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The helminth community of *Geophagus proximus* (Perciformes: Cichlidae) from a tributary of the Paraná River, Ilha Solteira Reservoir, São Paulo State, Brazil

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Abstract

This study aimed to evaluate the helminth parasites of *Geophagus proximus* from the São José dos Dourados River, a tributary of Paraná River, Ilha Solteira Reservoir, São Paulo State, Brazil. From May 2006 to May 2007, 116 *G. proximus* specimens were examined and seven different taxa of helminth were collected and identified: proteocephalidean plerocercoids (Cestoda); metacercariae of *Austrodiplostomum compactum*, *Clinostomum heluans* and *Clinostomum* sp. (Trematoda); and *Raphidascaris* (*Sprentascaris*) *hypostomi*, and larvae of *Raphidascaris* sp. and *Contracaecum* sp. (Nematoda). All parasites presented the typical aggregated pattern of distribution, as well as the presence of a high number of larval stages, an absence of influence of the host sex and seasonality upon community parameters, as well as a correlation between species richness and host body weight. Moreover, with the exception of *A. compactum* metacercariae, all helminths found in this study are reported for the first time in *G. proximus*.

Introduction

The family Cichlidae Bonaparte, 1840 is one of the major vertebrate families, with at least 1300 species and approaching an estimated 1900 species (Kullander, 1998). *Geophagus proximus* (Castelnau, 1855) is included in this family and is commonly known in Brazil as the *acará roi roi* or *acará tinga* (Kullander, 2003). This fish species is native to Brazil and lives in the Amazon River basin, in the Ucayali River drainage of Peru, and along the stretch of the Solimões–Amazon River to the Trombetas River (Kullander, 2003). This species has recently been introduced to the Paraná River basin, through fish-farming (Langeani *et al.*, 2007) and now has a prominent place in commercial fishing in the Ilha Solteira Reservoir which was previously occupied by endemic species of the Paraná River.

In the aquatic environment, the penetration of pathogens is facilitated and fish can be infected by

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numerous parasite species (Klein *et al.*, 2004). Studies on the health of aquatic organisms have expanded in Brazil and several recent surveys have been conducted (Azevedo *et al.*, 2006; Paes *et al.*, 2010a, b; Zica *et al.*, 2010, 2011). Several helminth species have been described parasitizing fish of the genus *Geophagus* Heckel, 1840, and *G. brasiliensis* Quoy & Gaimard, 1824 presents the largest number of literature reports for the occurrence of parasites. With respect to the nematodes, there are records of *Contracaecum* sp. Railliet & Henry, 1912 larvae in the visceral cavity (Kohn *et al.*, 1988, 1989) and mesentery (Paraguassú *et al.*, 2005; Carvalho *et al.*, 2010); *Procamallanus* (*Procamallanus*) *peraccuratus* Pinto, Fabio, Noronha & Rolas, 1976 (Pinto *et al.*, 1976; Kohn *et al.*, 1988; Carvalho *et al.*, 2010), *Raphidascaris* sp. Railliet & Henry, 1915 (Moravec *et al.*, 1993) and *Rhabdochona fasciata* Kloss, 1964 (Paraguassú *et al.*, 2005) in the intestine. In relation to cestodes, the occurrence of *Proteocephalus gibsoni* Rego & Pavanelli, 1990 was reported by Rego & Pavanelli (1990) in fish from the Amazon River, Brazil. For digenetic trematodes, *Homalometron pallidum* Stafford, 1904 has been reported in the stomach (Kohn & Fernandes, 1981), *Crassicutis cichlasomae* Manter, 1936 was observed in the intestine, immature forms of Strigeidae Railliet, 1919 have been found encysted in the fins (Fernandes & Kohn, 2001), *Austrodiplostomum compactum* (Lutz, 1928) metacercariae were observed in the eyes and swimbladder, *Neascus* Hughes, 1927 type 1 has been described in the eyes, *Neascus* type 2 in the tegument and *Posthodiplostomum* sp. Dubois, 1936 in the eyes, swimbladder and intestine (Carvalho *et al.*, 2010).

