

# New host records and a checklist of fishes infected with *Austrodiplostomum compactum* (Digenea: Diplostomidae) in Brazil

Novos registros de hospedeiros e “checklist” de peixes infectados por *Austrodiplostomum compactum* (Digenea: Diplostomidae) no Brasil

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## Abstract

This study reports the infection of fishes by *Austrodiplostomum compactum* metacercariae in the Chavantes reservoir, medium Paranapanema River, municipality of Ipaussu, São Paulo State, Brazil. Twenty-three fish species were analysed, and 13 were infected with *A. compactum* metacercariae (56.5%) in their eyes. The following six fish species are new hosts for this metacercaria: *Crenicichla haroldoi* (1/1), *Eigenmannia trilineata* (11/6), *Hoplosternum littorale* (11/1), *Iheringichthys labrosus* (17/2), *Leporinus amblyrhynchus* (11/1), and *Piaractus mesopotamicus* (3/1). These new species increase the number of Brazilian fish species infected with this parasite to 36. Based on these findings, we hypothesise that the metacercariae larval stage of the parasite has a low specificity for the second intermediate host (fish). The majority of fish species infected in Brazil belong to the Loricariidae and Cichlidae families. For the fish species with higher mean abundances in Brazil, six are non-native species, and currently, *Plagioscion squamosissimus* has the highest mean abundance. The majority of fish species infected with *A. compactum* in Brazil are concentrated in the Paraná basin, although this may be related to the distribution of researchers.

**Keywords:** Freshwater fishes, parasite, Trematoda, metacercariae, infection, Paraná basin.

## Resumo

Este estudo relata a infecção por metacercárias de *Austrodiplostomum compactum* em peixes do reservatório de Chavantes, médio Paranapanema, Ipaussu, São Paulo, Brasil. Vinte e três espécies de peixes foram analisadas, e 13 estavam infectadas com metacercárias (56,5%) em seus olhos. Seis espécies de peixes foram registradas como novos hospedeiros: *Crenicichla haroldoi* (1/1), *Eigenmannia trilineata* (11/6), *Hoplosternum littorale* (11/1), *Iheringichthys labrosus* (17/2), *Leporinus amblyrhynchus* (11/1), and *Piaractus mesopotamicus* (3/1), aumentando para 36 o número de peixes brasileiros infectados por este parasita. Assim, inferimos que este estágio larval do parasita possui baixa especificidade parasitária em relação ao seu segundo hospedeiro intermediário (peixes). No Brasil, a maioria das espécies de peixes infectadas pertence às famílias Loricariidae e Cichlidae. Quanto às espécies de peixes com as maiores abundâncias médias no Brasil, seis são espécies não-nativas, sendo *Plagioscion squamosissimus* a espécie com a maior abundância média. Ainda, a maioria das espécies de peixes infectadas por *A. compactum* no Brasil, estão concentradas na bacia do Paraná, sendo este fato possivelmente relacionado com a distribuição de pesquisadores.

**Palavras-chave:** Peixes de água doce, parasita, Trematoda, metacercária, infecção, bacia do Paraná.

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Introduction

Eye fluke diplostomids have complex life cycles, involving three hosts, of which two are intermediate and one is definitive (KARVONEN et al., 2006; VIOLANTE-GONZÁLEZ et al., 2009), and parasitise several fish species in the world (EIRAS, 1994). *Austrodiplostomum compactum* (Lutz, 1928) is widely distributed in the Neotropical region, and *A. compactum* metacercariae parasitise several species of Brazilian freshwater fishes.

The *A. compactum* cercariae (first larval stage) infect aquatic snails and molluscs of the genus *Biomphalaria* Preston, 1910 in Mexico (VIOLANTE-GONZÁLEZ et al., 2009) and Brazil (PINTO; MELO, 2013). *Diplostomum* and *Austrodiplostomum* metacercariae are frequently found in the eyes of freshwater fishes, which are the second intermediate hosts during the life cycle of the parasite (SEPPÄLÄ et al., 2004). The adult stage parasitises the digestive tract of piscivorous birds, and *Phalacrocorax brasilianus* (Gmelin, 1789) [= *Phalacrocorax olivaceus*] is considered definitive host of this digenean in Brazil (TRAVASSOS et al., 1969; NORONHA et al., 2009; MONTEIRO et al., 2011).

According to Eiras (1994) and Seppälä et al. (2005), the presence of Diplostomidae metacercariae in eyes of fishes can cause loss of vision, blindness and increases the coverage of cataracts of the lens area in fish with high rates of infection. This makes the fish more susceptible to predation and facilitates the transmission of the parasite to the definitive hosts (SEPPÄLÄ et al., 2004).

However, a few Brazilian fish species were evaluated for the presence of *A. compactum* metacercariae and their possible effects. This study reports the occurrence of *A. compactum* in fish species

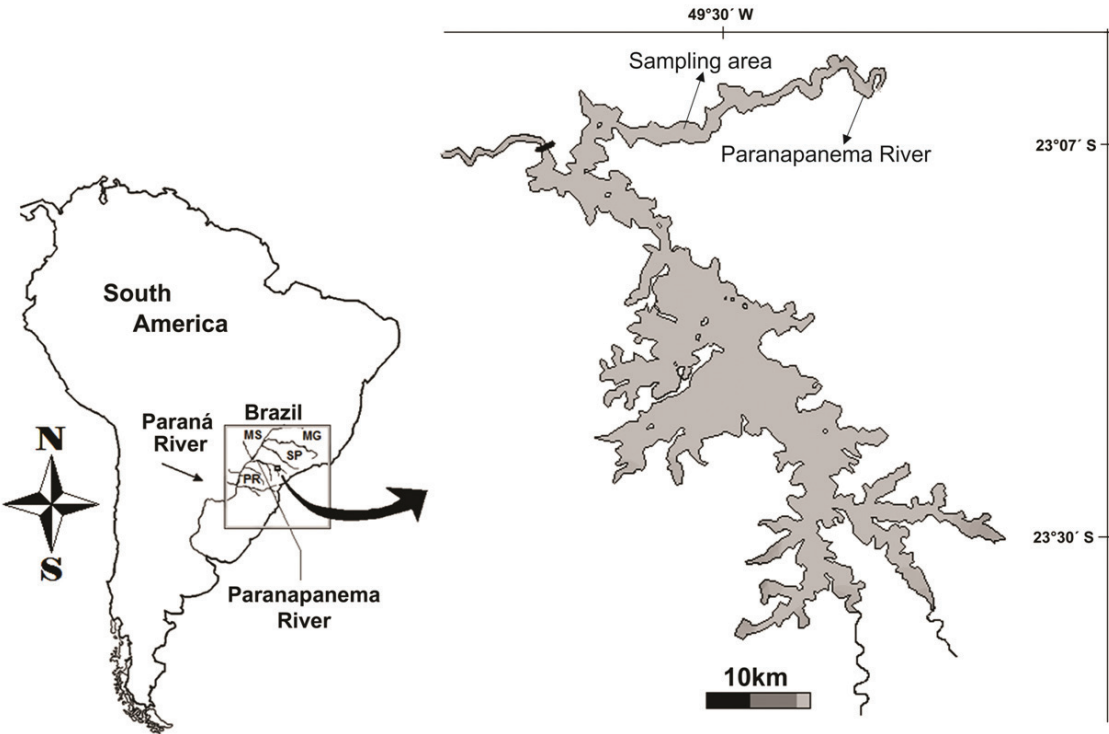
from the Paranapanema River and its parasitological indexes, as well as several considerations regarding ecological aspects and a checklist for fishes parasitised in Brazil.

