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Short Communication

Snail transmitters of schistosomiasis and other mollusks of medical and economic importance at the *Simplício Queda Única* Hydroelectric Plant, Southeast Brazil

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Abstract

Introduction: This paper presents the results of an extensive survey of freshwater mollusks in the *Simplício Queda Única* Hydroelectric Development area, Southeast Brazil. **Methods**: Mollusks were collected between 2008 and 2013. All specimens were examined for the presence of larval trematodes. **Results**: In total, 12,507 specimens classified into 16 genera were obtained. Known snail vectors of schistosomiasis and fascioliasis and exotic species were identified, and new records are reported. **Conclusions**: No specimens parasitized by larval trematodes of medical interest were detected. However, the results reinforce the importance of surveillance in study areas vulnerable to the occurrence of schistosomiasis transmission.

Keywords: Mollusk vector. Trematode. Reservoir.

Although Brazil has hydrographical characteristics that favor hydraulic energy production, the construction of reservoirs has both irreversible environmental and social impacts. The transition from a lotic to a lentic environment favors the establishment mollusk populations that transmit parasites[1], thereby facilitating the spread of schistosomiasis. Thus, epidemiological surveillance, registration of water bodies, identification and treatment of parasitized individuals, health education initiatives, and monitoring of the vector mollusks *Biomphalaria glabrata* (Say, 1818), *Biomphalaria tenagophila* (d'Orbigny, 1835), and *Biomphalaria straminea* (Dunker, 1848) are necessary[2].

Our main objective was to characterize the distribution of snail vectors occurring in the *Simplício Queda Única* Hydroelectric Development (AHE Simplício) area and the associated larval forms of trematodes. Additionally, we aimed to provide support to implement measures to prevent the transmission of schistosomiasis and a baseline for future comparative analyses of changes in the composition of malacofauna resulting from hydroelectric power plant establishment.

The AHE Simplício is located on the Paraíba do Sul River in Southeast Brazil between municipalities Três Rios and Sapucaia in Rio de Janeiro and Chiador and Além Paraíba in Minas Gerais. Mollusks were colected in 2008 (July and October), 2009 (February, April, July, and October), 2010 (February, April, July, and October), and 2011 (March, April, and July), and 55 sampling stations were georeferenced (**Figure 1**). Of these, 27 were selected for monitoring (temporal analysis: 12 expeditions) because they are located at sites adversely affected by the construction. At these stations, the species were classified according to their frequency of occurrence[3] into the categories of constant (present in more than 50% of samples), accessory (≤50% to ≥25%), or accidental (occurring in <25% of samples).

Malacological techniques and parasitological analysis were based on those used at the Laboratory of Malacology of the Oswaldo Cruz Institute/FIOCRUZ[4-6]. Samples were deposited at the Mollusk Collection of that institution. Some specimens could not be identified at the species level because only their shells were available or the specimens were immature.

Representatives of ten families were obtained (**Figure 2**). Although, owing to logistical difficulties, the sampling effort was not strictly standardized in all biotopes (direct collection with variations in search time), the absolute number of specimens collected in each expedition was recorded (631 specimens in July 2008; 757 in October 2008; 1,300 in February 2009; 882 in April 2009; 893 in July 2009; 740 in October 2009; 858 in February 2010; 2,572 in April 2010; 824 in July 2010; 644 in October 2010; 256 in March 2011; 844 in April 2011; and 1,316 in July 2011), totaling 12,507 mollusks.