Although *G. proximus* was first described in the 19th century, there are few records regarding its parasitic fauna. Takemoto *et al.* (2009) reported the occurrence of the nematode *Raphidascaris* (*Sprentascaris*) sp. Petter & Cassone, 1984, the digenean *Ascocotyle* sp. Looss, 1899 metacercariae, two probable species of monogeneans of the genus *Sciadicleithrum* sp. Kritsky, Thatcher & Boeger, 1989 and arachnids of the order Acarina in this fish species. Bellay *et al.* (2009) described two new species of monogeneans: *Sciadicleithrum kritskyi* Bellay, Takemoto, Yamada & Pavanelli, 2009 and *Sciadicleithrum paranaensis* Bellay, Takemoto, Yamada & Pavanelli, 2009; and Zica *et al.* (2010) observed *A. compactum* metacercariae in *G. proximus* from the Tietê River, Nova Avanhandava Reservoir, in the municipality of Buritama, São Paulo State, Brazil.

The aim of this study was to report the helminth fauna of *G. proximus* from the São José dos Dourados River, which is a tributary of the Paraná River, Ilha Solteira Reservoir, municipality of Ilha Solteira, São Paulo State, Brazil. This study employed a quantitative analysis of parasite community structure.

Materials and methods

Parasitological procedures

From May 2006 to May 2007, 10–11 specimens of *G. proximus* were collected monthly (except in January and February 2007), totalling 116 individuals. Fish were caught, using handmade fishing rods, from the São José dos Dourados River, a tributary of Paraná River, Ilha Solteira Reservoir (20°27′ 06.49″ S, 51°16′ 07.31″W), municipality of Ilha Solteira, São Paulo State, Brazil (fig. 1), and immediately taken to the laboratory, where necropsies were performed. The mean standard body length and body weight of fish were 12.87 (9.2–17) cm and 76.29 (24–165.2) g, respectively. There was no significant difference (*t*-test; $t = -0.95$; $P = 0.34$) in the standard body length of males ($n = 46$; 13.04 ± 0.26 cm) and females ($n = 68$; 12.75 ± 0.19 cm). The host sample was divided into four size class intervals, with amplitudes of 2 cm in length (9–11 cm, 11.1–13 cm, 13.1–15 cm and 15.1–17 cm).

Organs and body cavities of *G. proximus* were examined and the helminths found were collected, fixed and stained, according to standard parasitology techniques (Eiras *et al.*, 2006). Body surfaces were also examined for encysted metacercariae. For identification and diagnosis of parasites, the following references were used: Travassos *et al.* (1969), Kohn *et al.* (1995) and Gibson *et al.* (1996) for trematodes, Moravec *et al.* (1990) and Thatcher (2006) for nematodes, and Rego *et al.* (1999) for cestodes. For species identification, parasites were analysed using a computerized system for image analysis (Qwin Lite 3.1, Leica Microsystems, Wetzlar, Germany). Voucher specimens were deposited in the Coleção Helmintológica, of the Departamento de Parasitologia, Instituto de Biociências, Universidade Estadual Paulista – UNESP, municipality of Botucatu, São Paulo State, Brazil.

Data analysis

The ecological descriptors of the parasitism (prevalence, abundance and mean intensity of infection) were calculated according to Bush *et al.* (1997). Parasites were classified according to their prevalence in the core species (prevalence higher than 66.66%), secondary species (prevalence from 33.33 to 66.66%) and satellite species (prevalence lower than 33.33%) with the aim of verifying the Importance Value, i.e. the importance of each species in the helminth parasite community (Bush & Holmes, 1986).

The relationship between variance and mean of parasite abundance – dispersion index (Krebs, 1989) – and the calculation of the *k* parameter of the negative binomial distribution (Bliss & Fisher, 1953) were used for each parasite species to determine their distribution patterns. Parasite species diversity was calculated using the Brillouin index (*H*) with a logarithm to the base *e.* The condition factor (K), according to Le Cren (1951), is given by the relationship between body weight and body length of the individual and this was employed to verify the possible correlation with total parasite abundance, parasite species diversity and parasite species richness.