Materials and Methods

This study was conducted in the Chavantes reservoir (medium Paranapanema River), municipality of Ipaussu, São Paulo State, Brazil (23° 07' 36" S and 49° 59.23' 10" W) (Figure 1 and Table 1). Fish samples were collected monthly from March 2009 to February 2010 using gillnets (3 to 14 cm meshes between adjacent nodes) with 14 hours of exposure (from 5:00 PM to 7:00 AM). All

**Table 1.** Physical and chemical characteristics (mean and standard error) of the sampling sites in the Chavantes Reservoir, municipality of Ipaussu, São Paulo State, southeast Brazil from Carvalho et al. (2012a).

Sites	Values ± SE
Water temperature (°C)	23.8±2.5
Water transparency (m)	3.1±0.8
Dissolved oxygen (mg O <sub>2</sub> .L <sup>-1</sup> )	8.2±1.7
pH	7.1±0.3
Conductivity (µS.cm <sup>-1</sup> )	40.3±6.2
Depth (m)	11.7±0.4
Chlorophyll a (µg.L <sup>-1</sup> )	1.9±1.3
Total P (µg.L <sup>-1</sup> )	9.7±4.1
Total N (µg.L <sup>-1</sup> )	236.0±78.7



**Figure 1.** Map of the hydrographical network in São Paulo State highlighting the Chavantes reservoir and sampling location on the Paranapanema River in the municipality of Ipaussu, São Paulo State, southeast Brazil.

captured fishes were frozen and transported to the laboratory where their eyes were removed and examined with a stereomicroscope. The metacercariae were collected from the vitreous humour, fixed in 70% alcohol under cover slip pressure and preserved in 70% alcohol (EIRAS et al., 2006). The metacercariae were stained with carmine and cleared with eugenol for identification. Morphological analyses were performed with a computerised system for image analysis (Qwin Lite 3.2 – Leica Microsystems, Wetzlar, Germany).

Twenty-three fish species were analysed: 'peixe-cachorro', *Acestrorhynchus lacustris* n=33 (Lütken, 1875), 'canivete', *Apareiodon affinis* n=41 (Steindachner, 1879), 'lambari-do-rabo-amarelo', *Astyanax altiparanae* n=37 Garutti & Britski, 2000, 'lambari-do-rabo-vermelho', *Astyanax fasciatus* n=30 (Cuvier, 1819), 'saguiro-do-rabo-vermelho', *Cyphocharax modestus* n=1 (Fernández-Yépez, 1948), 'peixe-cadela', *Galeocharax knerii* n=32 (Steindachner, 1879), 'traíra', *Hoplias malabaricus* n=9 (Bloch, 1794), 'piava', *Leporinus amblyrhynchus* n=11 Garavello & Britski, 1987, 'ferreirinha', *Leporinus octofasciatus* n=1 Steindachner, 1915, 'pacu', *Piaractus mesopotamicus* n=3 (Holmberg, 1887), 'ximborê', *Schizodon nasutus* n=17 Kner, 1858, 'piranha', *Serrasalmus maculatus* n=21 Kner, 1858, 'sardela', *Triportheus nematurus* n=6 (Kner, 1858), 'caborjá', *Hoplosternum littorale* n=11 (Hancock, 1828), 'cascudo', *Hypostomus regani* n=4 (Ihering, 1905), 'mandiúva', *Iheringichthys labrosus* n=17 (Lütken, 1874), 'mandi-guaçu', *Pimelodus maculatus* n=34 Lacépède, 1803, 'bagre', *Rhamdia quelen* n=1 (Quoy & Gaimard, 1824), 'tucunaré', *Cichla kelberi* n=42 Kullander & Ferreira, 2006, 'joaninha', *Crenicichla haroldoi* n=1 Luengo & Britski, 1974, 'acará', *Geophagus brasiliensis* n=2 (Quoy & Gaimard, 1824), 'corvina', *Plagioscion squamosissimus* n=30 (Heckel, 1840), and 'tupia', *Eigenmannia trilineata* n=11 López & Castello, 1966.

The prevalence, mean intensity of infection and mean abundance were calculated according to Bush et al. (1997) for fish species with at least nine specimens collected. Parasite voucher specimens were deposited in the Coleção Helmintológica do Departamento de Parasitologia (CHIBB 6723, 6974-6985) at the Instituto de Biociências, Universidade Estadual Paulista (IB/UNESP), municipality of Botucatu, São Paulo State, Brazil. Fish voucher specimens were identified and deposited by Dr. Cláudio de Oliveira in the Coleção do Laboratório de Biologia e Genética de Peixes (LBP 4797, 9192, 9174, 9179, 9181, 9183, 9184, 9185, 9186, 9191, 9194) at IB/UNESP and the Coleção Ictiológica do Nupélia (NUP 6117), Universidade Estadual de Maringá, municipality of Maringá, Paraná State, Brazil.

A review of the fishes infected with *A. compactum* in Brazil was performed using books (EIRAS et al., 2010) and by searching databases (SciELO, ISI, Scopus and Google Scholar). When available, data regarding the prevalence, mean intensity of infection and mean abundance along with their errors or standard deviations were added to the Table. In cases where these data do not exist but data does exist that enable their calculations, we performed the calculations according to the method described by Bush et al. (1997).

## Results

In the present study, the fish collected in the Paranapanema River showed a total of 357 *A. compactum* metacercariae, recovered

from 43 fish specimens. Thirteen fish species were infected by at least one parasite (56.5% of the fish species analysed), *C. kelberi*, *C. haroldoi*, *E. trilineata*, *G. brasiliensis*, *H. regani*, *H. littorale*, *H. malabaricus*, *I. labrosus*, *L. amblyrhynchus*, *P. mesopotamicus*, *P. maculatus*, *P. squamosissimus*, and *S. nasutus*, of which, two were non-native species, *C. kelberi* and *P. squamosissimus*.

Of the thirteen species of fish parasitised (192 specimens), the prevalence was 22.3% (43 fishes). Six freshwater fish species were identified as new hosts for *A. compactum* metacercariae, *C. haroldoi*, *E. trilineata*, *H. littorale*, *I. labrosus*, *L. amblyrhynchus*, and *P. mesopotamicus*, totalling 46.2% of the infected fish species and 26.1% for all the fish species analysed. Three fish orders, Characiformes, Perciformes, and Siluriformes had four parasitised fish species, and Gymnotiformes had one infected fish species. The Cichlidae family had three infected species (23.1%), followed by Pimelodidae and Anostomidae, with two infected species each (15.4%) (Table 2).

