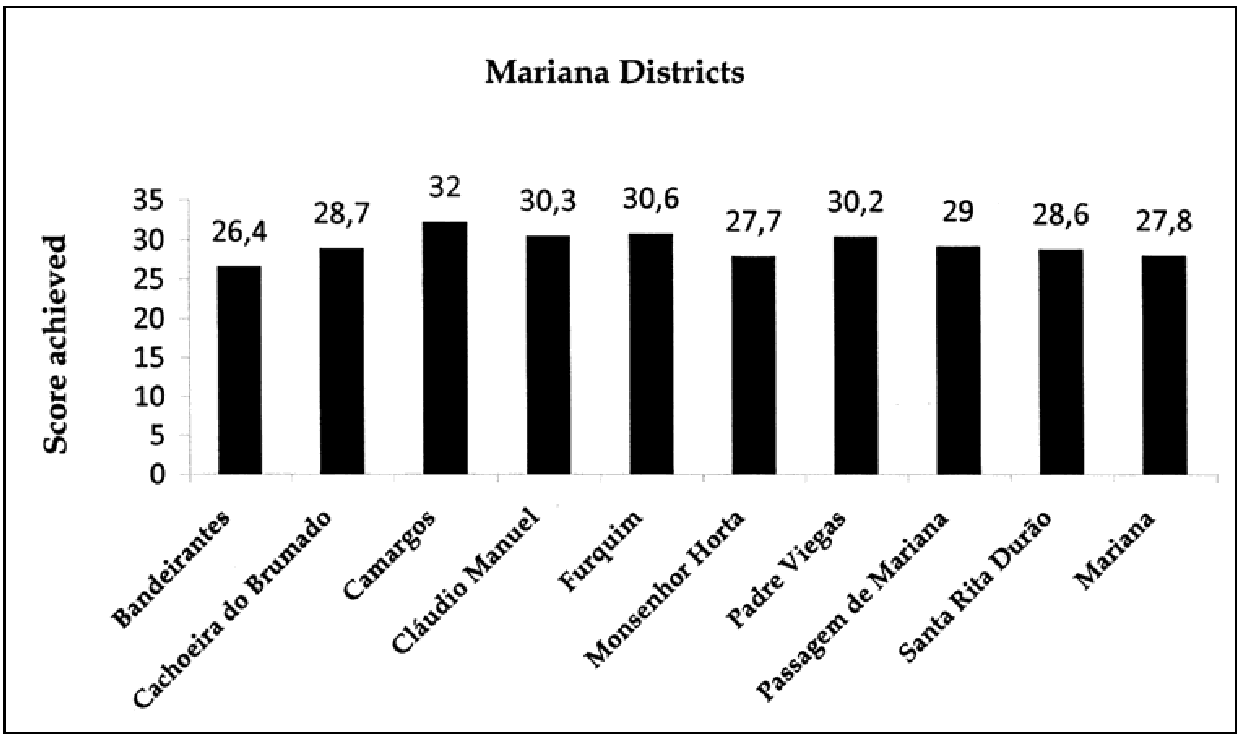

Fig. 7a. Rapid assessment of habitat diversity. Collection sites in the municipality of Mariana, Minas Gerais state. Impacted areas: up to 20 points; Altered areas: > 20 < 36 points; Natural areas: > 36 points