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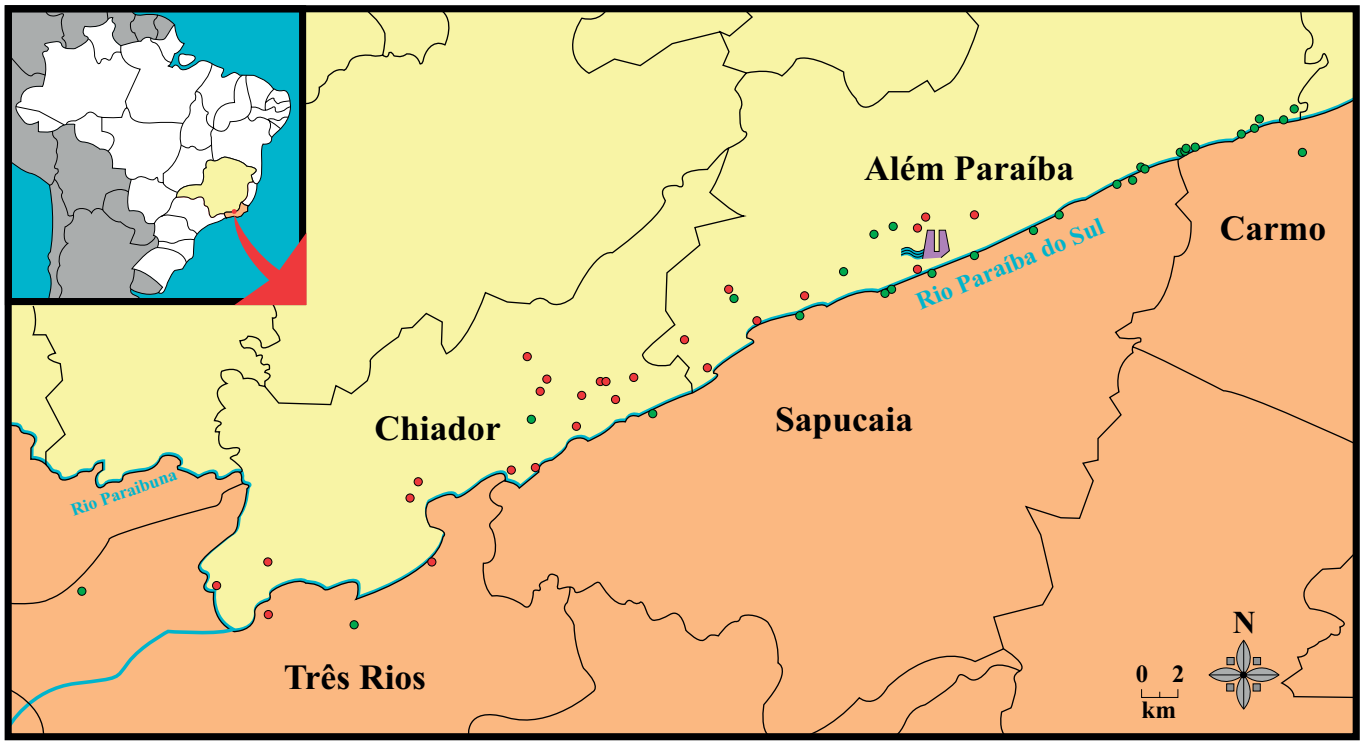

FIGURE 1: Sampling stations in the *Simplício Queda Única* Hydroelectric Development installation area, where surveys were conducted from July 2008 to July 2011. **Red:** sampling stations monitored in the temporal study.

The vector species for schistosomiasis and fasciolosis were represented by well-established populations: *B. straminea* and *B. tenagophila* were observed at 20 and 29 sampling stations, respectively, and, with the exception of Carmo, were found in all the municipalities surveyed. They were recorded sympatrically in 13 sampling stations: four in Três Rios (corresponding to 100% of the area surveyed in this municipality), three in Além Paraíba (13%), and six in Chiador (35%). *Lymnaea columella* Say, 1817 was found at 16 sampling stations (29% of the analyzed biotopes) in Além Paraíba, Chiador, Sapucaia, and Três Rios. Regarding the other planorbids, the occurrence rates at the 55 sampling stations or only in the Paraíba do Sul River (19 stations) were, respectively, as follows: 36.4% and 5.3% for *Drepanotrema anatinum* (d'Orbigny, 1835); 21.8% and 5.3% for *Drepanotrema cimex* (Moricand, 1837); 14.5% and 5.3% for *Drepanotrema depressissimum* (Moricand, 1839); 21.8% and 5.3% for *Drepanotrema lucidum* (Pfeiffer, 1839), and 27.3% and 10.5% for *Gundlachia* sp. No species of Ancylinae were found in the Paraíba do Sul River, whereas in the municipalities, the percentage occurrences were 1.8% for *Burnupia* sp. and *Hebetancylus* sp., 3.6% for *Gundlachia radiata* (Guilding, 1828), 5.4% for *Gundlachia ticaga* (Marcus & Marcus, 1962), and 7.3% for *Ferrissia* sp.