Comparison of the prevalence of each parasite species in relation to the host sex and seasonality was performed using the *Z*-test. The variation of intensity of infection, abundance, parasite species diversity and parasite species richness, according to sex and seasonality, were compared by Mann–Whitney's test (*U*). Spearman's rank correlation (r_s) was used to study possible correlations of intensity of infection and abundance of each parasite species in relation to standard body length, weight and

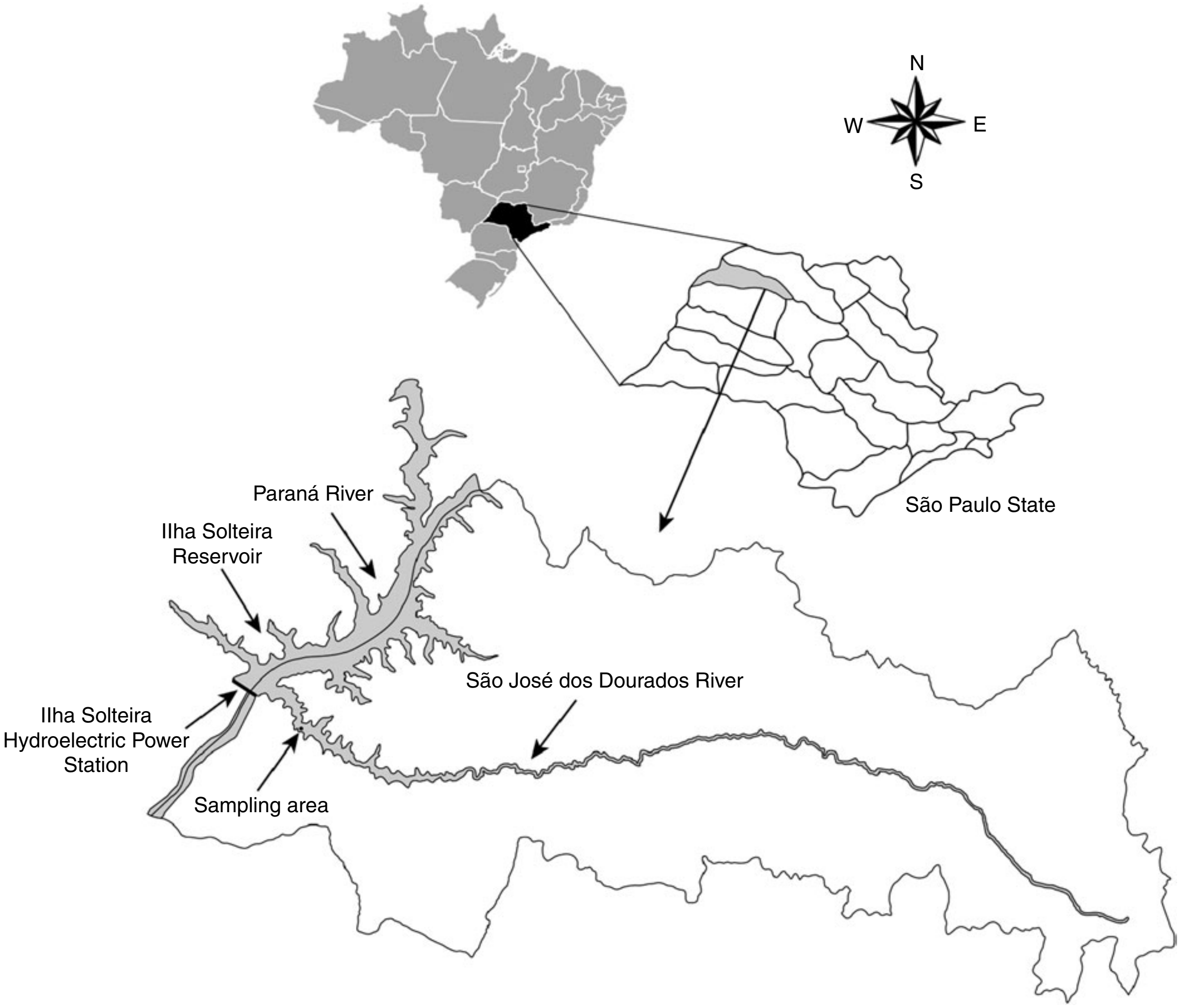

Fig. 1. Map of Brazil highlighting São Paulo State and the sampling area at São José dos Dourados River, a tributary of Paraná River, Ilha Solteira Reservoir, municipality of Ilha Solteira, São Paulo State, Brazil (20°27′06.49″S, 51°16′07.31″W).

condition factor (K) at the level of the community component during the whole year. This test was also used to verify the possible correlations of standard body length, body weight and condition factor (K) of the hosts, in relation to total parasite abundance, parasite species diversity and parasite species richness at the level of infracommunity during the whole year.