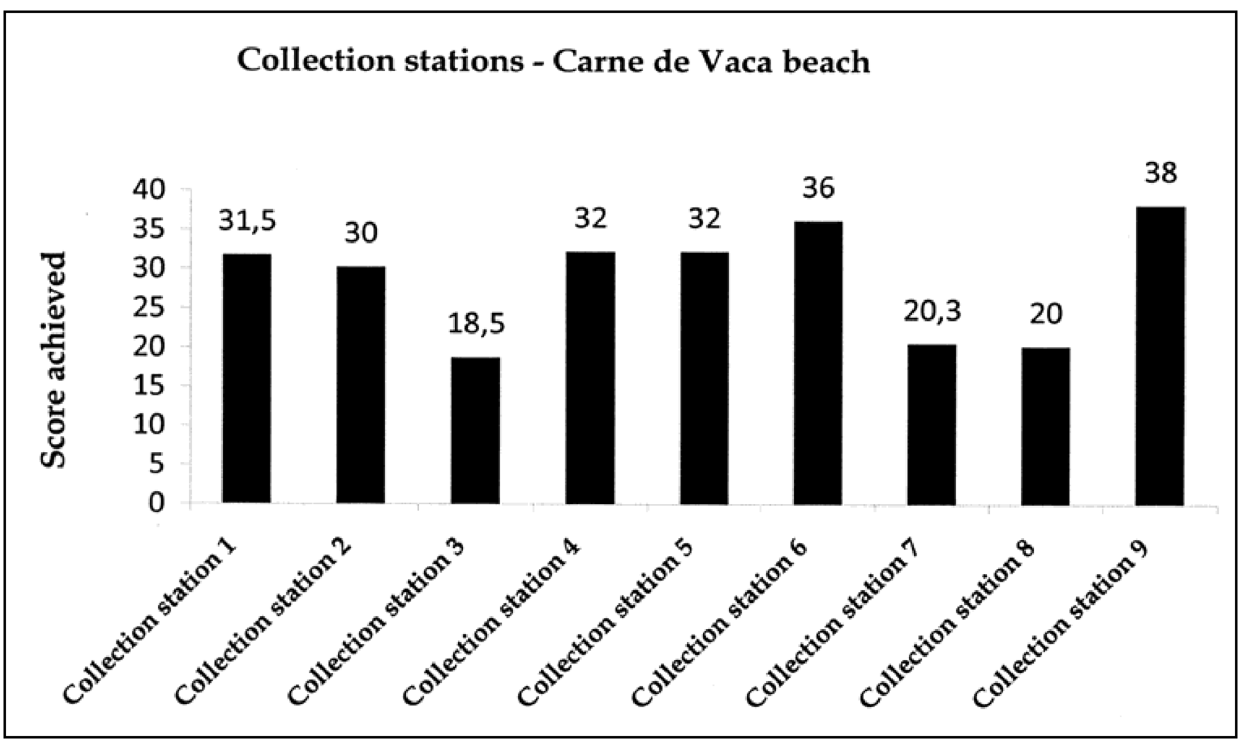

Fig. 7b. Rapid assessment of habitat diversity. Collection stations in Carne de Vaca beach, PE. Impacted areas: up to 20 points; Altered areas: > 20 < 36 points; Natural areas: > 36 points