The overall prevalence was 10.9%, and the highest prevalence was observed in *P. squamosissimus* (66.6%), followed by *E. trilineata* (54.5%) and *I. labrosus* (11.8%). The mean intensity of infection and mean abundance were low for all fish species, with *P. squamosissimus* having the highest values ( $13.1 \pm 6.1$  and  $8.7 \pm 4.2$ , respectively). All other fish species had values less than or equal to 2.0 for the mean intensity of infection and less than 1.0 for the mean abundance (Table 2).

*Austrodiplotomum compactum* metacercariae parasitised 36 Brazilian fish species and two taxa not identified (*Cichla* sp. and *Hypostomus* sp.) belonging to 13 families and four orders. The reports identified the fish species as follows: Characiformes (families: Anostomidae, three species; Curimatidae, one species; Erythrinidae, one species; and Serrasalminidae, four species); Siluriformes (families: Auchenipteridae, two species; Callichthyidae, one species; Loricariidae, eight species; and Pimelodidae, three species); Gymnotiformes (families: Gymnotidae, one species; and Sternopygidae, one species); and Perciformes (families: Centropomidae, one species; Cichlidae, 10 species; and Sciaenidae, one species). Eight infected fish species are non-native according to Langeani et al. (2007): *Cichla* sp., *C. kelberi*, *C. ocellaris*, *G. proximus*, *G. surinamensis*, *Metynnis maculatus*, *P. squamosissimus* and *Satanoperca pappaterra* (Table 2).

Of the 36 fish species parasitised, only eight showed a mean abundance higher than five metacercariae. Of these fishes, six are non-native species of the order Perciformes. The non-native species, *P. squamosissimus* had the highest mean abundance of all the parasitised species (Table 2). The Paranapanema River showed the highest number of parasitised fish species (21), followed by the Paraná River (nine species), Tietê and Guandu Rivers (seven species each) and Grande River (two species). The other rivers had one fish infected species each (Table 2).

## Discussion

*Austrodiplotomum compactum* metacercariae have been recorded in a wide variety of Brazilian fishes (Table 2). This study demonstrated that 56.5% of all fish species collected were infected. These fish species belong to four orders, Characiformes,

**Table 2.** List of fish species reported as an intermediate host of *Austrodiplostomum compactum* metacercariae in Brazil. Number of specimens examined (N), prevalence (P), mean intensity of infection (MI), mean abundance (MA) and site of infection (SI).

Taxa	N	P(%)	MI	MA	SI	State/River	References
<b>Order Characiformes</b>							
<b>Family Erythrinidae</b>							
<i>Hoplias malabaricus</i> (Bloch, 1794)*	9	11.1	1.0	0.1±0.1	E	SP/Paranapanema	present study
<i>Hoplias malabaricus</i> **	198	11.1	1.4±1.3	0.2±0.6	E/CC	PR/Paraná	Machado et al. (2005)
<i>Hoplias malabaricus</i>	7	14.3	9.0	1.3	E	SP/Tietê	Paes et al. (2010b)
<i>Hoplias malabaricus</i>	28	60.7	32.6	19.8	E	PR/Paraná	Santos et al. (2012)
<i>Hoplias malabaricus</i>	10	57.1	2.5	1.4	E	MG/Doce	Belei et al. (2013)
<b>Family Serrasalmidae</b>							
<i>Metynnis maculatus</i> (Kner, 1858) <sup>ε</sup>	298	0.3	1	0.003	E	SP/Tietê	Paes et al. (2010b)
<i>Piaractus mesopotamicus</i> (Holmberg, 1887)** <sup>§</sup>	3	33.3	6.0	2.0±2.0	E	SP/Paranapanema	present study
<i>Pygocentrus nattereri</i> Kner, 1858*	40	15.0	1.6±0.7	0.1±0.7	M	AM/Solimões	Morais et al. (2011)
<i>Serrasalmus maculatus</i> Kner, 1858	3	33.3	1.0	0.3	E	PR/Paranapanema	Yamada et al. (2008)
<b>Family Anostomidae</b>							
<i>Leporinus amblyrhynchus</i> Garavello & Britski, 1987** <sup>§</sup>	11	9.1	2.0	0.2±0.2	E	SP/Paranapanema	present study
<i>Schizodon borellii</i> (Boulenger, 1900) <sup>†</sup>	-	-	-	-	-	PR/Paraná	Pavanelli et al. (1997)
<i>Schizodon borellii</i>	15	6.6	2.0	0.1	E	PR/Paranapanema	Yamada et al. (2008)
<i>Schizodon nasutus</i> Kner, 1858*	17	5.9	2.0	0.1±0.1	E	SP/Paranapanema	present study
<i>Schizodon nasutus</i>	84	4.8	1.2	0.05	E	SP/Tietê	Paes et al. (2010b)
<b>Family Curimatidae</b>							
<i>Cyphocharax gilbert</i> (Quoy & Gaimard, 1824)	60	1.6	1.0	0.01	E	RJ/Guandu	Abdallah et al. (2005)
<b>Order Siluriformes</b>							
<b>Family Auchenipteridae</b>							
<i>Auchenipterus osteomystax</i> (Miranda Ribeiro, 1918)	2	50.0	1.0	0.5	E	PR/Paranapanema	Yamada et al. (2008)
<i>Trachelyopterus striatulus</i> (Steindachner, 1877)*	60	1.6	1.0±0.5	0.02±0.3	E	RJ/Guandu	Mesquita et al. (2011)
<b>Family Callichthyidae</b>							
<i>Hoplosternum littorale</i> (Hancock, 1828)** <sup>§</sup>	11	9.1	1.0	0.1±0.1	E	SP/Paranapanema	present study
<b>Family Loricariidae</b>							
<i>Hypostomus</i> sp.*	5	40.0	17.5±16.5	7.0±6.8	E	SP/Paranapanema	Zica et al. (2011)
<i>Hypostomus affinis</i> (Steindachner, 1877)	31	-	-	-	-	RJ/Guandu	Azevedo et al. (2010)
<i>Hypostomus hermanni</i> (Ihering, 1905)	1	100	27.0	27.0	E	SP/Paranapanema	Zica et al. (2011)
<i>Hypostomus iheringii</i> (Regan, 1908)*	28	64.3	13.1±3.2	8.4±2.4	E	SP/Paranapanema	Zica et al. (2011)
<i>Hypostomus margaritifer</i> (Regan, 1908)	1	100	35.0	35.0	E	SP/Paranapanema	Zica et al. (2011)
<i>Hypostomus regani</i> (Ihering, 1905)*	4	50.0	21.0±18.0	10.5±9.5	E	SP/Paranapanema	present study
<i>Hypostomus regani</i>	8	25.0	0.5	0.1	E	PR/Paranapanema	Yamada et al. (2008)
<i>Hypostomus regani</i>	1	100	1.0	1.0	E	SP/Paranapanema	Zica et al. (2009)
<i>Hypostomus regani</i>	3	33.3	10.0	3.3±3.3	E	SP/Paranapanema	Zica et al. (2011)
<i>Hypostomus strigaticeps</i> (Regan, 1908)*	45	24.4	10.3±2.4	2.7±0.9	E	SP/Paranapanema	Zica et al. (2011)
<i>Loricariichthys castaneus</i> (Castelnau, 1855)*	30	30	13.6	4.1±10.4	E	RJ/Paraíba do Sul	Paraguassú and Luque (2007)
<b>Family Pimelodidae</b>							
<i>Conorhynchus conirostris</i> (Valenciennes, 1840)*	24	8.3	7.5±9.2	0.6±0.4	G/E	MG/S. Francisco	Brasil-Sato and Santos (2005)
<i>Iheringichthys labrosus</i> (Lütken, 1874)** <sup>§</sup>	17	11.8	1.0±0.0	0.1±0.08	E	SP/Paranapanema	present study
<i>Pimelodus maculatus</i> Lacepède, 1803*	34	5.9	2.0±1.0	0.1±0.1	E	SP/Paranapanema	present study
<i>Pimelodus maculatus</i> <sup>†</sup>	239	20.5	4.0	0.8	SB/K/G	MG/São Francisco	Brasil-Sato and Pavanelli (2004)
<i>Pimelodus maculatus</i> <sup>†</sup>	229	1.3	1.0	0.01	SB/K/G	PR/Paraná	Brasil-Sato and Pavanelli (2004)
<i>Pimelodus maculatus</i> ** <sup>†</sup>	28	17.0	1	0.2±0.4	E	SC/Itajaí-Açu	Bachmann et al. (2007)
<i>Pimelodus maculatus</i>	60	16.6	1.1	0.2	E	RJ/Guandu	Santos et al. (2007)
<i>Pimelodus maculatus</i>	40	-	-	-	-	RJ/Guandu	Azevedo et al. (2010)

