

# A malacological survey in the Manso Power Plant, State of Mato Grosso, Brazil: new records of freshwater snails, including transmitters of schistosomiasis and exotic species

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## ABSTRACT

**Introduction:** Schistosomiasis is a parasitic disease of public health concern in Brazil, and the construction of hydroelectric dams, in addition to increasing permanent human settlement and tourism, has created conditions suitable for the establishment of mollusks that can transmit schistosomiasis. Such areas require a number of actions to prevent the establishment of schistosomiasis. This paper reports on a freshwater malacological survey carried out in the geographical area of the Manso Power Plant. **Methods:** Mollusks were collected in 18 municipalities in the State of Mato Grosso between February 2002 and February 2004 (qualitative study) and from April 2009 to February 2011 (quantitative study). **Results:** Thirty-one species of mollusks were collected, including newly recorded species (*Antillorbis nordestensis* and *Burnupia ingae*). In addition, the geographic distributions of known species, including *Biomphalaria straminea*, a snail vector of *Schistosoma mansoni*, were expanded. A total of 4,507 specimens were collected in the APM Manso reservoir (*Usina Hidrelétrica de Aproveitamento Múltiplo de Manso*) during the quantitative study, and *Biomphalaria amazonica* was found in six of the 10 localities analyzed. The Afro-asiatic species *Melanooides tuberculata*, introduced after February 2009, was the dominant species (relative abundance 94.96%). **Conclusions:** The study area is epidemiologically important due to the occurrence of *B. straminea* and *B. amazonica*, which are vectors of schistosomiasis, and *M. tuberculata*, a snail host of *Centrocestus formosanus*, which is responsible for centrocestiasis transmission. Observations of *M. tuberculata* and the exotic freshwater clams *Corbicula fluminea* and *Corbicula largillierti* raise concerns about biodiversity.

**Keywords:** Distribution. Reservoir. *Schistosoma mansoni*. Exotic species of freshwater mollusk. Asiatic mollusks.

## INTRODUCTION

Schistosomiasis is an important endemic disease associated with environmental changes caused by major economic development projects, such as the construction of hydroelectric power facilities (dams and lakes created by dams)<sup>1-4</sup>. The difficulty in predicting emerging outbreaks of schistosomiasis associated with these types of projects, and the existence of conditions unique to particular projects, require studies in each particular locality to implement appropriate preventive measures. The energy matrix of Brazil utilizes hydroelectric power<sup>5</sup>, and the increasing number of dams being built throughout the country is problematic because these dams create conditions suitable for the establishment of mollusk vectors

of schistosomiasis and lead to increased permanent human settlement and tourism<sup>6,7</sup>.

Environmental changes caused by dams affect water quality, produce eutrophic effects, and alter the hydrological pattern and ecological dynamics of the rivers and basins<sup>8</sup>. Despite the effects of dams on the richness of the fauna, species density, and other aspects of biodiversity, longitudinal studies of invertebrate fauna in dam areas are still scarce in Brazil. In qualitative study carried out between 1997 and 2004 in the geographical area of the Serra da Mesa Power Plant, State of Goiás, Thiengo et al.<sup>9</sup> noted the spread of the schistosomiasis vector *Biomphalaria straminea* (Dunker, 1848) and the exotic snail *Melanooides tuberculata* (Müller, 1774), as well as a reduction in the local species *Gundlachia ticaga* (Marcus & Marcus, 1962) and *Aylacostoma tenuilabris* (Reeve, 1860). In the Itabapoana River, between the States of Rio de Janeiro and Espírito Santo, an increase in the population of *Biomphalaria tenagophila* (d'Orbigny, 1835) was observed in the geographical area of the Rosal Power Plant during the construction phase, mainly due to the change from a lotic to a lentic ecosystem and the eutrophication of the water<sup>4</sup>.

Since 1986, Brazilian environmental laws have required the development of preventive measures to minimize the environmental impact of dams and avoid new foci of endemic disease caused by impoundments. The possibility of introducing

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**Received** 9 June 2014

**Accepted** 14 August 2014

schistosomiasis to non-endemic areas in Brazil via the introduction of vector snails was reported by Fernandez and Thiengo<sup>10-11</sup>, who observed different degrees of susceptibility to *Schistosoma mansoni* Sambon, 1907 in an experimental infection of *B. straminea* from three different reservoirs in the Upper Tocantins river basin. Three species of *Biomphalaria* that play a role in the transmission of *S. mansoni* in Brazil were recently found in the Pampulha reservoir, which is a potential urban focus of schistosomiasis located in the municipality of Belo Horizonte, State of Minas Gerais<sup>12</sup>.

The pathways of introduction and dispersion of exotic species in reservoirs have been poorly documented. In the three reservoirs of the Middle Tietê River, State of São Paulo, Suriani et al.<sup>13</sup> registered eight species of mollusks that most likely compete with native species, including *M. tuberculata* and *Corbicula fluminea* (Müller, 1774). Studies of these exotic species are urgently needed, as their impact on aquatic environments is unpredictable<sup>14,15</sup>.

This paper presents the results of qualitative and quantitative studies of freshwater mollusks in the area of the Manso Power Plant (APM Manso, i.e., *Usina Hidrelétrica de Aproveitamento Múltiplo de Manso*). The paper also notes the distribution of two species of medical importance, *B. straminea* and *Biomphalaria amazonica* Paraense 1966, as well as exotic species, in particular the invasive Asiatic clams *C. fluminea* and *Corbicula largillierii* (Philippi, 1844) and the gastropod *M. tuberculata*. In addition, newly recorded mollusk species are reported.