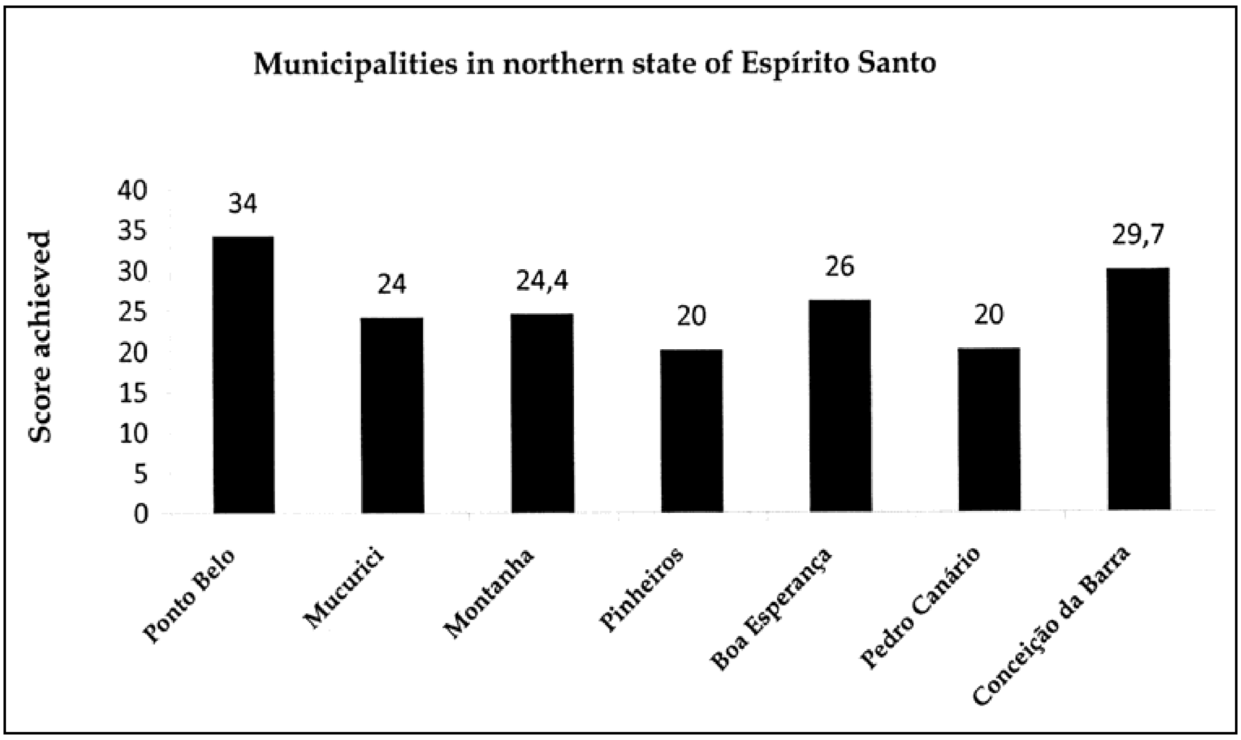

Fig. 7c. Rapid assessment of habitat diversity. Collection sites in municipalities from northern state of Espírito Santo. Impacted areas: up to 20 points; Altered areas: > 20 < 36 points; Natural areas: > 36 points

Fig. 8. Collection sites with the presence of snails *Biomphalaria*. Mariana (both pictures on top), Carne de Vaca (left) and northern state of Espírito Santo (right)

directly related to impacted areas and areas altered by human activity. Of the 10 districts from the municipality of Mariana, in 6 of them (Cachoeira do Brumado, Cláudio Manuel, Furquim, Monsenhor Horta, Santa Rita and Mariana), the gathering of snails infected by *S. mansoni* was directly related to the presence of anthropogenic changes. This characteristic also applies to the Carne de Vaca beach, where the presence of *B. glabrata* infected by *S. mansoni* was observed in sampling stations II, VII and VIII (Figures 7a, 7b). Similarly, although no infected snails were found in the northern Espírito Santo, its presence was also related to impacted areas, especially in the municipalities of Ponto Belo, Mucurici, Montanha, Pinheiros, Boa Esperança and Pedro Canário. Among the environment analyzed, it seems that the highest prevalence of infected snails was found in lotic environments, demonstrating the dispersal of snails and therefore the disease in these municipalities. The present study also assessed some geographical variables of these municipalities, relating them to areas positive for *S. mansoni.* The greatest number of localities with the presence of positive snails showed prevalence of grassland and pastures as vegetal cover, represented by regions devoid of trees and areas cleared by human activity (Baltazar & Raposo, 1993). Analyzing the morphological territorial units (relief), it was observed that the positive sites were those with predominant smooth undulated relief, with predominance of slopes below 35%, with softer slopes and floodplains. Floodplains are areas of materials from larger relieves, represented by the bottom of the more open valleys. They have elevations below 600 m ((Environmental urban plan of Mariana [PDUAM] 2003), which is a factor consistent with the hypsometric analysis performed in the municipalities in which the largest number of locations positive for *S. mansoni* was between 500 and 600 m. Although representing only 3.5% of the total area of these municipalities, floodplains are important because they have conditioned the development of many villages, either due to the concentration of placer gold, or to the flatter relief or the soil fertility (PDUAM, 2003). In both units, better conditions for urban development were observed, and consequently, there were increased human activities. During the study period, comprising in all locations, dry and rainy seasons, it was found that the smallest planorbid snails, whose shell diameters ranged from 1 to 6 mm, were found in greater amounts during the dry season, suggesting a lower dispersion in this season and higher during the rainy season, which favors the expansion of the distribution area of snails and in consequence of the disease. The pH measured in the study areas ranged from 5.5 to 8.4 in the most impacted environments and with high concentration of organic matter, especially environments with lower water flow (lotic environments), such as irrigation ditches or small deviations from the natural course. Although *Biomphalaria* had been found in some wooded and well-preserved environments, in some other areas, with prevalence of grassland and pasture and devoid of trees, in general, snails were more abundant in lentic environments. However, most areas considered foci of transmission were concentrated close to urban populations, which have contact with aquatic environments for leisure or domestic activities, and show higher population density of snails, probably due to anthropogenic input of nutrients that results in higher pH, favouring the growth of aquatic vegetation (algae and macrophytes) such as some Cyperaceae (*Eleocharis* spp.), Araceae (*Pistia stratioides*), Lemnaceae (*Lemna* sp.), Nymphaeacaeae (*Nymphaea* sp.), Pontederiaceae (*Eichhornia* spp. and *Heteranthera reniformis*), Salviniaceae (*Salvinia molesta*) and, consequently, providing shelter and food for snails. Moreover, the bed of most breeding spots and foci was almost muddy and some were sometimes covered with sand, sometimes with fine mud, favouring the camouflage of snails. The heterogeneity in the study areas was also verified, for example, in relation to climate (rainy season from October to March in the Southeastern region and from May to July in the Northeastern region) and almost all temperatures above 25°C, topography, vegetation and altitude (from 0 to ~ 800 m a.s.l.) and the presence of snails and other aquatic gastropod mollusks, thus making a more precise characterization of the breeding spots difficult. In fact, similar results were obtained by Pieri (1995). The presence of fish (mainly *Australoheros Cf. facetus* and *Tilapia* spp.), *Pomacea canaliculata* and *Melanoides tuberculata* apparently did not change the dynamics of the planorbid population. It is noteworthy that in higher areas and in places with higher anthropogenic contribution, high densities of *Physa* spp. associated with *B. glabrata* were found. Other predators mainly hirudinea (*Helobdella* sp.) and several species of aquatic heteroptera in large amounts were also associated with snails without, however, apparently be pushing their population (Souza et al., 2006).