\* The values are presented as the mean and standard error; \*\* the values are presented as the mean and standard deviation; <sup>ε</sup> non-native fish species; <sup>§</sup> new host; <sup>†</sup> parasite identified as *Austrodiplostomum* sp. or *Diplostomum* sp.; E eye; CC cranial cavity; G gills; M muscle; SB swimming bladder; K kidney; CF cage farm; CT control.



Table 2. Continued...

Taxa	N	P(%)	MII	MA	SI	State/River	References
<b>Order Gymnotiformes</b>							
<b>Family Gymnotidae</b>							
<i>Gymnotus carapo</i> Linnaeus, 1758	30	-	-	-	-	RJ/Guandu	Azevedo et al. (2010)
<b>Family Sternopygidae</b>							
<i>Eigenmannia trilineata</i> López & Castello, 1966* <sup>§</sup>	11	54.5	1.3±0.2	0.7±0.2	E	SP/Paranapanema	present study
<b>Order Perciformes</b>							
<b>Family Centropomidae</b>							
<i>Centropomus undecimalis</i> (Bloch, 1792)	31	-	-	-	-	RJ/Guandu	Azevedo et al. (2010)
<b>Family Cichlidae</b>							
<i>Cichla</i> sp. <sup>£</sup>	23	52.2	5.9	3.1	E	PR/Paraná	Santos et al. (2012)
<i>Cichla kelberi</i> Kullander & Ferreira, 2006* <sup>£</sup>	42	7.1	2.0±0.6	0.1±0.1	E	SP/Paranapanema	present study
<i>Cichla kelberi</i> (=C. <i>monoculus</i> ) <sup>£</sup>	136	5.2	2.7	0.1	E	PR/Paraná	Machado et al. (2000)
<i>Cichla kelberi</i> (=C. <i>monoculus</i> )** <sup>£</sup>	40	65.0	7.8±13.0	5.1±11.1	E/CC	PR/Paraná	Machado et al. (2005)
<i>Cichla ocellaris</i> Bloch & Schneider, 1801 <sup>£</sup>	66	10.6	6.3	0.6	E	MG/Grande	Martins et al. (2002)
<i>Cichla ocellaris</i> <sup>£</sup>	81	55.5	9.3	5.2	E	SP/Paraná	Santos et al. (2002)
<i>Cichla piquiti</i> <sup>£†</sup>	27	0.3	13.4	3.5	E	PR/Paraná	Lacerda et al. (2013)
<i>Cichla piquiti</i> <sup>†</sup>	24	0.1	1.0	0.1	E	TO/Tocantins	Lacerda et al. (2013)
<i>Cichlasoma paranaense</i> Kullander, 1983**	25	12.0	1.0±0.0	0.1±0.3	E	PR/Paraná	Machado et al. (2005)
<i>Crenicichla britskii</i> Kullander, 1982**	44	22.7	6.2±9.0	1.4±4.9	E/CC	PR/Paraná	Machado et al. (2005)
<i>Crenicichla haroldoi</i> Luengo & Britski, 1974 <sup>§</sup>	1	100	6.0	6.0	E	SP/Paranapanema	present study
<i>Geophagus brasiliensis</i> (Quoy & Gaimard, 1824)*	2	100	8.0±5.0	8.0±5.0	E	SP/Paranapanema	present study
<i>Geophagus brasiliensis</i> *	50	14.0	1.6±1.1	0.2±0.2	E	RJ/Guandu	Azevedo et al. (2006)
<i>Geophagus brasiliensis</i>	1	100	1.0	1.0	E	SP/Tietê	Novaes et al. (2006)
<i>Geophagus brasiliensis</i> *	200	18.0	2.1±1.4	0.4±1.0	E/SB	RJ/Guandu	Carvalho et al. (2010)
<i>Geophagus brasiliensis</i>	64	3.1	4.0	0.1	E	PR/several rivers	Bellay et al. (2012)
<i>Geophagus brasiliensis</i> *	200	18.0	2.1±1.4	0.4±1.0	E/SB	RJ/Guandu	Carvalho et al. (2012b)
<i>Geophagus proximus</i> (Castelnau, 1855)* <sup>£</sup>	41	92.7	12.8±5.1	11.8±4.7	E	SP/Tietê	Zica et al. (2010)
<i>Geophagus proximus</i> * <sup>£</sup>	116	58.6	3.6±0.5	2.1±0.3	E	SP/S. J. Dourados	Zago et al. (2013)
<i>Geophagus surinamensis</i> (Bloch, 1791) <sup>£</sup>	40	45.0	13.8	6.2	E	PR/Paraná	Santos et al. (2012)
<i>Satanoperca pappaterra</i> (Heckel, 1840) <sup>£†</sup>	-	-	-	-	-	PR/Paraná	Pavanelli et al. (1997)
<i>Satanoperca pappaterra</i> (Heckel, 1840)** <sup>£</sup>	89	71.9	8.0±8.6	5.8±8.1	E/CC	PR/Paraná	Machado et al. (2005)
<i>Satanoperca pappaterra</i> <sup>£</sup>	25	60.0	6.4	3.8	E	SP/Tietê	Paes et al. (2010b)
<b>Family Sciaenidae</b>							
<i>Plagioscion squamosissimus</i> (Heckel, 1840)* <sup>£</sup>	30	66.7	13.1±6.1	8.7±4.2	E	SP/Paranapanema	present study
<i>Plagioscion squamosissimus</i> <sup>£</sup>	17	100.0	2-100/eye	-	E	PR/Paraná	Kohn et al. (1995)
<i>Plagioscion squamosissimus</i> <sup>£</sup>	-	-	-	-	-	PR/Paraná	Pavanelli et al. (1997)
<i>Plagioscion squamosissimus</i> <sup>£</sup>	68	45.6	7.1	3.2	E	MG/Grande	Martins et al. (1999)
<i>Plagioscion squamosissimus</i> <sup>£</sup>	70	52.8	5.3	2.8	E	MG/Grande	Martins et al. (2002)
<i>Plagioscion squamosissimus</i> <sup>£</sup>	61	91.8	42.0	38.5	E	SP/Paraná	Santos et al. (2002)
<i>Plagioscion squamosissimus</i> ** <sup>£</sup>	81	95.1	38.9±64.3	37.0±63.2	E/CC	PR/Paraná	Machado et al. (2005)
<i>Plagioscion squamosissimus</i> <sup>£</sup>	378	94.2	21.7	20.4	E	SP/Tietê	Paes et al. (2010a)
<i>Plagioscion squamosissimus</i> <sup>£</sup>	213	90.1	20.8	18.7	E	SP/Tietê	Paes et al. (2010b)
<i>Plagioscion squamosissimus</i> <sup>£</sup>	61	36.1	-	-	E	PR/Paraná	Kohn et al. (2011)
<i>Plagioscion squamosissimus</i> ** <sup>£†</sup>	35	88.6	98.8	87.5±153.3	E	PR/Paraná	Lacerda et al. (2012)
<i>Plagioscion squamosissimus</i> ** <sup>†</sup>	35	40.0	10.8	4.3±7.8	E	AM/Solimões	Lacerda et al. (2012)
<i>Plagioscion squamosissimus</i> ** <sup>†</sup>	35	8.3	2.9	0.1±0.5	E	TO/Tocantins	Lacerda et al. (2012)
<i>Plagioscion squamosissimus</i> <sup>£</sup>	57	98.0	42.7	41.9	E	PR/Paraná	Santos et al. (2012)
<i>Plagioscion squamosissimus</i> CF* <sup>£</sup>	37	86.4	20.3±1.1	17.7±6.3	E	SP/Paranapanema	Ramos et al. (2013)
<i>Plagioscion squamosissimus</i> CT* <sup>£</sup>	28	57.1	4.3±7.1	2.3±0.8	E	SP/Paranapanema	Ramos et al. (2013)