The exotic species *Physa acuta* Draparnaud, 1805 was found at only nine sampling stations (16.4% of the sampling area), whereas the native species *Physa marmorata* Guilding, 1828 was present in 27 (49.1%) biotopes. However, considering only the Paraíba do Sul River, *Physa acuta* and *P. marmorata* were found at 26.3% and 5.3% of the sampling stations, with one biotope being inhabited by both species. *Melanoides tuberculata* (Müller, 1774), was found at 12 sampling stations, corresponding to 21.8% of the area surveyed. Some specimens of *Omalonyx* sp. were collected from the marginal vegetation of the sampling stations in the municipalities of Além Paraíba, Chiador, and Sapucaia. Bivalvia specimens were found at 33 stations, with Sphaeriidae members predominating (26 sampling stations). We highlight the occurrence of two invasive exotic species in seven sampling stations in the Paraíba do Sul River, namely, *Corbicula fluminea* (Müller, 1774) and *Corbicula largillierti* (Philippi, 1844). These Corbiculidae were also observed in four other sampling stations in Chiador and Sapucaia (**Figure 2**), with the two species occurring together in Jamapará.

Based on a survey of larval helminths harbored by the mollusks, although we detected cercariae, neither *Schistosoma mansoni* Sambon, 1907 nor *Fasciola hepatica* Linnaeus, 1758 were found. Of the six parasitized species, *B. tenagophila* was identified as having the highest number of parasitic interactions: armatae cercaria (Xiphidiocercaria), brevifurcate apharyngeate cercaria (Furcocercous), echinostome cercaria (Echinostome), ornatae cercaria (Xiphidiocercaria), strigea cercaria (Furcocercous), ubiquita cercaria (Xiphidiocercaria), and virgulate cercaria (Xiphidiocercaria). The other mollusks were parasitized by a single larval type: armatae cercaria in *D. lucidum*, echinostome cercaria in *P. marmorata*, ornatae cercaria in *L. columella*, ubiquita cercaria in *Pomacea* sp., and strigea cercaria in *B. straminea*. Only in July 2010 were no parasitized mollusks found. The most common cercariae types were ubiquita cercaria and ornatae cercaria, observed in eight of

		Minas Gerais			Rio de Janeiro			
		Além Paraíba		Chiador	Carmo	Sapucaia		Três Rios
		Além Paraíba	Benjamin Constant	Penha Longa	Paquequer	Jamapará	Sapucaia	Três Rios
Bivalvia	Corbiculidae							
	C. fluminea	+	+			+	+	
	C. largillierti	+				+	+	
	Corbicula sp.	+	+	+				
	Sphaeriidae	+	+	+			+	
Gastropoda / Caenogastropoda	Ampullariidae							
	Pomacea sp.	+	+	+				+
	Hydrobiidae							
	Heleobia sp.							+
	Potamolithus		+					
	Pomatiopsidae							
	Idiopyrgus sp.	+	+	+			+	+
	Thiaridae							
	Melanoides tuberculata	+	+	+			+	+
Gastropoda / Heterobranchia	Planorbidae							
	Ancylinae							
	Burnupia sp.		+					
	Ferrissia sp		+	+				+
	Gundlachia radiata		+	+				
	Gundlachia ticaga			+				+
	Gundlachia sp.	+	+	+				
	Hebetancylus sp.							+
	Planorbinae							
	Antillorbis nordestensis			+				+
	Biomphalaria straminea	+	+	+			+	+
	Biomphalaria tenagophila	+	+	+		+	+	+
	Drepanotrema anatinum	+	+	+			+	+
	Drepanotrema cimex		+	+				+
	Drepanotrema depressissimum		+	+				+
	Drepanotrema lucidum		+	+			+	+
	Lymnaeidae							
	Lymnaea columella		+	+			+	+
	Physidae							
	Physa acuta	+	+	+	+	+		
	Physa marmorata	+	+	+				+

FIGURE 2: Freshwater malacofauna from the area influenced by the *Simplício Queda Única* Hydroelectric Development, Minas Gerais/Rio de Janeiro, collected from 55 sampling stations between July 2008 and July 2011.