## METHODS

APM Manso is located in the Cuiabá River basin, State of Mato Grosso, and covers an area of 427km<sup>2</sup> between the municipalities of Chapada dos Guimarães and Nova Brasilândia. Freshwater snails were collected in the reservoir and surrounding municipalities in 2002 (February, April, August, October and December), 2003 (every two months from February to December), 2004 (February), 2009 (April, June, August, October and December), 2010 (February, April, June, August, October and December) and 2011 (February). Malacological collections were also performed at other sites (streams, ponds, lakes, ditches, etc.) in the following municipalities: Acorizal, Alto Paraguai, Chapada dos Guimarães, Cuiabá, Diamantino, Jaciara, Jangada, Juscimeira, Nobres, Nova Brasilândia, Nossa Senhora do Livramento, Pedra Preta, Poxoréu, Primavera do Leste, Rondonópolis, Rosário Oeste, São Pedro da Cipa and Várzea Grande. All sampling sites were georeferenced.

Between April 2009 and October 2010, the abundance of species in APM Manso was evaluated every two months in 10 sampling stations (quantitative study) distributed in the major rivers of the reservoir (**Figure 1**) and georeferenced: two locations in the Manso River [(1) = 14°49'06"S, 55°37'02"W; (4) = 14°48'00"S, 55°40'10"W], two locations in the Palmeiras River [(2) = 14°48'22"S, 55°36'32"W; (3) = 14°48'53"S, 55°35'07"W], one stream at the junction of the Casca and Manso Rivers near the dam [(5) = 14°54'39"S, 55°45'50"W], four

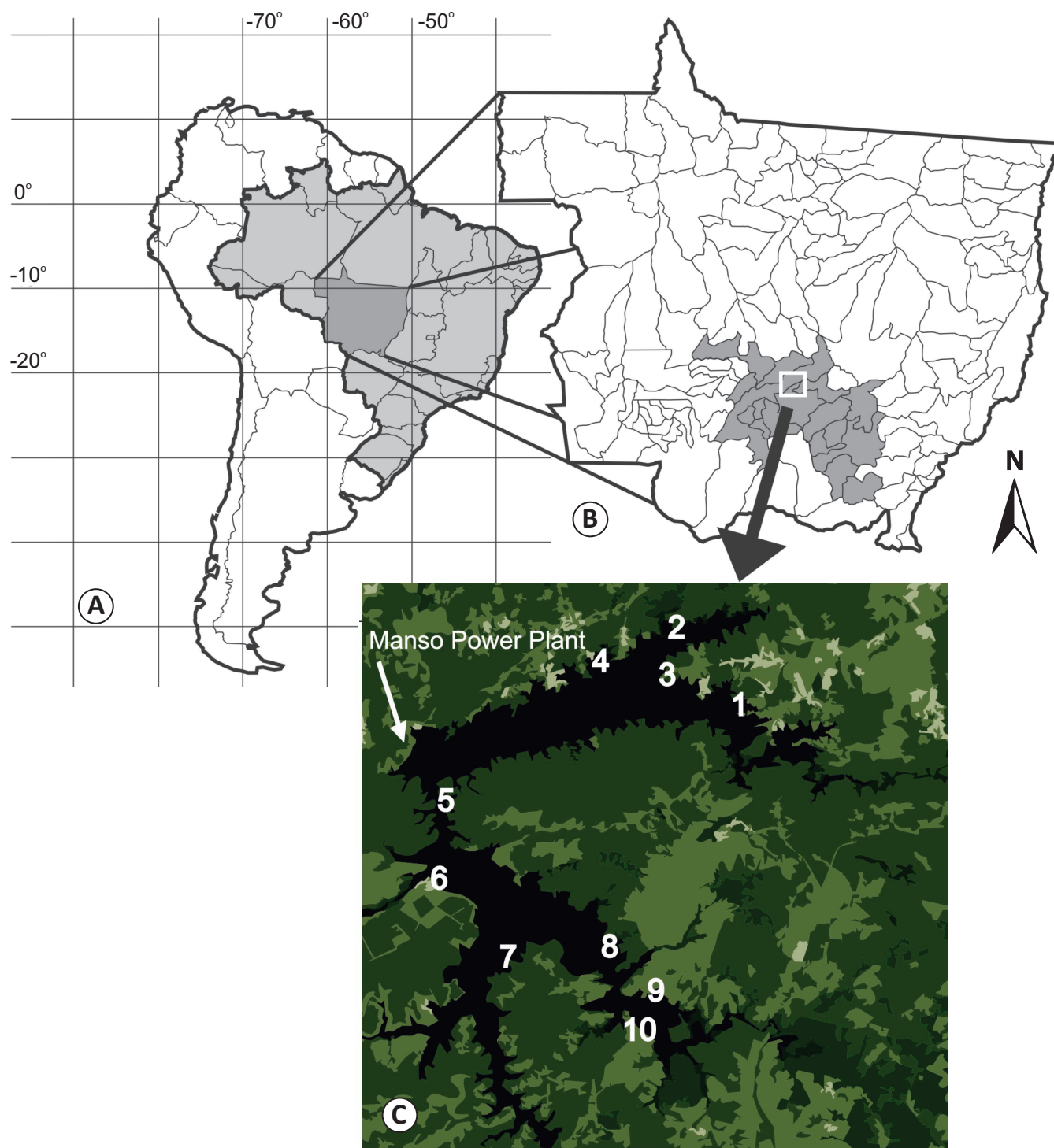
locations in the Casca River [(6) = 14°56'24"S, 55°47'33"W; (8) = 14°57'35"S, 55°40'12"W; (9) = 15°00'47"S, 55°35'51"W; (10) = 15°01'38"S, 55°36'14"W], and one location in the Quilombo River [(7) = 15°00'50"S, 55°43'35"W]. The mollusks were obtained by direct collection (three collectors performed 10-minute searches at each site) without interruption to calculate the number of snails collected per man per unit of time. The relative abundance of freshwater mollusks in the APM Manso reservoir was calculated by dividing the total number of individuals of a given species by the total number of individuals of all species.