\* The values are presented as the mean and standard error; \*\* the values are presented as the mean and standard deviation; <sup>£</sup> non-native fish species;

<sup>§</sup> new host; <sup>†</sup> parasite identified as *Austrodiplotomum* sp. or *Diplostomum* sp.; E eye; CC cranial cavity; G gills; M muscle; SB swimming bladder; K kidney; CF cage farm; CT control.

Perciformes, Siluriformes and Gymnotiformes, and six new records of hosts to these metacercariae. Thus, the number of Brazilian fish species infected by *A. compactum* increased to 36, and the number of families parasitised for 13. Based on these observations, we hypothesise that this larval stage of the parasite has a low specificity for the second intermediate host (fish), similar to that reported by Yamada et al. (2008). In addition, the six new hosts identified in the present study demonstrates that parasitological studies with fish communities should significantly expand the list of fish identified as second intermediate hosts for *A. compactum*.

The mean intensity of infection for the analysed fish species was lower than Höglund and Thulin (1990), who reports that fish harbouring more than 40 *Diplostomum* metacercariae on their eyes are largely parasitized. According to several authors, the high infection rate with diplostomid metacercariae in fish can cause blindness or visual impairment (EIRAS, 1994), cataracts (SHARIFF et al., 1980; KARVONEN et al., 2004), problems with a food intake and growth (OWEN et al., 1993) and increased susceptibility to predation (CROWDEN; BROOM, 1980; SEPPÄLÄ et al., 2004). However, Karvonen et al. (2004) and Owen et al. (1993) report effects in fish with less than 10 *Diplostomum spathaceum* metacercariae (Rudolphi, 1819) and correlations between the number of metacercariae and the intensity of the effect. Another study reported that fish heavily infected with *D. spathaceum* occupied surface waters with more frequency, exposing them to higher levels of predation by birds. Therefore, fish with high infection rates would be subject to the effects of parasitism by *A. compactum* metacercariae, and fish with low infection show less intense effects of parasitism. Among these effects is the difficulty to detect prey, which results in fitness consequences for the individual (OWEN et al., 1993).

The prevalence of *A. compactum* in the present study is low, with exception of the prevalence in *E. trilineata* and *P. squamosissimus*. Studies of the infection of *A. compactum* in *P. squamosissimus* showed a prevalence greater than 90% and a mean intensity of infection greater than 20 (KOHN et al., 1995; SANTOS et al., 2002, 2012; MACHADO et al., 2005; PAES et al., 2010a, b), whereas in the current study, the prevalence was 66.6% and the mean intensity of infection was  $13.1 \pm 6.1$ . According to Karvonen et al. (2006), the infection dynamics of *D. spathaceum* in fish is related to the snail population variance. Voutilainen et al. (2009) found a positive correlation between *Lymnaea stagnalis* (Linnaeus, 1758) density (an intermediate host for *Diplostomum* spp. in Finland) and *Diplostomum* sp. prevalence in lakes and ponds in Finland. Additionally, Martins et al. (2002) and Santos et al. (2002, 2012) suggested that high infection rates of *A. compactum* are dependent on high temperatures. According to Berrie (1960), *Diplostomum* cercariae emerge in waters only at temperatures greater than 10 °C. Despite the high water temperature observed in the current study location (CARVALHO et al., 2012a), which may lead to a high intensity of infection, the values of water transparency, conductivity and chlorophyll *a* (Table 1), suggest a small quantity of available nutrients in the local aquatic ecosystem. This can limit the size of the snail populations (first intermediate hosts), leading to the low values observed for the prevalence, mean intensity of infection and mean abundance for the majority fish species analysed.

The majority of fish species infected with *A. compactum* metacercariae in Brazil belong to the Perciformes (12 species),

Siluriformes (13 species), and Characiformes (nine species), and the Cichlidae (10 species) and Loricariidae (eight species) families were the most infected. However, the other fish species analysed in this study also live in this habitat and were not infected. Therefore, the absence of *A. compactum* metacercariae infection in these fish species may be related to species-specific characteristics, which remain unknown.