Sampling stations	2008		2009				2010				2011	
	July	October	February	April	July	October	February	April	July	October	March	April
1	Bt, Gu, Lc, Mt	Lc, Pa		Mt	Bt, Mt, Pa, Po	Lc	Mt, Po	Mt, Po		Mt, Pa	Mt	
2	Da, Dd, Pm	Bt, Da	Da, Pm	Da, Pm	Da, Pm	Bt, Da, Dd, Pm	Bt, Id, Pm	Da, Dc, Dl		Da	Bt, Da	Bt, Da, Lc
3	Bs	Bs	Po	Bs, Po	Bs, Bt, Po	Pm, Po	Bs, Mt, Po	Bs, Gr, Mt, Pm, Po	Bs, Mt, Po	Bt, Mt, Po	Bs, Mt, Po	Bs, Po
4	Bt, Dc	Bt, Dc, Pm	Bt, Gu	Bt, Gu			Bt, Pa		Bs, Gu	Bt		Bt
5	Bs	Bs, Pm	Bs	Da, Pm	Bt		Bs					Bt
6	Bs, Mt, Pm	Pm		Mt	Pm	Pm	Mt	Mt	Mt, Pm	Mt, Pm	Mt, Pm	Mt, Pm
7	Bs, Pm, Po	Po	Bt, Lc, Po	Bs, Lc, Po	Bs, Lc	Bs, Da, Gu	Bs, Po	Bs, Da, Gu, Lc, Po	Bs, Lc, Pm, Po	Bs, Lc, Po		Bs, Po
8			Bs, Po	Bs, Da, Po	Bs, Po	Bs, Gu, Pm, Po	Bs, Po	Bs, Po	Bs, Gu, Po	Bs, Pm, Po		
9	Bs, Po	Pm	Pm	Da, Pm	Pm	Gu, Pm	Pm				Bs, Po	Da, Pm
10		Bt, Da, Dc, Pm	Bt, Da, Dd, Dl, Gu	Bt, Da, Dl	Dl, Pm					Pa		
11		Bt, Dl	Dl	Bt, Da, Dc, Pm	Bt	Dl	Bt, Dl			Dl, Id	Bt, Dl	Bs
12		Bt, Da, Dc, Dl, Lc	Bt, Dl	Bt, Da, Dl	Bt, Da, Dl, Gu	Bt, Da, Dl	Dl	Dl		Da		Bt, Gr, Pm
13	Bs		Bs			Bs, Dd, Dl		Bs		Gu		
14	Bt, Dl	Bt, Lc, Pm	Bs, Dl, Pa, Po	Bs, Pm, Po	Pa	Bs	Bs, Dl, Pa	Bs, Pa	Bs	Bt, Pm	Bs, Bt, Gu, Pa, Po	Bs, Bt, Gu, Pa
15			Bt, Dc	Mt	Dd	Bt, Pm	Bt, Pm	Bt	Da, Dc, Gu	Bt		Bt, Dc, Gu
16	Bt, Da, Lc, Mt, Pm	Mt	Bt, Dd, Mt	Mt	Mt	Mt				Bt, Da, Dc, Pm		
17		Fe, Lc, Pm	Bt, Da, Pm	Fe					Gu			
18	Bt	Bt, Pm		Gu	Gu	Pm	Bt, Lc	Dd			An	
19	Bt, Lc, Pm	Bt, Lc, Pm	An, Bt, Lc, Pm	Bs, Bt, Da, Lc, Pm	Bt	An, Bt, Lc, Pm	Bt	Bt, Da, Pm	Bt	Bt, Da, Lc	Bt, Lc, Pm	Bt, Lc, Pm
20	Bt, Da, Dc, Gt, Pm	Bt, Da, Dc, Pm	Bs, Bt, Dd, Pm	Bt, Da, Gu, Pm	Da, Gu	Bt	Bt, Dd, Pm	Da, Dd, Pm	Bt, Dc, Gu	Da, Dc, Pm		Bt, Pm
21		Bt, Da, Pm		Bt, Dl	Bt, Da, Pm	Bt, Dc, Pm	Bt, Da, Dc, Pm		Bt	Da Dc	Gu	Da, Gu, Pm
22	Bt, Gu	Gt	Bt, Da, Lc	Bs, Pm	Bs, Bt, Pm	Bt			Bs, Fe, Lc, Pm	Bs, Pm		Bs, Bt, Pm
23	Bs	Bs, Da, Dc, Lc, Pm	Bs, Bt, Dc, Dl, Pm	Bs				Gu		Bs, Lc	Dl, Gu	Bs, Gu
24	Bt, Da, Pm	Bt	Bt, Pm	Bt, Da	Bt, Da, Gu, Pm	Bt	Bt, Gu, Pm	Bt		Bt, Da, Dc, Pm		Bt, Pa
25	Bt, Dl	Dl	Bt, Dl			Bt, Dl		Bt, Da	Dl	Bt, Dl	Bt, Dl, Lc	Bt, Da, Dl
26		Bt, Fe, Mt	An, Bs, Dl, Mt, Pm	Mt, Pm	Mt, Pm	Bt		Mt, Pm	Mt	Mt		
27		Bt, Da, Pm	Bs, Bt, Id, Lc, Pm, Po	Bs, Bt, Pm, Po	Bs, Bt, Dl, Gt, Id, Po	Bs, Da, Dd, Dl, Id, Lc, Pm, Po	Bs, Dl, Id, Mt, Pm, Po	Da, Dl, Id, Mt	Bs, Da, Dc, Dl, Lc, Pm, Po	Bt, Hb, Lc, Pm	Dc, Dl, Hl, Pm, Po	Dl, Po