In the Laboratório de Malacologia of Instituto Oswaldo Cruz, Fundação Oswaldo Cruz, Rio de Janeiro, State of Rio de Janeiro, the specimens were placed in aquaria containing dechlorinated tap water with a thin bottom layer of a 2:1 mixture of screened soil and ground oyster shells as a source of mineral nutrients. For species identification, the snails were anesthetized in Hypnol 0.05% solution (Cristália – Produtos Químicos e Farmacêuticos LTDA, Itapira, São Paulo) for five hours, killed using hot water (70°C) and fixed in Railliet-Henry solution<sup>16</sup>.

## RESULTS

Thirty-one freshwater mollusk species were collected (nine families and 17 genera) from 18 municipalities in the State of Mato Grosso, Brazil (**Table 1** and **Table 2**): *Anodontites elongatus* (Swainson, 1823); *Anodontites tenebricosus* (Lea, 1834); *Anisancylus* sp.; *Antillorbis nordestensis* (Lucena, 1954); *B. amazonica*; *Biomphalaria occidentalis* Paraense, 1981; *Biomphalaria schrammi* (Crosse, 1864); *B. straminea*; *Biomphalaria* sp.; *Burnupia ingae* Lanzer, 1991; *C. fluminea*; *C. largillierii*; *Drepanotrema anatinum* (d'Orbigny, 1835); *Drepanotrema depressissimum* (Moricand, 1839); *Drepanotrema lucidum* (Pfeiffer, 1839); *Eupera tumida* (Clessin, 1879); *Eupera* sp.; *Ferrissia* sp.; *Gundlachia radiata* (Guilding, 1828); *G. ticaga*; *Gundlachia* sp.; *Idiopyrgus* sp.; *Laevapex* sp.; *M. tuberculata*; *Physa marmorata* Guilding, 1828; *Pisidium* sp.; *Pomacea maculata* Perry, 1810; *Pomacea lineata* (Spix in Wagner, 1827); *Pomacea scalaris* (d'Orbigny, 1835); *Pomacea* sp. and *Uncancylus concentricus* (d'Orbigny, 1835). The mollusk samples from all the municipalities were deposited in the Mollusk Collection of Instituto Oswaldo Cruz (CMIOC), Rio de Janeiro, Brazil.

Among the medically important species, *B. straminea* was found in nine localities of the three municipalities (Cuiabá, Diamantino and Várzea Grande): 15°35'59"S, 56°03'54"W; 15°34'08"S, 56°04'43"W; 15°35'53"S, 56°06'57"W; 15°33'58"S, 56°02'28"W; 15°36'54"S, 56°06'30"W; 15°39'21"S, 56°00'13"W; 15°32'56"S, 56°02'15"W 14°24'23"S, 56°26'59"W and 15°40'15"S, 56°04'32"W. *Biomphalaria amazonica*, a potential intermediate host of *S. mansoni*, was found in the Casca and Manso rivers, which form the reservoir, in six areas of the municipality of Chapada dos Guimarães. *B. amazonica* was frequently associated with the macrophytes *Salvinia auriculata* Aublet, 1775 and *Pistia stratiotes* Linnaeus, 1753.



**FIGURE 1 - Location of study area. A:** Map of South America showing Brazil and the State of Mato Grosso. **B:** Municipalities that were surveyed for the presence of snails. **C:** APM Manso reservoir showing the sampling station of the quantitative study: 1 and 4: Manso River; 2 and 3: Palmeiras River; 5: Stream in the junction of the Casca and Manso Rivers near the dam; 6, 8, 9 and 10: Casca River; and 7: Quilombo River. APM Manso: *Usina Hidrelétrica de Aproveitamento Múltiplo de Manso*.

**TABLE 1 - Freshwater bivalves and gastropods (Order Caenogastropoda) and municipalities where mollusks were found in the area of APM Manso, State of Mato Grosso, Brazil, from February 2002 to February 2004 and from April 2009 to February 2011.**

Municipalities	Bivalvia						Gastropoda: Caenogastropoda					
	Mycetopodiidae		Sphaeriidae			Corbiculidae	Ampullariidae			Pomatopsidae		Thiaridae
	<i>Anodonta elongatus</i>	<i>Anodonta tenebricosus</i>	<i>Eupera tumida</i>	<i>Eupera</i> sp.	<i>Pisidium</i> sp.	<i>Corbicula largillierii</i>	<i>Corbicula fluminea</i>	<i>Pomacea maculata</i>	<i>Pomacea lineata</i>	<i>Pomacea scalaris</i>	<i>Pomacea</i> sp.	<i>Idiopyrgus</i> sp.
Alto Paraguai								+			+	
Chapada dos Guimarães	+	*		*			*	*+				*
Cuiabá						+	+	+	+		+	+
Jaciara											+	
Jangada							+					
Juscimeira								+				
Nobres			+					+			+	+
Nossa Senhora do Livramento											+	
Rosário Oeste					+			+			+	+
Várzea Grande	+									+	+	+
São Pedro da Cipa								+				

**APM Manso:** Usina Hidrelétrica de Aproveitamento Múltiplo de Manso. +: occurrence in biotopes in the municipalities; \*: occurrence in biotopes in the APM Manso reservoir.

The quantitative study carried out in APM Manso revealed the occurrence of mollusks in all the surveyed localities during the dry season (from June to November). *M. tuberculata* was obtained in all the searches (Table 3). Three species were found only once: *P. maculata* in the Casca River (Sampling station No. 10) in August 2010, and *C. fluminea* and *P. marmorata* in the Manso River in October 2009 (N° 1) and April 2009 (N° 4), respectively. During the qualitative study in the APM Manso reservoir from February 2002 to February 2004, when 38 collection sites were analyzed, *M. tuberculata* was not found, but specimens of *A. nordestensis*, *A. tenebricosus*, *B. amazonica*, *B. occidentalis*, *Biomphalaria* sp., *C. fluminea*, *D. anatinum*, *D. depressissimum*, *D. lucidum*, *Eupera* sp., *Ferrissia* sp., *G. ticaga*, *G. radiata*, *Laevapex* sp., *P. maculata*, *P. marmorata* and *U. concentricus* were obtained.