For the fish species with higher mean abundances in Brazil, six are non-native species, and currently, *P. squamosissimus* has the highest mean abundance. This was also demonstrated by Pojmanska and Chabros (1993), who showed that the prevalence of diplostomids was significantly lower in native fishes than non-native fishes. However, Lacerda et al. (2012) demonstrated an inverse situation in which the native fish *H. malabaricus* showed a higher abundance of *Austrodiplostomum* sp. than the introduced *P. squamosissimus*. Lacerda et al. (2012) also demonstrated that *P. squamosissimus* in native regions showed a prevalence and abundance of diplostomids that was significantly lower than *P. squamosissimus* in the region where they were introduced. According to Lacerda et al. (2012), migratory birds, such as *P. brasiliensis* are the final hosts for *Austrodiplostomum*; therefore, geographic barriers for the parasite may be reduced or eliminated. Rather than introducing a new parasite, *P. squamosissimus* may be acting as a new and suitable host for a local parasite. This may also occur with other species of fish, such as the six non-native Brazilian fish species, which had higher abundances.

The majority of infected fish species are in the Paranapanema River. Specifically, the Paraná basin is the most studied region for *A. compactum* in Brazil, and this is possibly related to the distribution of researchers in Brazil. Despite the large number of studies, further investigations are necessary to understand the relationship between environmental aspects and life strategies because diplostomiasis causes large aquaculture losses each year worldwide (PAPERNA; DZIKOWSKI, 1995; OVERSTREET; CURRAN, 2004).

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## References

- Abdallah VD, Azevedo RK, Luque JL. Ecologia da comunidade de metazoários parasitos do sairú *Cyphocharax gilbert* (Quoy e Gaimard, 1824) (Characiformes: Curimatidae) do rio Guandu, estado do Rio de Janeiro, Brasil. *Rev Bras Parasitol Vet* 2005; 14(4): 154-159. PMID:16445872.
- Azevedo RK, Abdallah VD, Luque JL. Ecologia da comunidade de metazoários parasitos do acará *Geophagus brasiliensis* (Quoy e Gaimard, 1824) (Perciformes: Cichlidae) do rio Guandu, Estado do Rio

- de Janeiro, Brasil. *Acta Sci Biol Sci* 2006; 28(4): 403-411. <http://dx.doi.org/10.4025/actascibiolsci.v28i4.406>
- Azevedo RK, Abdallah VD, Luque JL. Acanthocephala, Annelida, Arthropoda, Myxozoa, Nematoda and Platyhelminthes parasites of fishes from the Guandu river, Rio de Janeiro, Brazil. *Check List* 2010; 6(4): 659-667.
- Bachmann F, Greinert JA, Bertelli PW, Silva HH F<sup>o</sup>, Lara NOT, Ghiraldelli L, et al. Parasitofauna de *Pimelodus maculatus* (Osteichthyes: Pimelodidae) do rio Itajaí-Açu em Blumenau, estado de Santa Catarina, Brasil. *Acta Sci Biol Sci* 2007; 29(1): 109-114. <http://dx.doi.org/10.4025/actascibiolsci.v29i1.159>
- Belei F, Ferreira SR, Perin LM, Braga FR, Sampaio WMS, Araújo JV, et al. First report of *Austrodiplotomum compactum* and *Ithyoclinostomum dimorphum* in trahira (*Hoplias malabaricus*) from the middle course of the Rio Doce, Minas Gerais, Brazil. *Arq Inst Biol* 2013; 80(2): 249-252. <http://dx.doi.org/10.1590/S1808-16572013000200017>
- Bellay S, Ueda BH, Takemoto RM, Lizama MAP, Pavanelli GC. Fauna parasitária de *Geophagus brasiliensis* (Perciformes: Cichlidae) em reservatórios do estado do Paraná, Brasil. *R Bras Bioci* 2012; 10(1): 74-78.
- Berrie AD. Two *Diplostomulum* larvae (Strigeida, Trematoda) in the eyes of sticklebacks (*Gasterosteus aculeatus* L.). *J Helminthol* 1960; 34(3-4): 211-216. <http://dx.doi.org/10.1017/S0022149X00021143>
- Brasil-Sato MC, Pavanelli GC. Digenea de *Pimelodus maculatus* (Osteichthyes, Pimelodidae) das bacias dos rios São Francisco e Paraná, Brasil. *Parasitol Latinoam* 2004; 59(3-4): 123-131.
- Brasil-Sato MC, Santos MD. Metazoan parasites of *Conorhynchus conirostris* (Valenciennes, 1840), an endemic siluriform fish of the São Francisco basin, Brazil. *Rev Bras Parasitol Vet* 2005; 14(4): 160-166.
- Bush AO, Lafferty KD, Lotz JM, Shostak AW. Parasitology meets ecology on its own terms: Margolis et al. revisited. *J Parasitol* 1997; 83(4): 575-583. PMID:9267395. <http://dx.doi.org/10.2307/3284227>
- Carvalho AR, Tavares LER, Luque JL. Variação sazonal dos metazoários parasitos de *Geophagus brasiliensis* (Perciformes: Cichlidae) no rio Guandu, Estado do Rio de Janeiro, Brasil. *Acta Sci Biol Sci* 2010; 32(2): 159-167. <http://dx.doi.org/10.4025/actascibiolsci.v32i2.4883>
- Carvalho ED, Silva RJ, Ramos IP, Paes JVK, Zanatta AS, Brandão H, et al. Ecological Features of Large Neotropical Reservoirs and Its Relation to Health of Cage Reared Fish. In: Carvalho ED, David-Silva G, Silva RJ. *Health and environment in aquaculture*. Rijeka: InTech; 2012a. p. 361-382. <http://dx.doi.org/10.5772/2462>