Differences in abundance (Kruskal–Wallis), parasite species diversity and richness (one-way analysis of variance (ANOVA)) in relation to the host sex and seasonality among the size class intervals were checked. Statistical tests were performed using SigmaStat 3.1 (Systat Software Inc., California, USA), adopting a significance level of 5%. Parasite species richness and parasite species diversity were calculated using the computer program MVSP 3.13 (Multivariate Statistical Package, Kovach Computing Services, Anglesey, Wales, UK) and parasite distributions were analysed using the Quantitative Parasitology 3.0 computer software (Rozsa *et al.*, 2000).

Results

Component community

Cestodes were the most prevalent parasites (96.55%), followed by digenetic trematodes (60.34%) and nematodes (26.72%). Seven different helminth parasite taxa were collected: Proteocephalidea gen. sp. plerocercoids (Cestoda), metacercariae of *Austrodiplostomum compactum*, *Clinostomum heluans* Braun, 1899 and *Clinostomum* sp. Leidy, 1856 morphotype 2 (Trematoda), and *Raphidascaris* (*Sprentascaris*) *hypostomi* (Petter & Cassone, 1984), and larvae of *Raphidascaris* sp. and *Contracaecum* sp. (Nematoda) (table 1).

The large number of proteocephalidean plerocercoids did not allow the number of individuals to be counted and only the prevalence and Importance Value were calculated for this parasite taxa. Proteocephalidean plerocercoids were found in 96.55% of the *G. proximus* examined and were the most prevalent parasites (table 1). According to their prevalence, only proteocephalidean

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Table 1. Prevalence, mean intensity of infection, mean abundance and site of infection of helminth parasites of *Geophagus proximus* from the São José dos Dourados River, a tributary of Paraná River, Ilha Solteira Reservoir, municipality of Ilha Solteira, São Paulo State, Brazil.

Helminth	Prevalence (%)	Mean intensity[a]	Mean abundance[a]	Species importance[b]	Site of infection
Cestoda					
Proteocephalidea gen. Sp. (plerocercoids)[c]	96.55	–	–	Co	Visceral cavity
Trematoda					
Austrodiplostomum compactum (Lutz, 1928) (metacercariae)	58.62	3.63 ± 0.53 (1–28)	2.13 ± 0.35 (0–28)	Se	Eye (vitreous humor)
Clinostomum heluans Braun, 1899 (metacercariae)	6.03	2.57 ± 0.78 (1–6)	0.16 ± 0.07 (0–6)	Sa	Fins
Clinostomum sp. Leidy, 1856 morphotype 2 (metacercariae)	0.86	1	0.01 ± 0.01 (0–1)	Sa	Under the skin
Nematoda					
Raphidascaris (Sprentascaris) hypostomi (Petter & Cassone, 1984)	13.79	2.19 ± 0.45 (1–7)	0.3 ± 0.09 (0–7)	Sa	Intestine
Raphidascaris sp. Railliet & Henry, 1915 (larvae)	17.24	3.8 ± 1.17 (1–19)	0.66 ± 0.24 (0–19)	Sa	Intestine
Contracaecum sp. Railliet & Henry, 1912 (larvae)	6.03	1.57 ± 0.3 (1–3)	0.09 ± 0.04 (0–3)	Sa	Mesentery
Total	97.41	4.57 ± 0.57 (1–32)	3.35 ± 0.47 (0–32)	–	–

[a] Values presented as mean standard error (range).
[b] Species importance based on prevalence: Co, core species (prevalence higher than 66.66%); Se, secondary species (prevalence from 33.33 to 66.66%); Sa, satellite species (prevalence lower than 33.33%).
[c] Due to the large number of individuals found, it was not possible to count the total number of individuals, precluding the calculation of mean intensity of infection and mean abundance.

plerocercoids were considered as a core species, *A. compactum* metacercariae constituted a secondary species and *R.* (*S.*) *hypostomi*, *Raphidascaris* sp. larvae, *Contracaecum* sp. larvae, *C. heluans* metacercariae and *Clinostomum* morphotype 2 metacercariae were satellite species (table 1).