5. Conclusions and perspectivies

In the dynamics of schistosomiasis transmission, environment plays a crucial role. Among the environment analyzed, lotic environments, those represented by collections of running waters, contributed with the greatest number of locations worked (143), while lentic environments, those represented by collections of waters with little flow, contributed with 54. Among the lotic environments, streams stood out, with 119 occurrences in municipalities. According to the score obtained using the protocol for rapid assessment of habitat diversity, it appears that almost all municipalities in the areas under study are within areas in altered situation as a result of disordered development process, also observed in most municipalities in Brazil. This fact is very relevant, considering that the presence of diseases is directly related to environmental degradation and human activity, as observed by Souza et al. (2006, 2008), which reflects the need for combined public policies to prevent their transmission. Among these diseases, schistosomiasis stands out, which control can only be achieved through multidisciplinary engineering, sanitation and healthy actions knowledge. This endemic condition has important epidemiological, parasitological, ecological and malacological determinants and only combined efforts in different areas could lead to the development of effective control. However, health agencies responsible for applying this knowledge in health care should be empowered to implement control procedures adequately. Outbreaks of the disease should be epidemiologically characterized, municipal managers and health agents should be appropriately trained to diagnose, plan and implement appropriate control measures to each situation and prevent future outbreaks, based on the following actions:

- Identification of breeding spots containing naturally infected snails.
- Classification of the focus area according to the risk factors involved.
- Reduction of the relative abundance of vector snails through the environmental manipulation of breeding spots.
- Identification of individuals with history of infection reported by reports of specific symptoms.
- Identification of carriers of the infection based on parasitological examination.
- Chemotherapy treatment of infected individuals with consequent reduction of the prevalence and severity of the disease in affected localities.

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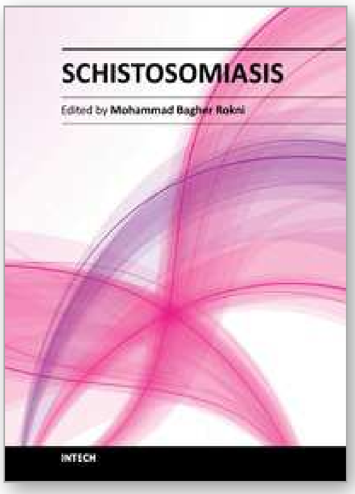

Schistosomiasis

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In the wake of the invitation by InTech, this book was written by a number of prominent researchers in the field. It is set to present a compendium of all necessary and up-to-date data to all who are interested. Schistosomiasis or blood fluke disease, also known as Bilharziasis, is a parasitic disease caused by helminths from a genus of trematodes entitled Schistosoma. It is a snail-borne trematode infection. The disease is among the Neglected Tropical Diseases, catalogued by the Global Plan to combat Neglected Tropical Diseases, 2008-2015 and is considered by the World Health Organization (WHO) to be the second most socioeconomically devastating parasitic disease, next to malaria. WHO demonstrates that schistosomiasis affects at least 200 million people worldwide, more than 700 million people live in endemic areas, and more than 200.000 deaths are reported annually. It leads to the loss of about 4.5 million disability-adjusted life years (DALYs).

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InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
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Phone: +86-21-62489820
Fax: +86-21-62489821