- Carvalho AR, Azevedo RK, Abdallah VD, Luque JLF. Metacercárias de Diplostomidae (Digenea: Diplostomoidea) em *Geophagus brasiliensis* (Perciformes: Cichlidae) do rio Guandu, Estado do Rio de Janeiro, Brasil. *Acta Sci Biol Sci* 2012b; 34(2): 233-239. <http://dx.doi.org/10.4025/actascibiolsci.v34i2.5957>
- Crowden AE, Broom DM. Effects of the eyefluke, *Diplostomum spathaceum*, on the behaviour of dace (*Leuciscus leuciscus*). *Anim Behav* 1980; 28(1): 287-294. [http://dx.doi.org/10.1016/S0003-3472\(80\)80031-5](http://dx.doi.org/10.1016/S0003-3472(80)80031-5)
- Eiras JC. *Elementos de ictioparasitologia*. Porto: Fundação Engenheiro Antônio de Almeida; 1994.
- Eiras JC, Takemoto MR, Pavanelli GC. *Métodos de estudo e técnicas laboratoriais em parasitologia de peixes*. 2nd ed. Maringá: EdUEM; 2006.
- Eiras CJ, Takemoto MR, Pavanelli GC. *Diversidade dos parasitas de peixes de água doce do Brasil*. Maringá: Clichetec; 2010.
- Höglund J, Thulin J. The epidemiology of the metacercariae of *Diplostomum baeri* and *D. spathaceum* in perch (*Perca fluviatilis*) from the warm water effluent of a nuclear power station. *J Helminthol* 1990; 64(2): 139-150. PMID:2387975. <http://dx.doi.org/10.1017/S0022149X00012050>
- Karvonen A, Sepällä O, Valtonen ET. Eye fluke-induced cataract formation in fish: quantitative analysis using an ophthalmological microscope. *Parasitology* 2004; 129(Pt4): 473-478. <http://dx.doi.org/10.1017/S0031182004006006>
- Karvonen A, Savolainen M, Seppälä O, Valtonen ET. Dynamics of *Diplostomum spathaceum* infection in snail hosts at a fish farm. *Parasitol Res* 2006; 99(4): 341-345. <http://dx.doi.org/10.1007/s00436-006-0137-8>
- Kohn A, Fernandes BMM, Baptista-Farias MFD. Metacercariae of *Diplostomum (Austrodiplotomum) compactum* (Trematoda, Diplostomidae) in the eyes of *Plagioscion squamosissimus* (Teleostei, Sciaenidae) from the reservoir of the Hydroelectric Power Station of Itaipu, Brazil. *Mem Inst Oswaldo Cruz* 1995; 90(3): 341-344. <http://dx.doi.org/10.1590/S0074-02761995000300005>
- Kohn A, Moravec F, Cohen SC, Canzi C, Takemoto RM, Fernandes BMM. Helminths of freshwater fishes in the reservoir of the Hydroelectric Power Station of Itaipu, Paraná, Brazil. *Check List* 2011; 7(5): 681-690.
- Lacerda ACF, Takemoto RM, Tavares-Dias M, Poulin R, Pavanelli GC. Comparative parasitism of the fish *Plagioscion squamosissimus* in native and invaded river basins. *J Parasitol* 2012; 98(4): 713-717. <http://dx.doi.org/10.1645/GE-2882.1>
- Lacerda ACF, Takemoto RM, Poulin R, Pavanelli GC. Parasites of the fish *Cichla piquiti* (Cichlidae) in native and invaded Brazilian basins: release not from the enemy, but from its effects. *Parasitol Res* 2013; 112(1): 279-288. PMID: 23052767. <http://dx.doi.org/10.1007/s00436-012-3135-z>
- Langeani F, Corrêa e Castro RM, Oyakawa OT, Shibatta OA, Pavanelli CS, Casatti L. Diversidade da ictiofauna do Alto Rio Paraná: composição atual e perspectivas futuras. *Biota Neotrop* 2007; 7(3): 181-197.
- Machado PM, Almeida SC, Pavanelli GC, Takemoto RM. Ecological aspects of endohelminths parasitizing *Cichla monoculus* Spix, 1831 (Perciformes: Cichlidae) in the Paraná River near Porto Rico, State of Paraná, Brazil. *Comp Parasitol* 2000; 27(2): 210-217.
- Machado PM, Takemoto RM, Pavanelli GC. *Diplostomum (Austrodiplotomum) compactum* (Lutz, 1928) (Platyhelminthes, Digenea) metacercariae in fish from the floodplain of the Upper Paraná River, Brazil. *Parasitol Res* 2005; 97(6): 436-444. <http://dx.doi.org/10.1007/s00436-005-1483-7>
- Martins ML, Fujimoto RY, Nascimento AA, Moraes FR. Ocorrência de *Diplostomum* sp. Nordmann, 1832 (Digenea: Diplostomatidae), em *Plagioscion squamosissimus* Heckel, 1840, proveniente do Reservatório de Volta Grande, MG, Brasil. *Acta Sci* 1999; 21(2): 263-266.
- Martins ML, Paiva AMFC, Fujimoto RY, Schalch SHC, Colombano NC. Prevalência, sazonalidade e intensidade de infecção por *Diplostomum (Austrodiplotomum) compactum* Lutz, 1928 (Digenea, Diplostomidae), em peixes do reservatório de Volta Grande, Estado de Minas Gerais, Brasil. *Acta Sci Biol Sci* 2002; 24(2): 469-474.
- Mesquita RLB, Azevedo RK, Abdallah VD, Luque JL. Ectoparasites as numerical dominant species in parasite community of *Trachelyopterus striatulus* (Siluriformes: Auchenipteridae) from Guandu River, southeastern Brazil. *Braz J Biol* 2011; 71(3): 623-627. PMID: 21881785. <http://dx.doi.org/10.1590/S1519-69842011000400006>
- Monteiro CM, Amato JFR, Amato SB. Helminth parasitism in the Neotropical cormorant, *Phalacrocorax brasilianus*, in Southern Brazil: effect of host size, weight, sex, and maturity state. *Parasitol Res* 2011; 109(3): 849-855. <http://dx.doi.org/10.1007/s00436-011-2311-x>