The dispersion index and the k parameter of the negative binomial distribution (for which the observed and expected frequencies did not differ significantly) indicated that the majority of parasite species of *G. proximus* presented the typical aggregated pattern of distribution (table 2). The prevalence (Z-test), intensity of infection and abundance (Mann–Whitney's test) of each parasite species of *G. proximus* were not significantly different between male and female hosts and did not differ in relation to seasonality ($P > 0.05$). The intensity of infection and the abundance of each parasite species did not correlate with host body length, weight or condition factor ($P > 0.05$).

Infracommunities

Ninety-seven per cent of *G. proximus* were parasitized by at least one helminth species. Three hundred and thirty-eight individual parasites were collected, with a mean of 2.91 parasites/fish. Associations between the total parasite abundance and the standard body length ($r_s = 0.11$, $P = 0.24$), body weight ($r_s = 0.18$, $P = 0.05$) and condition factor ($r_s = 0.13$, $P = 0.18$) of *G. proximus* were not observed. Therefore, the total parasite abundance was not different between size class intervals ($H = 4.69$, $P = 0.20$).

The mean parasite species richness was 1.99 ± 0.08 (0–4) and was not related to seasonality ($U = 1959.5$, $P = 0.36$), host sex ($U = 2638$, $P = 0.97$) or size class intervals ($H = 4.56$, $P = 0.21$). Parasite species richness was positively correlated to the body weight of fish ($r_s = 0.20$, $P = 0.03$), but not to standard body length ($r_s = 0.14$, $P = 0.15$) and condition factor ($r_s = 0.16$, $P = 0.10$).

The mean parasite species diversity (H) was 0.14 ± 0.03 and the maximum diversity value was 0.80. Parasite species diversity showed no significant differences in relation to seasonality ($U = 1117.50$, $P = 1$), host sex ($U = 1449.5$, $P = 0.07$) and size class intervals ($H = 3.63$, $P = 0.12$), and there was also no correlation with body weight ($r_s = 0.11$, $P = 0.29$), standard body length ($r_s = 0.12$, $P = 0.22$) or condition factor ($r_s = 0.09$, $P = 0.33$).

Discussion

The present study evaluated the helminth parasite community of *G. proximus* from São José dos Dourados River, a tributary of Paraná River, Ilha Solteira Reservoir, São Paulo State, Brazil. Seven different taxa of parasites were found and some patterns of the parasite community structure were observed, as follows: a high prevalence of proteocephalidean plerocercoids, a high number of larval stages, absence of influence of the host sex and seasonality upon community parameters, correlation

Table 2. Dispersion index (DI) and *k* parameter of the negative binomial distribution of the helminth parasites of *Geophagus proximus* from the São José dos Dourados River, a tributary of Paraná River, Ilha Solteira Reservoir, municipality of Ilha Solteira, São Paulo State, Brazil.

Parasites	DI	k^a
Austrodiplostomum compactum (Lutz, 1928) (metacercariae)	6.75	0.53
Raphidascaris (*Sprentascaris*) *hypostomi* (Petter & Cassone, 1984)	3.3	0.12
Raphidascaris sp. Railliet & Henry, 1915 (larvae)	10.09	0.09
Clinostomum heluans Braun, 1899 (metacercariae)	3.88	0.04
Clinostomum sp. morphotype 2 Leidy, 1856 (metacercariae)	–[c]	–[b]
Contracaecum sp. Railliet & Henry, 1912 (larvae)	1.83	–[b]

[a] Observed and expected frequencies do not differ significantly (at $P = 0.05$).
[b] Not enough categories: fit to the negative binomial cannot be tested.
[c] Dispersion index was not calculated because only one host was infected by this parasite.

between species richness and host body weight, and the aggregated pattern of distribution for all parasites.