Considering the occurrence of species in 18 municipalities, the most frequently found *Biomphalaria* species was *B. occidentalis*, occurring in twelve municipalities, followed by *B. amazonica* and *B. straminea*. The most frequently found Caenogastropoda species were *P. maculata* and *Pomacea* sp., followed by

*Melanoides tuberculata*, which was found in five municipalities. Samples of *P. scalaris* and *Idiopyrgus* sp. were found only in the municipalities of Várzea Grande and Rosário Oeste, respectively.

A total of 4,507 specimens were collected in the quantitative study; *M. tuberculata* was the most common, comprising 94.96% of the overall population. The most representative species was *G. radiata*, followed by *M. tuberculata* and *B. amazonica*, found in six (60%) and seven (70%) sampling stations, respectively (Table 4). In the qualitative study, *G. radiata* was also the most frequent species, found in 41 out of the 104 surveyed localities in eight municipalities. Among the planorbids, *D. anatinum* was the most widespread in the study area (36 localities in six municipalities) from 2002 to 2004; in the quantitative study, *D. anatinum* was only found in two areas (stations 3 and 9). The most common species found at the APM Manso reservoir between 2002 and 2004 was *D. anatinum*, which was collected from 25 out of the 31 surveyed localities (27 in the Chapada dos Guimarães and four in Nova Brasilândia); the next most common species found was *G. radiata* (23 localities).

**TABLE 2 - Freshwater gastropods (Order Pulmonata: Suborder Basommatophora) and municipalities where mollusks were found in the area of APM Manso, State of Mato Grosso, Brazil, from February 2002 to February 2004 and from April 2009 to February 2011.**

Municipalities	Planorbidae							Physidae	Ancyliidae									
	<i>Antilorbis nordestensis</i>	<i>Biomphalaria amazonica</i>	<i>Biomphalaria</i> sp.	<i>Biomphalaria occidentalis</i>	<i>Biomphalaria schrammi</i>	<i>Biomphalaria straminea</i>	<i>Drepanotrema anatinum</i>		<i>Drepanotrema depressissimum</i>	<i>Drepanotrema lucidum</i>	<i>Physa marmorata</i>	<i>Anisancylus</i> sp.	<i>Burnupia ingae</i>	<i>Ferrissia</i> sp.	<i>Gundlachia ticaga</i>	<i>Gundlachia radiata</i>	<i>Gundlachia</i> sp.	<i>Laevapex</i> sp.
Acorizal	+							+				+		+				
Alto Paraguai				+				+	+									
Chapada dos Guimarães	*+	*+	*+	*+			*+	*+	*+	*+	+	+	*	*+	*+		*+	*+
Cuiabá	+	+	+	+		+	+	+	+	+	+	+		+	+		+	
Diamantino				+		+			+									
Jaciara				+				+										
Jangada	+			+				+	+	+				+	+		+	
Juscimeira							+	+	+	+								
Nobres	+	+	+	+	+		+	+	+	+		+		+	+			
Nossa Senhora do Livramento				+	+			+	+									
Nova Brasilândia		*	*				*+	+	+	+								
Pedra Preta	+			+				+	+						+			
Poxoréu			+					+	+									
Primavera do Leste											+			+				
Rondonópolis				+				+	+	+								
Rosário Oeste	+			+			+	+	+	+				+	+	+	+	
Várzea Grande	+			+		+		+	+					+	+			

**APM Manso:** Usina Hidrelétrica de Aproveitamento Múltiplo de Manso. +: occurrence in biotopes in the municipalities; \*: occurrence in biotopes in the APM Manso reservoir.

## DISCUSSION

The study area is epidemiologically important due to the environmental effects of the APM Manso project and the occurrence of *B. straminea* and *B. amazonica* in State of Mato Grosso. Additionally, from a medical standpoint, the abundance of *M. tuberculata* in the study area is a matter of concern. This exotic species, which is a natural host of *Centrocestus formosanus* (Nishigori, 1924) in Brazil<sup>17</sup>, is responsible for

centrocestiasis transmission. The biological interaction between *M. tuberculata* and *C. formosanus* has previously been found in China, Colombia, India, Iran, Japan, Malaysia, Mexico, Taiwan, the United States and Venezuela<sup>18</sup>. Human transmission has already been reported in Asia and occurs through the ingestion of fish that are infected with metacercariae, a larval stage that develops after the fish is exposed to *Pleurolophocercous* cercaria eliminated by infected snails. This type of cercariae, most likely *C. formosanus*, has also been obtained in specimens of *M. tuberculata* collected in the Manso River<sup>19</sup>.

**TABLE 3 - Freshwater mollusks collected in ten sampling stations in the reservoir of APM Manso, State of Mato Grosso, from April 2009 to October 2010.**

	2009					2010				
	April	June	August	October	December	February	April	June	August	October
<i>Biomphalaria amazonica</i>				(2) 2 (4) 3 (5) 2					(3) 1 (9) 1 (10) 1	(3) 2
<i>Corbicula fluminea</i>				(1) 3						
<i>Drepanotrema anatinum</i>		(3) 9	(9) 1			(3) 1				
<i>Drepanotrema depressissimum</i>	(1) 8	(3) 2		(2) 2	(2) 1					
<i>Ferrissia</i> sp.			(3) 6	(3) 3			(2) 1			
<i>Gundlachia radiata</i>		(4) 2 (8) 16 (10) 1		(3) 37 (4) 77		(8) 3	(1) 1		(1) 1 (3) 5 (5) 3 (7) 1 (10) 21	(3) 5
<i>Melanoides tuberculata</i>	(3) 3 (5) 2 (6) 26	(2) 88 (3) 84 (4) 168 (5) 1 (6) 201	(2) 15 (3) 35 (4) 8 (5) 5 (6) 236	(1) 5 (2) 165 (3) 8 (4) 6 (5) 17 (6) 90	(1) 6 (2) 60 (3) 5 (4) 1 (5) 3	(6) 74	(3) 51 (4) 2 (6) 72	(1) 29 (2) 3 (3) 59 (4) 60 (6) 87	(1) 13 (2) 13 (3) 61 (4) 4 (5) 30 (6) 121	(1) 317 (2) 258 (3) 93 (4) 1560 (5) 78 (6) 57
<i>Physa marmorata</i>	(4) 2									
<i>Pomacea maculata</i>									(10) 3	
Number of mollusks/month	41	572	306	420	76	78	127	238	279	2,370