- Morais AM, Varella AMB, Fernandes BMM, Malta JCO. *Clinostomum marginatum* (Braun, 1899) and *Austrodiplostomum compactum* (Lutz, 1928) metacercariae with zoonotic potencial on *Pygocentrus nattereri* (Kner, 1858) (Characiformes: Serrasalminidae) from Central Amazon, Brazil. *Neotrop Helminthol* 2011; 5(1): 8-15.
- Noronha D, Sá MR, Knoff M, Muniz-Pereira LC, Pinto RM. *Adolpho Lutz e a coleção helmintológica do Instituto Oswaldo Cruz*. Rio de Janeiro: Museu Nacional; 2009.
- Novaes JLC, Ramos IP, Carvalho ED, Silva RJ. Metacercariae of *Diplostomum compactum* Lutz, 1928 (Trematoda, Diplostomidae) in the eyes of acará *Geophagus brasiliensis* Quoy & Gaimard, 1824 (Teleostei, Cichlidae) from Barra Bonita Reservoir – São Paulo, Brazil. *Arq Bras Med Vet Zootec* 2006; 58(6): 1229-1231. <http://dx.doi.org/10.1590/S0102-09352006000600037>
- Overstreet R, Curran S. Defeating diplostomoid dangers in USA catfish aquaculture. *Folia Parasitol* 2004; 51(2-3): 153-165. PMID:15357393.
- Owen SF, Barber I, Hart PJB. Low level infection by eye fluke, *Diplostomum* spp., affects the vision of three-spined sticklebacks, *Gasterosteus aculeatus*. *J Fish Biol* 1993; 42(5): 803-806. <http://dx.doi.org/10.1111/j.1095-8649.1993.tb00387.x>
- Paes JVK, Carvalho ED, Silva RJ. Infection by *Austrodiplostomum compactum* metacercariae in fish from the Nova Avanhandava Reservoir, Tietê River, São Paulo, Brazil. *Acta Sci* 2010a; 32(3): 273-278. <http://dx.doi.org/10.4025/actasciobiolsci.v32i3.5675>
- Paes JVK, Carvalho ED, Silva RJ. Infection levels of *Austrodiplostomum compactum* (Digenea, Diplostomidae) metacercariae in *Plagioscion squamosissimus* (Teleostei, Sciaenidae) from the Nova Avanhandava reservoir, São Paulo State, Brazil. *J Helminthol* 2010b; 84(3): 284-291. PMID:19889255. <http://dx.doi.org/10.1017/S0022149X09990617>
- Paperna I, Dzikowski R. Digenea (Phylum Platyhelminthes). In: Woo PT. *Fish diseases and disorders. Vol. I: protozoans and metazoan infections*. Wallingford: CAB International; 1995. p. 345-390.
- Paraguassú AR, Luque JL. Metazoários parasitos de seis espécies de peixes do reservatório de Lajes, estado do Rio de Janeiro, Brasil. *Rev Bras Parasitol Vet* 2007; 16(3): 121-128. <http://dx.doi.org/10.1590/S1984-29612007000300002>
- Pavanelli GC, Machado MH, Takemoto RM. Fauna helmintica de peixes do rio Paraná, região de Porto Rico, Paraná. In: Vazzoler AEAM, Agostinho AA, Hahn NS. *A planície de inundação do alto rio Paraná: aspectos físicos, biológicos e sócioeconômicos*. Maringá: EdUEM; 1997. p. 307-329.
- Pinto HA, Melo AL. *Biomphalaria straminea* and *Biomphalaria glabrata* (Mollusca: Planorbidae) as new intermediate hosts of the fish eyefluke *Austrodiplostomum compactum* (Trematoda: Diplostomidae) in Brazil. *J Parasitol* 2013; 99(4): 729-733. <http://dx.doi.org/10.1645/12-13.1>
- Pojmanska T, Chabros M. Parasites of common carp and three introduced cyprinid fish in pond culture. *Acta Parasitol* 1993; 38(3): 101-108.
- Ramos IP, Francheschini L, Zica EOP, Carvalho ED, Silva RJ. The influence of cage farming on infection of the corvine fish *Plagioscion squamosissimus* (Perciformes: Sciaenidae) with metacercariae of *Austrodiplostomum compactum* (Digenea: Diplostomidae) from the Chavantes reservoir, São Paulo State, Brazil. *J Helminthol* 2013; 30: 1-7. <http://dx.doi.org/10.1017/S0022149X13000229>
- Santos RS, Pimenta FDA, Martins ML, Takahashi HK, Marengoni NG. Metacercárias de *Diplostomum* (*Austrodiplostomum*) *compactum* Lutz, 1928 (Digenea: Diplostomidae) em peixes do rio Paraná, Brasil. Prevalência, sazonalidade e intensidade de infecção. *Acta Sci Biol Sci* 2002; 24(2): 475-480.
- Santos MD, Lemos-Pita SRLC, Brasil-Sato MC. Metazoan parasite fauna of *Pimelodus maculatus* La Cépède, 1803 (Siluriformes, Pimelodidae) from the Guandu river, Rio de Janeiro State, Brazil. *Acta Sci Biol Sci* 2007; 29(1): 101-107. <http://dx.doi.org/10.4025/actasciobiolsci.v29i1.130>
- Santos RS, Marchiori N, Santarem VA, Takahashi K, Mourino JLP, Martins ML. *Austrodiplostomum compactum* (Lutz, 1928) (Digenea, Diplostomidae) in the eyes of fishes from Paraná River, Brazil. *Acta Sci Biol Sci* 2012; 34(2): 225-231. <http://dx.doi.org/10.4025/actasciobiolsci.v34i2.9337>
- Seppälä O, Karvonen A, Valtonen ET. Parasite-induced change in host behaviour and susceptibility to predation in an eye fluke–fish interaction. *Anim Behav* 2004; 68(2): 257-263. <http://dx.doi.org/10.1016/j.anbehav.2003.10.021>
- Seppälä O, Karvonen A, Valtonen ET. Manipulation of fish host by eye flukes in relation to cataract formation and parasite infectivity. *Anim Behav* 2005; 70(4): 889-894. <http://dx.doi.org/10.1016/j.anbehav.2005.01.020>
- Shariff M, Richards RH, Sommerville C. The histopathology of acute and chronic infections of rainbow trout *Salmo gairdneri* Richardson with eye flukes, *Diplostomum* spp. *J Fish Dis* 1980; 3(6): 455-465. <http://dx.doi.org/10.1111/j.1365-2761.1980.tb00432.x>
- Travassos L, Freitas T, Kohn A. Trematódeos do Brasil. *Mem Inst Oswaldo Cruz* 1969; 67(fasc. Único): 1-886.
- Violante-González J, García-Varela M, Rojas-Herrera A, Guerrero SG. Diplostomiasis in cultured and wild tilapia *Oreochromis niloticus* in Guerrero State, Mexico. *Parasitol Res* 2009; 105(3): 803-807. <http://dx.doi.org/10.1007/s00436-009-1458-1>
- Voutilainen A, Van Ooik T, Puurtinen M, Kortet R, Taskinen J. Relationship between prevalence of trematode parasite *Diplostomum* sp. and population density of its snail host *Lymnaea stagnalis* in lakes and ponds in Finland. *Aquat Ecol* 2009; 43(2): 351-357. <http://dx.doi.org/10.1007/s10452-008-9203-x>
- Yamada FH, Moreira LHA, Ceschini TL, Takemoto RM, Pavanelli GC. Novas ocorrências de metacercária de *Austrodiplostomum compactum* (Lutz, 1928) (Platyhelminthes: Digenea) parasito de olhos de peixes da bacia do rio Paraná. *Rev Bras Parasitol Vet* 2008; 17(3): 163-166. <http://dx.doi.org/10.1590/S1984-29612008000300010>
- Zago AC, Franceschini L, Zocoller-Seno MC, Veríssimo-Silveira R, Maia AAD, Ikefuti CV, et al. The helminth community of *Geophagus proximus* (Perciformes: Cichlidae) from a tributary of the Paraná River, Ilha Solteira Reservoir, São Paulo State, Brazil. *J Helminthol* 2013; 87(2): 203-211. <http://dx.doi.org/10.1017/S0022149X12000223>
- Zica EOP, Santos KR, Ramos IP, Zanatta AS, Carvalho ED, Silva RJ. First case of an infection of the metacercariae of *Austrodiplostomum compactum* (Lutz, 1928) (Digenea, Diplostomidae) in *Hypostomus regani* (Ihering, 1905) (Siluriformes: Loricariidae). *Panamias* 2009; 4(1): 35-38.
- Zica EOP, Wunderlich AC, Ramos IP, Silva RJ. *Austrodiplostomum compactum* (Lutz, 1928) (Digenea, Diplostomidae) infecting *Geophagus proximus* Castelnau, 1855 (Cichlidae, Perciformes) in the Tietê River, Nova Avanhandava reservoir, Municipality of Buritama, São Paulo State, Brazil. *Neotrop Helminthol* 2010; 4(1): 9-15.
- Zica EOP, Brandão H, Zawadzki CH, Nobile AB, Carvalho ED, Silva RJ. The occurrence of *Austrodiplostomum compactum* (Lutz, 1928) (Digenea: Diplostomidae) metacercariae in the eyes of loricariid fish (Siluriformes: Osteichthyes: Loricariidae) from Brazil. *J Helminthol* 2011; 85(1): 73-79. <http://dx.doi.org/10.1017/S0022149X10000271>