The high prevalence of plerocercoids found in these fish may be related to their diet, which includes copepods that can act as first intermediate hosts of proteocephalideans. Moretto *et al.* (2008) examined the stomach contents of *G. proximus* from the Tietê River Basin, São Paulo State, Brazil, and found that copepods, along with other food items, such as molluscs, sediment, decomposing organic matter, allochthonous plant fragments and insects, were food items of the diet of this fish species. Plerocercoids found in *G. proximus* formed tissue-like masses that resemble adipose or testicular formations in the visceral cavity, as reported by Thatcher (2006). In some cases, a chronic inflammatory response that involves the encapsulation of the parasites by collagenous connective tissue may occur (O'Neill *et al.*, 1988).

Metacercariae of digenetic trematodes presented the second highest prevalence among the parasites studied. The abundance and intensity of the infection of *A. compactum* in *G. proximus* did not correlate with body length, body weight or condition factor. This parasite species was found in the eyes of *G. proximus* and, according to Eiras (1994), the presence of parasites in this organ can cause blindness or impair vision, causing the fish to become an easier prey for capture by the definitive host (in this case, piscivorous birds), so that the parasite can complete its life cycle faster.

In Brazil, *A. compactum* metacercariae have been reported in several fish species (Santos *et al.*, 2002; Machado *et al.*, 2005; Yamada *et al.*, 2008; Takemoto *et al.*, 2009; Zica *et al.*, 2009, 2011; Paes *et al.*, 2010a, b), and were recently found in *G. proximus* from the Nova Avanhandava Reservoir, Medium Tietê River, Brazil (Zica *et al.*, 2010). In the present study, the prevalence of *A. compactum* in *G. proximus* was lower than that found by Zica *et al.* (2010). The high prevalence of *A. compactum* metacercariae, according to Zica *et al.* (2010), could be related to the fact that this fish species has been introduced; its high susceptibility to infection by this trematode was similar to that found in *Plagioscion squamosissimus* Heckel, 1840, which is also an introduced species and highly susceptible to this parasite. The fact that the prevalence of *A. compactum* metacercariae in the present study was lower than that found by Zica *et al.* (2010) may be related to the low presence of molluscs (intermediate hosts of this parasite) in the Ilha Solteira Reservoir, due to environmental characteristics such as the low quantity of organic matter and aquatic vegetation (Milward-de-Andrade, 1959; Madi, 2005) or due to the population size of the definitive host, which may be lower in the reservoir studied (Madi, 2005). The fact that the intensity of infection of *A. compactum* was not correlated with host body length and weight may be related to the method of parasite infection (active penetration) and thus this parasite species could infect young and adult fish in the same manner.

Metacercariae of the genus *Clinostomum* were also found in *G. proximus*, but with low prevalence, mean intensity of infection and mean abundance. Paraguassú *et al.* (2005), studied *G. brasiliensis* from the Lajes Reservoir, Rio de Janeiro State, Brazil, and found results similar to those observed in this study for this parasite. *Clinostomum* spp. metacercariae are responsible for the yellow spot disease in freshwater fish (Silva *et al.*, 2008). In Brazil, *Clinostomum* spp. metacercariae have been reported in several fish species, including *G. brasiliensis* (Paraguassú *et al.*, 2005), *Astyanax altiparanae* Garutti & Britski, 2000, *Acestrorhynchus lacustris* Lütken, 1875, *Schizodon borellii* Boulenger, 1900, *Pimelodus maculatus* Lacepède, 1803, and *Cichla kelberi* Kullander & Ferreira, 2006 (Takemoto *et al.*, 2009).

In our sample, two *Clinostomum* species were found. However, only one of these could be identified, and this species was closely related to *C. heluans* (fig. 2) and was present in seven host specimens. Another *Clinostomum* sp. metacercaria was damaged during collection and the identification to the species level was not possible. However, this species was very different to that of the first species observed and was considered as morphotype 2. This metacercaria was found in only one *G. proximus* specimen and its morphology is closely related to that of *Clinostomum complanatum* Rudolphi, 1814. Future studies will be necessary to confirm this. In relation to *C. heluans*, there are no reports of fish parasitized by metacercariae of this species; however there are reports of molluscs (Moraes *et al.*, 2009) and piscivorous birds (Travassos *et al.*, 1969) infected by this trematode. Fish containing metacercariae have a zoonotic potential if eaten raw or undercooked (Kitagawa *et al.*, 2003) and some human cases have been published. Tiewchaloern *et al.* (1999) reported the presence of *Clinostomum* sp. in the eye of a Thai man, and Chung *et al.* (1995) found *C. complanatum* parasitizing the pharynx of a man in Korea. In Brazil,