FIGURE 3: Temporal analysis of freshwater malacofauna in the area influenced by the Simplício Queda Única Hydroelectric Development, Minas Gerais/Rio de Janeiro, at 27 sampling stations between July 2008 and April 2011. **Bt:** *Biomphalaria tenagophila*; **Gu:** *Gundlachia* sp.; **Lc:** *Lymnaea columella*; **Pa:** *Physa acuta;* **Mt:** *Melanoides tuberculata*; **Po:** *Pomacea* sp*;* **Da:** *Drepanotrema anatinum*; **Dd:** *Drepanotrema depressissimum*; **Pm:** *Physa marmorata;* **Id**: *Idiopyrgus* sp.**;** **Dc:** *Drepanotrema cimex*; **Dl**: *Drepanotrema lucidum*; **Bs:** *Biomphalaria straminea*; **Gr:** *Gundlachia radiata*; **Fe:** *Ferrissia* sp.; **An**: *Antillorbis nordestensis*; **Gt:** *Gundlachia ticaga*; **Hl**: *Heleobia* sp.; **Hb:** *Hebetancylus* sp.

the 13 expeditions conducted, throughout the year. Brevifurcate apharyngeate cercaria and virgulate cercaria were observed only in July and October 2008, respectively.

The temporal study revealed a prevalence of *P. marmorata* (88.9% occurrence rate), followed by *B. tenagophila* (81.5%). *B. straminea* and *B. tenagophila* were detected sympatrically at 11 of the 27 stations monitored and only at a sampling station were these species not found. Individually, *B. tenagophila* and *B. straminea* had populations at 10 and five sampling stations, respectively. In Chiador, both species were observed during different expeditions until October 2010, and thereafter, were found to occur sympatrically (**Figure 3**).

Lymnaea columella was obtained during all 12 expeditions, with the highest occurrence in October 2008 (six sampling stations).

The lowest species richness was recorded in April 2009 and July 2010, when only 11 species were collected in each expedition. Based on the frequency of occurrence, no species was classified as constant. *B. tenagophila* and *P. marmorata* were the only accessory species (frequency of occurrence of 33.0% and 27.8%, respectively), whereas all the other species were classified as accidental: *Antillorbis nordestensis* (Lucena, 1954), 1.2%; *B. straminea*, 20.7%; *D. anatinum*, 16.9%; *D. cimex*, 6.8%; *D. depressissimum*, 3.4%; *D. lucidum*, 12.3%; *Ferrissia* sp., 1.2%; *G. radiata*, 0.9%; *G. ticaga*, 1.2%; *Gundlachia* sp., 8.6%; *Hebetancylus* sp., 0.3%; *Heleobia* sp., 0.3%; *Idiopyrgus* sp., 2.2%; *L. columella*, 9.9%; *M. tuberculata*, 11.1%; *P. acuta*, 3.7%; and *Pomacea* sp., 12.0%.