**APM Manso:** Usina Hidrelétrica de Aproveitamento Múltiplo de Manso. **Sampling stations:** Manso River [(1) and (4)]; Palmeiras River [(2) and (3)]; Casca River [(6), (8), (9) and (10)]; Quilombo River [(7)] and in the junction of Casca and Manso Rivers [(5)]. Beside each sampling station is the specific abundance of mollusks (number of individuals) collected in the reservoir, at each sampling station, during the quantitative study.

**TABLE 4 - Number of specimens of mollusks collected in each sampling station in the APM reservoir during the quantitative study carried out between April 2009 and October 2010.**

Sampling stations											Relative abundance
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(%)
<i>Biomphalaria amazonica</i>		2	3	3	2				1	1	0.27
<i>Corbicula fluminea</i>	3										0.07
<i>Drepanotrema anatinum</i>			10						1		0.24
<i>Drepanotrema depressissimum</i>	8	3	2								0.29
<i>Ferrissia</i> sp.		1	9								0.22
<i>Gundlachia radiata</i>	2		47	79	3		1	19		22	3.84
<i>Melanoides tuberculata</i>	370	602	399	1,809	136	964					94.94
<i>Physa marmorata</i>				2							0.04
<i>Pomacea maculata</i>										3	0.07

**APM Manso:** Usina Hidrelétrica de Aproveitamento Múltiplo de Manso.

The present study extends the known distribution of *B. straminea* in the State of Mato Grosso, as it has previously been reported in the municipalities of Diamantino and Várzea Grande<sup>20</sup>. *B. straminea* is of great epidemiological importance because it is responsible for areas of active transmission of schistosomiasis in northeastern Brazil, and its occurrence in the Cuiabá River (municipality of Cuiabá) is significant because of the frequent presence of fishermen at this site. Experimental infection studies of *B. amazonica* populations from the APM Manso reservoir (collected from Chapada dos Guimarães) revealed infection rates of 2.02% and 9.09% with the BH and EC strains of *S. mansoni*, respectively<sup>21</sup>. Although natural infection of *B. amazonica* with *S. mansoni* has never been described, since the 1970s experimental infection studies have raised concerns about the transmission of schistosomiasis in the range of *B. amazonica*<sup>22</sup>. Considering these studies, in addition to environmental and social factors in the area, the possibility of the introduction of schistosomiasis in this reservoir, although low, cannot be ignored.

The results of this study confirm the report by Paraense<sup>23</sup> of the widespread occurrence of the non-vector *Biomphalaria* species *B. occidentalis* in the State of Mato Grosso. Six new localities were reported in our study, bringing the total number to 23 municipalities in the state: Alto Paraguai, Arenópolis, Barão de Melgaço, Cabaçal, Cáceres, Cachoeirinha, Chapada dos Guimarães, Cuiabá, Diamantino, Jaciara, Jangada, Jauru, Nobres, Nortelândia, Nossa Senhora do Livramento, Pedra Preta, Poconé, Pontes e Lacerda, Quatro Marcos, Rondonópolis, Rosário Oeste, Santo Antônio do Leverger, and Várzea Grande.

Reservoirs have been continually subject to the introduction and establishment of alien species, as reported by Rocha et al.<sup>24</sup> in State of São Paulo. The authors showed that rapid invasion processes were ongoing on the Tietê River basin for three species of mollusks: *C. fluminea*, *Limnoperna fortunei* (Dunker, 1857) and *M. tuberculata*. Similar findings were observed in the APM Manso reservoir for *M. tuberculata*; (between 2009 and 2010), introduced after February 2009, it became the most abundant species. As well as being an intermediate host of *C. formosanus*, *M. tuberculata* destabilizes the course of periphyton colonization, suggesting that it may also disrupt natural food chains<sup>25</sup>.

This study extends the known distribution of *A. nordestensis* in 11 States (Alagoas, Goiás, Maranhão, Minas Gerais, Pará, Paraná, Pernambuco, Rio Grande do Sul, Rio de Janeiro, Santa Catarina, and São Paulo) and Distrito Federal<sup>26-28</sup> to include eight municipalities in the State of Mato Grosso. However, *Drepanotrema cimex* (Moricand, 1839), previously reported to be present in Cáceres and Cuiabá<sup>23</sup>, was not found in any of the surveyed municipalities. *Drepanotrema heloicum* (d'Orbigny, 1835) and *Drepanotrema kermatooides* (d'Orbigny, 1835), which have also previously been found in Mato Grosso<sup>26</sup>, were not found in the study area, confirming the results reported by Paraense in 21 municipalities of the state<sup>23</sup>.

With regard to the Ancyliidae, the distribution of the genus *Anisancylus* Pilsbry, 1924 was extended to the Central-West Region. *Anisancylus dutrae* Santos, 1994 occurs in northeastern

Brazil, from Pernambuco to Bahia<sup>29,30</sup>; *Anisancylus obliquus* (Broderip & Sowerby, 1832) has been recorded from southern Brazil to Uruguay, Argentina and Chile<sup>30,31</sup>. These species occur in shallow lotic waters, especially over stones, and seldom occur on the abaxial surface of leaves. *Burnupia ingae* was observed for the first time in three municipalities (Chapada dos Guimarães, Cuiabá and Nobres) in the State of Mato Grosso. This finding of *B. ingae* in Mato Grosso extends its known range, as it was previously found only in southern Brazil, in the States of Santa Catarina and Rio Grande do Sul<sup>30-32</sup>. Lacerda and Santos<sup>33</sup> reviewed samples housed in the Malacological Collections, including the CMIOC, and a literature search estimating the current distribution of *B. ingae* in Brazil showed that it was present in 20 municipalities in seven states. The genus *Laevapex* Walker, 1903 was also recorded for the first time in the State of Mato Grosso, in the municipalities of Chapada dos Guimarães, Cuiabá, Jangada and Rosário Oeste; it was previously cited as present in the Serra da Mesa dam<sup>9</sup> as well as other scattered locations in Brazil<sup>30,31</sup>.