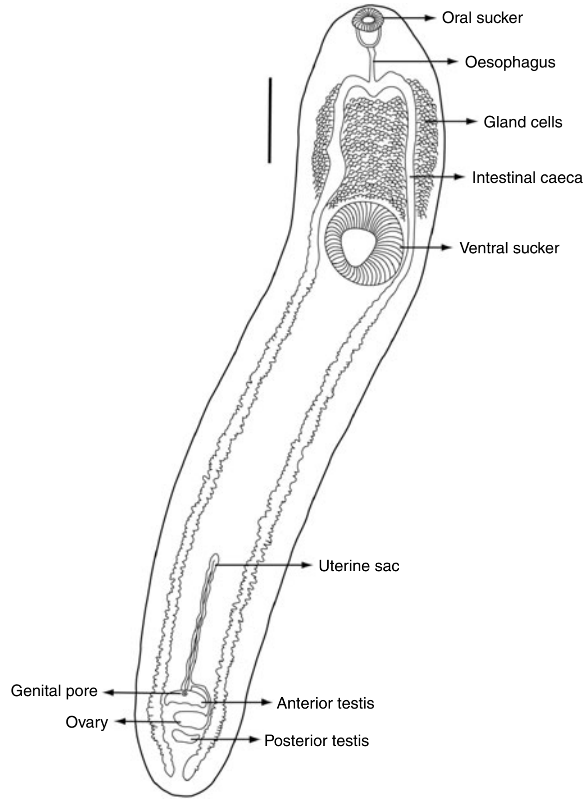

Fig. 2. *Clinostomum heluans* metacercaria collected in the fins of *Geophagus proximus* from São José dos Dourados River, a tributary of Paraná River, Ilha Solteira Reservoir, municipality of Ilha Solteira, São Paulo State, Brazil. Scale bar = 500 μm.

there are no reports of infection with these trematode metacercariae in humans.

The nematodes found in the present study are included in the family Anisakidae Skrjabin & Karokhin, 1945, and represented the group of parasites with the lowest prevalence. Anisakids are associated with aquatic organisms (fish and marine mammals) and piscivorous birds, and the transmission of species in this family is dependent upon water and frequently involves aquatic invertebrates and fish intermediate or paratenic hosts (Anderson, 2000). In this study, we found one anisakid species in the adult stage (*R.* (*Sprentascaris*) *hypostomi*) and two anisakid species in the larval stage (*Raphidascaris* sp. and *Contracaecum* sp.), suggesting that *G. proximus* can act as a definitive and intermediate host to nematodes of this family.

Nematode larvae of the family Anisakidae are important in public health, because they may be responsible for the emerging disease, anisakiasis. Humans acquire this infection by eating raw food dishes such as sushi, sashimi, ceviche or undercooked fish and squid dishes (Sakanari & McKerrow, 1990). This disease occurs mainly in countries whose populations have the habit of eating raw fish, such as those belonging to the Asian continent (Asami *et al.*, 1965; Sohn & Seol, 1994). In Brazil, there are no reports of cases in humans, although studies show the occurrence of fish infected with these larvae (Bicudo *et al.*, 2005; Barros *et al.*, 2007; Knoff *et al.*, 2007). Considering the site of infection of anisakid larvae in *G. proximus* it was not possible to confirm their zoonotic potential because none of these species were found in the host musculature.

With regard to *R.* (*Sprentascaris*) *hypostomi*, there have been few studies reporting the occurrence of this parasite species in fishes. Moravec *et al.* (1990) reported its occurrence in the intestine and stomach of *Hypostomus albopunctatus* Regan, 1908 (=*Plecostomus albopunctatus* Regan, 1908), *H. commersoni* Valenciennes, 1836 (=*P. commersoni* Valenciennes, 1836), *H. derbyi* Haseman, 1911 (=*P. derbyi* Haseman, 1911) and *Ancistrus cirrhosus* Valenciennes, 1836, in Salto Osório, Paraná State, Brazil and Passo Fundo, Rio Grande do Sul State, Brazil. This nematode was also found infecting *H. cochliodon* Kner, 1854 (=*Cochliodon cochliodon* Kner, 1854), *Hypostomus* sp. Lacépède, 1803, and *Ancistrus cirrhosus* (Thatcher, 2006).