However, at the generic level, *Biomphalaria* was constant (frequency of occurrence of 53.7%), *Drepanotrema* and *Physa* were accessory (39.5% and 31.5%, respectively), and the remaining genera were accidental. Considering each year, *Biomphalaria* was constant (61.1% in 2008 and 63.9% in 2009) and accessory (43.5% in 2010 and 46.3% in 2011). *B. tenagophila* was accessory (42.6% in 2008, 39.8% in 2009, and 29.6% in 2011) and accidental (23.1% in 2010), and *B. straminea* was accidental (18.5% in 2008, 24.1% in 2009, 20.4% in 2010, and 16.7% in 2011). Similarly, *L. columella* and *M. tuberculata* were accidental: 16.7% and 9.2% (2008), 9.2% and 10.1% (2009), 8.3% and 14.8% (2010), and 7.4% and 7.4% (2011), respectively.

The frequency of occurrence of the exotic species *P. acuta* and the native species *P. marmorata* for each year of the survey were, respectively, as follows: 1.8% and 37% in 2008, 2.8% and 34.3% in 2009, 4.6% and 21.3% in 2010, and 5.5% and 18.5% in 2011.

The malacofauna found in the AHE Simplício area are consistent with the observation of Thiengo et al.[7] for the State of Rio de Janeiro. Regarding Minas Gerais, the findings of this study extend the geographical distributions of *B. straminea* and *B. tenagophila* to Além Paraíba and Chiador, thereby increasing the records of occurrence[8] to 143 and 63 municipalities, respectively.

In the area influenced by the Rosal Hydroelectric Plant[9] reduced abundance of *B. tenagophila* and *B. glabrata* was observed after reservoir construction. Following onset of the first cases of schistosomiasis in the vicinity of the Americana Dam[10] in São Paulo, a study on malacofauna was conducted, and six *S. mansoni* transmission foci were identified by examining 1,101 specimens of *B. tenagophila*. These findings, coupled with the coexistence of *B. straminea* and *B. tenagophila* in the area influenced by the AHE Simplício plant, reinforce the need for a continuation of these studies, including a quantitative evaluation.

The record of *L. columella* in the studied area extends this species' distribution to Minas Gerais[11], increasing the number of inhabited municipalities to 42.

Our identification of the invasive exotic mollusks *C. fluminea, C. largillierti, M. tuberculata,* and *P. acuta* is noteworthy. The first two species are currently widely distributed in several river basins and are having irreversible socioeconomic or environmental effects, such as causing a reduction in native bivalve populations[12]. In the reservoir of the Manso Power Plant in the State of Mato Grosso[13] *M. tuberculata* was introduced after February 2009 and showed the highest relative abundance (94.96%) among the nine species recorded between April 2009 and October 2010. The present study is the first to report the occurrence of *M. tuberculata* in Além Paraíba, Chiador, and Três Rios.

We highlight the predominance of the native species *P. marmorata* over the exotic species *P. acuta* in the study area because, in the Serra da Mesa Hydroelectric Power Plant reservoir, a population decline occurred in *P. marmorata* after the introduction of *P. acuta*[14]. Although it was considered an accidental species (<25% of samples) in the present study, the frequency of occurrence of *P. acuta* increased during the temporal study, confirming its dispersal and colonization capacity in the reservoir environments of hydroelectric plants.

Regarding species of Ancylinae, although *G. radiata* occurs in seven Brazilian states (Alagoas, Amazonas, Goiás, Pará, Paraíba, Pernambuco, and Rio de Janeiro)[15], occurrence in Minas Gerais was recorded for the first time.

Of the larval forms of trematodes detected, brevifurcate apharyngeate cercaria and echinostome cercaria stand out among the cercariae types found due to their importance as possible causal agents of human cercarial dermatitis and for being associated with the transmission of *Echinostoma* spp., respectively.

The presence of two known snail vectors of schistosomiasis, the environmental transformations resulting from the installation of reservoirs, and the establishment of resorts that encourage the contact between people and water, define the area of the AHE *Simplício Queda Única* as vulnerable to the transmission of schistosomiasis. Moreover, we highly ghted the proximity of the municipality of Sumidouro (approximately 40km), in Rio de Janeiro, where there is transmission of schistosomiasis.

Although the burgeoning demand for energy generation in the country is unequivocal, the Brazilian energy matrix undoubtedly contributes to the fragmentation of biomes

and modification of river regimes. Therefore, adoption of multidisciplinary approaches in the areas of health, environment, and education is imperative to reconcile regional development with a good quality of human life and a healthy environment through public health policies and appropriate environmental management.

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Conflict of interest

The authors declare that there is no conflict of interest.

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