The diversity of lentic habitats provided by dam construction seems to favor the expansion and establishment of *G. radiata*, which has a wide distribution, from the southern United States, Central America and Caribbean, to northern and northeastern Brazil<sup>30,31</sup>. Recently, this species has been found in the State of Rio de Janeiro, extending its known distribution to southeastern Brazil<sup>34</sup>. The results of this quantitative study were similar to previous studies performed in the Serra da Mesa dam<sup>9</sup> in central Brazil, where an intense colonization by *G. radiata* and the disappearance of *G. ticaga* was reported a few years after the creation of the reservoir.

High densities of the macrophytes *P. stratiotes* and *S. auriculata* were found in the Manso and Casca Rivers, respectively, which form the APM Manso reservoir, between 2002 and 2003<sup>3</sup>. Takeda et al.<sup>35</sup> noted 25 groups of invertebrates associated with five different macrophytes in the floodplain of the high Parana River, with *P. stratiotes* having the largest invertebrate density, followed by *Salvinia* sp. The present study confirmed the importance of these macrophytes in the establishment and colonization of mollusks in the APM Manso reservoir, as it was common to find snails attached to macrophyte roots that were floating on the lake far from the edge of the reservoir.

The present study extends the distribution of some species of the Ampullariidae and Corbiculidae, including *P. lineata*, which occurs from northeastern to southeastern Brazil but generally in the coastal region and *P. maculata*, which is among the largest of the freshwater snails and, together with *P. scalaris*, occurs frequently in the basins of the Prata, Paraguay and Uruguay Rivers<sup>36</sup>.

In the Manso Power Plant area, the discovery of two Corbiculidae species, *C. largillierti* and *C. fluminea*, is a major problem, mainly because of the ecological and economic impact on local fauna and hydroelectric power. These Asiatic species were introduced in the State of Rio Grande do Sul in the 1980s, and, in 1998, they were reported in the flooded area of Pantanal Mato-Grossense near Cuiabá<sup>37,38</sup>. The present paper reports both species in Cuiabá, confirming previous reports, and

adds *C. fluminea* to three municipalities, including the reservoir area. Recently, Pereira et al.<sup>39</sup> listed the freshwater bivalve species of South America, including the families Corbiculidae, Mycetopodidae and Sphaeriidae, and commented that changes from lotic to lentic ecosystems interfere in the life cycle of these mollusks, which depend on fish for their dispersal.

Mollusks are particularly common in the dry season; in an analysis of the diversity of mollusks in a reservoir in Thailand, Tesana<sup>40</sup> reported that many species increased in population during the cold season. These species appear to hatch during the rainy season and grow large enough to be detected by the dry season<sup>40</sup>. Furthermore, Paraense<sup>41</sup> commented that populations decrease substantially at the peak of the rainy season, due to the effects of floods and other environmental disturbances.

Cercarial dermatitis<sup>42</sup>, which is considered an emerging disease, may be occurring in the study area because Ampullariidae and Planorbidae specimens have been found harboring Brevifurcate aphyaryngeate cercaria in the municipalities of Alto Paraguai, Poconé and Nobres<sup>43</sup>. According to Horák and Kolárová<sup>44</sup>, the dispersal of bird schistosomes to new regions and an increased availability of snail hosts, together with the use of new water reservoirs for recreational purposes, may contribute to a higher number of outbreaks of cercarial dermatitis. In the State of Espírito Santo, Brevifurcate aphyaryngeate cercariae were found in naturally infected *P. marmorata* and identified by morphological and molecular methods as *Trichobilharzia* sp., the main etiological agents of cercarial dermatitis in humans<sup>45</sup>. This observation suggests an increased possibility of the existence of unknown cases of avian cercarial dermatitis in Brazil, including the Central-West Region, due to the presence of well-established populations of *P. marmorata* in areas affected by hydroelectric plants in the Tocantins<sup>9,46</sup> and Araguaia<sup>47</sup> Rivers, in addition to those found in this study. Given the increasing number of dams in the middle-west region of the country over the past few years, malacological surveys should be performed in such areas. Those studies are an important strategy to prevent new foci of schistosomiasis and other zoonoses and will provide data on the effect of dams on freshwater mollusk populations.

## ACKNOWLEDGMENTS

To *Furnas Centrais Elétricas* for the facilities provided during field work; to Dr. Maria Cristina Dreher Mansur for the identification of bivalve species, and to Ms. Anne Louise G. Nemer for the preparation of figure.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## FINANCIAL SUPPORT

*Fundação Oswaldo Cruz* and *Furnas Centrais Elétricas* (Convênio 023/98 e Projeto IOC-002-CAC-09-2-2).