The majority of helminths found in *G. proximus* were in the larval stage, suggesting that this fish species occupies an intermediate position in the food chain and may be part of the diet of many species of piscivorous birds (definitive hosts of *Contracaecum* sp., *A. compactum* and *Clinostomum* sp.), as well as fish, amphibians and reptiles, which are definitive hosts of proteocephalidean plerocercoids (Silva *et al.*, 2000; Alves & Luque, 2006). Paraguassú *et al.* (2005) studied the structure of the parasite infracommunity of *G. brasiliensis* in the Lajes Reservoir, Rio de Janeiro State, Brazil, and some characteristics observed were similar to those found for *G. proximus* in the Ilha Solteira Reservoir, São Paulo State, Brazil. The parasites showed the typical aggregated pattern of distribution, all parasite species did not present a correlation between body length and parasite prevalence and abundance, the sex of hosts did not influence the prevalence or the abundance of any parasite species, and mean parasite species diversity was not correlated with body length.

The aggregated pattern of distribution, presented by all parasites found in *G. proximus* in this study, is a common feature of infections in invertebrate and vertebrate hosts (Zuben, 1997). Thus, most hosts harboured fewer parasites while only a small number of hosts harboured a large proportion of the parasite population (Zuben, 1997). Many biological forces operate to shape the distribution of parasites among hosts and the causes of the aggregated pattern of distribution are many and varied, because they are usually associated with variability in susceptibility to infection within the host population (Anderson, 1993; Poulin, 2007). Such variability may be due to differences in the spatial aggregation of infective stages, host behaviour, or differences in the ability of hosts to mount effective immunological responses to parasite invasion (due to past experiences of infection, other parasitic species within the host or genetic constitution) (Anderson, 1993). The hosts with heavy infections are often predisposed to this state by, as yet undetermined, factors involving genetic, behavioural and environmental components (Anderson, 1993). Although the parasites found in *G. proximus* presented low values of mean species richness and mean species diversity, they were similar when compared with studies carried out with another fish species belonging to the family Cichlidae from Brazil (Paraguassú *et al.*, 2005; Azevedo *et al.*, 2006, 2007).

In the present study, neither the body length nor condition factor (K) was correlated with the rates of parasitism. The number of species (richness) of parasite infracommunities varies among host individuals in a population, among host populations and among host species (Poulin, 1995). According to Bell & Burt (1991), who analysed the mean number of parasitic helminth species among Canadian freshwater fish, the helminth diversity is positively correlated with host size, longevity, diet and geographical range. Therefore, the lack of relationship between the rates of parasitism and the host body length or condition factor (K) could indicate that the diet of *G. proximus* does not vary according to their growth, indicating homogeneity in its behaviour during the life cycle and permitting the uniform recruitment of the same species of parasites throughout ontogenetic evolution (Machado *et al.*, 1996).

There was no influence of the sex of the host and seasonality upon the rates of parasitism in *G. proximus*. These parameters are important factors in the host–parasite relationship and the pattern found suggests that ecological relationships, such as behaviour, habitat and diet, and physiological resistance between male and female hosts are similar (Abdallah *et al.*, 2005; Azevedo *et al.*, 2007). With regard to seasonality, there are no well-defined seasons in Brazil and this characteristic may have contributed to the lack of relationship between parasitism rates and seasonality.

In summary, seven taxa of helminths were found in *G. proximus* from the São José dos Dourados River, a tributary of Paraná River, Ilha Solteira Reservoir, municipality of Ilha Solteira, São Paulo State, Brazil. A high rate of infection with larval stages was observed, as well as the absence of the influence of the host sex and seasonality upon community parameters. Correlation between species richness and host body weight was also not observed. Moreover, with the exception of *A. compactum* metacercariae, all helminths found in this study are reported for the first time in *G. proximus.*

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