## REFERENCES

- Southgate VR. Schistosomiasis in the Senegal river basin; before and after the construction of the dams at Diama, Senegal and Manantali, Mali and future prospects. *J Helminthol* 1997; 71:125-132.
- Magalhães LA, Dias LCS, Piza JT, Takaku L, Pereira AA. Aspectos epidemiológicos da esquistossomose mansônica na região da Represa de Americana, Estado de São Paulo, Brasil. *Rev Saude Publica* 1973; 7:21-28.
- Thiengo SC, Fernandez MA. Moluscos límnicos em reservatórios de Usinas Hidrelétricas no Brasil: aspectos biológicos e epidemiológicos. In: Carvalho OS, Coelho PMZ, Lenzi H, editors. *Schistosoma mansoni* & Esquistossomose: uma visão multidisciplinar. Rio de Janeiro: Editora FIOCRUZ; 2008. p. 435-457.
- Rezende HR, Sessa PA, Ferreira AL, Santos CB, Leite GR, Falqueto A. Efeitos da implantação da Usina Hidrelétrica de Rosal, Rio Itabapoana, Estados do Espírito Santo e Rio de Janeiro, sobre anofelinos, planorbídeos e flebotomíneos. *Rev Soc Bras Med Trop* 2009; 42:160-164.
- Bronzatti FL, Iarozinski Neto A. Matrizes energéticas no Brasil: cenário 2010-2030. XXVIII Encontro Nacional de Engenharia de Produção (16 a 18 de outubro). Rio de Janeiro, RJ: Associação Brasileira de Engenharia de Produção; 2008.
- Leme FBM. As represas como lugares turísticos: novas significações e valorizações de uma paisagem sem memória. *Cultur: Rev Cultura Turismo* 2007; 1:65-85.
- Lima SFS, Batista GT. Impacto da Represa Hidrelétrica de Paraibuna, SP, Brasil. *Ambi-Água* 2010; 5:208-221.
- Nogueira MG, Henry R, Jorcin A. Ecologia de reservatórios: impactos potenciais, ações de manejo e sistemas em cascata. São Carlos: Editora Rima; 2005.
- Thiengo SC, Santos SB, Fernandez MA. Freshwater molluscs of the lake of Serra da Mesa dam, Goiás, Brazil. I. Qualitative study. *Rev Bras Zool* 2005; 22:867-874.
- Fernandez MA, Thiengo SC. Susceptibility of *Biomphalaria straminea* (Dunker, 1848) from Serra da Mesa dam, Goiás, Brazil to infection with three strains of *Schistosoma mansoni* Sambon, 1907. *Mem Inst Oswaldo Cruz* 2002; 97 (supl 1):49-60.
- Fernandez MA, Thiengo SC. Susceptibility of *Biomphalaria straminea* from Peixe Angical dam, Tocantins, Brazil to infection with three strains of *Schistosoma mansoni*. *Mem Inst Oswaldo Cruz* 2010; 105:488-491.
- Pinto HA, Mati VLT, Melo AL. The Pampulha reservoir remains a potential urban focus of schistosomiasis mansoni in Brazil: changes in the occurrence patterns of *Biomphalaria* species and a new record of the parasite. *Rev Soc Bras Med Trop* 2013; 46:478-483.
- Suriani AL, França RS, Rocha O. A malacofauna bentônica das represas do médio rio Tietê (São Paulo, Brasil) e uma avaliação ecológica das espécies exóticas invasoras, *Melanooides tuberculata* (Müller) e *Corbicula fluminea* (Müller). *Rev Bras Zool* 2007; 24:21-32.
- Mansur MCD, Santos CP, Pereira D, Paz ICP, Zurita MLL, Rodriguez MTR, et al. Moluscos límnicos invasores no Brasil. Biologia, prevenção, controle. Porto Alegre, RS: Redes Editora Ltda; 2012.
- Bagatini YM, Higuti J, Benedito E. Temporal and longitudinal variation of *Corbicula fluminea* (Mollusca, Bivalvia) biomass in the Rosana reservoir, Brazil. *Acta Limnol Bras* 2007; 19:357-366.
- Fernandez MA, Thiengo SC, Amaral RS. Técnicas malacológicas. In: Amaral RS, Thiengo SC, Pieri OS, editors. *Vigilância e Controle de Moluscos de importância Médica: Diretrizes Técnicas*. Brasília: Editora do Ministério da Saúde 2008; p. 43-70.
- Pinto HA, Melo AL. *Melanooides tuberculata* (Mollusca: Thiaridae) as an intermediate host of *Centrocestus formosanus* (Trematoda: Heterophyidae) in Brazil. *Rev Inst Med Trop São Paulo* 2010; 52: 207-210.



18. Pinto HA, Melo AL. A checklist of trematodes (Platyhelminthes) transmitted by *Melanoides tuberculata* (Mollusca: Thiariidae). *Zootaxa* 2011; 2799: 15-28.19.
19. Lopes BG, Fernandez MA, Thiengo SC. Parasitologic and biologic invasions aspects of the exotic freshwater snail *Melanoides tuberculatus* from APM Manso, MT, Brazil. II Jornada de Espécies Invasoras. 13-16 de dezembro. São Carlos, SP: Universidade Federal de São Carlos; 2010.
20. Carvalho OS, Amaral RS, Dutra LV, Scholte RGC, Guerra MAM. Distribuição espacial de *Biomphalaria glabrata*, *B. straminea* e *B. tenagophila*, hospedeiros intermediários do *Schistosoma mansoni* no Brasil. In: Carvalho OS, Coelho PMZ, Lenzi H, editors. *Schistosoma mansoni* & Esquistossomose: uma visão multidisciplinar. Rio de Janeiro: Editora FIOCRUZ; 2008. p. 393-418.
21. Fernandez MA, Thiengo SC. Susceptibility of *Biomphalaria amazonica* and *Biomphalaria occidentalis* from Manso Dam, Mato Grosso, Brazil to infection with three strains of *Schistosoma mansoni*. *Mem Inst Oswaldo Cruz* 2006; 101 (supl I):235-237.
22. Corrêa LR, Paraense W. Susceptibility of *Biomphalaria amazonica* to infection with two strains of *Schistosoma mansoni*. *Rev Inst Med Trop São Paulo* 1971; 13:387-390.
23. Paraense WL. A survey of planorbid molluscs in the Amazonian region of Brazil. *Mem Inst Oswaldo Cruz* 1983; 78:343-361.
24. Rocha O, Espíndola LG, Rietzler AC, Fenerich-Verani N, Verani JR. Animal invaders in São Paulo state reservoir. *Oecol Aust* 2011; 15: 631-642.
25. Vasconcelos JF, Barbosa JEL, Azevêdo EL, Azevêdo DJS, Anacleto MJP. Predation effects of *Melanoides tuberculatus* (Müller, 1774) on periphytic biofilm colonization: an experimental approach. *Biota Neotrop* 2013; 13:96-101.
26. Paraense WL. Estado atual da sistemática dos planorbídeos brasileiros. *Arq Mus Nac* 1975; 55:105-128.
27. Santos SB, Monteiro DP, Fernandez MA, Thiengo SC. Primeiro registro de *Antillorhis nordestensis* (Lucena) (Mollusca, Gastropoda, Planorbidae) para a Ilha Grande, Angra dos Reis, Rio de Janeiro. *Rev Bras Zool* 1999; 16:257-259.
28. Thiengo SC, Mattos AC, Santos SB, Fernandez MA. Freshwater snails and schistosomiasis mansoni in the state of Rio de Janeiro, Brazil: VI – Noroeste Fluminense Mesoregion. *Mem Inst Oswaldo Cruz* 2006; 101 (supl I):239-245.
29. Santos SB. *Gundlachia dutrae* n. sp. from north-eastern Brazil (Mollusca: Basommatophora: Ancyliidae). *Mem Inst Oswaldo Cruz* 1994; 89:153-160.
30. Santos SB. Estado atual do conhecimento dos ancilídeos na América do Sul (Mollusca: Gastropoda: Pulmonata: Basommatophora). *Rev Biol Trop* 2003; 51 (supl III):191-224.
31. Lanzer RM. Ancyliidae (Gastropoda: Basommatophora) na América do Sul: sistemática e distribuição. *Rev Bras Zool* 1996; 13:175-210.
32. Lanzer RM. Duas novas espécies de Ancyliidae (Gastropoda: Basommatophora) para o sul do Brasil. *Rev Bras Biol* 1991; 51:703-719.
33. Lacerda LEM, Santos SB. *Burnupia ingae* Lanzer, 1991 (Gastropoda, Ancyliidae): current distribution on Brazil. *Check List* 2011; 7:862-864.
34. Lacerda LEM, Miyahira IC, Santos SB. First record and range extension of the freshwater limpet *Gundlachia radiata* (Guilding, 1828) (Mollusca, Gastropoda, Planorbidae) in Brazil. *Check List* 2013; 9:125-128.
35. Takeda AM, Souza-Franco GM, Melo SM, Monkolski A. Invertebrados associados às macrófitas aquáticas da planície de inundação do alto rio Paraná (Brasil). In: Thomaz SM, Bini LM, editors. *Ecologia e manejo de macrófitas aquáticas*. Maringá: Editora da Universidade Estadual de Maringá; 2003. p. 243-260.
36. Hayes KA, Cowie RH, Thiengo SC, Strong EE. Comparing apples to apples: clarifying the identities of two highly invasive Neotropical Ampullariidae (Caenogastropoda). *Zool J Linn Soc*, 2012; 166:723-753.
37. Mansur MCD, Callil CT, Cardoso FR, Ibarra JAA. Uma retrospectiva e mapeamento da invasão de espécies de *Corbicula* (Mollusca, Bivalvia, Veneroidea, Corbiculidae) oriundas do sudeste Asiático, na América do Sul. In: Silva JSV, Souza RCCL, editors. *Água de Lastro e Bioinvasão*. Rio de Janeiro: Editora Interciência; 2004. p. 39-58.
38. Santos SB, Thiengo SC, Fernandez MA, Miyahira IC, Gonçalves ICB, Ximenes RF. Espécies de moluscos límnicos invasores no Brasil. In: Mansur MCD, Santos CP, Pereira D, Paz ICP, Zurita MLL, Rodriguez MTR, editors. *Moluscos límnicos invasores no Brasil: biologia, prevenção e controle*. Porto Alegre, RS: Redes Editora Ltda; 2012. p. 25-49.
39. Pereira D, Mansur MCD, Duarte LDS, Oliveira ASO, Pimpão DM, Callil CT, et al. Bivalve distribution in hydrographic regions in South America: historical overview and conservation. *Hydrobiologia* 2013; 735:15-44.
40. Tesana S. Diversity of mollusks in the Lan Ta Khong reservoir, Nakhon Ratchasima, Thailand. *Southeast Asian J Trop Med Public Health* 2002; 33:733-738.
41. Paraense WL. Fauna planorbídica do Brasil. In: Lacaz CS, Baruzzi RG, Siqueira W, editors. *Introdução à Geografia Médica do Brasil*. São Paulo: Edgard Blücker & Universidade de São Paulo; 1972. p. 213-239.
42. Pinto HA, Mati VLT, Melo AL. Dermatite cercariana por esquistossomatídeos de aves: é possível a ocorrência de casos no Brasil? *Rev Patol Trop* 2012; 41:1-14.
43. Mattos AC, Boaventura MFF, Fernandez MA, Thiengo SC. Larval trematodes in freshwater gastropods from Mato Grosso, Brazil: diversity and host-parasites relationships. *Biota Neotrop* 2013; 13:34-38.
44. Horák P, Kolárová L. Snails, waterfowl and cercarial dermatitis. *Freshwater Biol* 2011; 56:779-790.
45. Pinto HA, Brant SV, Melo AL. *Physa marmorata* (Mollusca: Physidae) as a natural intermediate host of *Trichobilharzia* (Trematoda: Schistosomatidae), a potential causative agente of avian cercarial dermatites in Brazil, *Acta Trop* 2014; 138:38-43.
46. Fernandez MA. Variação espaço-temporal da malacofauna límnica em dois reservatórios no rio Tocantins, com ênfase na transmissão da esquistossomose, no período entre junho de 2004 e outubro de 2010. [Doctors Thesis] [Rio de Janeiro]: Instituto Oswaldo Cruz, Fundação Oswaldo Cruz; 2011.
47. Teles HMS, Leite RPA, Rodrigues FL. Moluscos límnicos de uma área do Alto Araguaia (Brasil). *Rev Saude Publica* 1991; 25:179-183.