

Nematodes of *Astyanax fasciatus* (Actinopterygii: Characidae) and their parasitic indices in the São Francisco river, Brazil

Nematoides de *Astyanax fasciatus* (Actinopterygii: Characidae) e seus índices parasitários do rio São Francisco, Brasil

Flavia Guerra Vieira-Menezes¹; Danielle Priscilla Correia Costa¹; Marília Carvalho Brasil-Sato^{2*}

¹ Curso de Pós-graduação em Ciências Veterinárias, Universidade Federal Rural do Rio de Janeiro – UFRRJ, Seropédica, RJ, Brasil

² Departamento de Biologia Animal, Universidade Federal Rural do Rio de Janeiro – UFRRJ, Seropédica, RJ, Brasil

Received June 8, 2016

Accepted September 19, 2016

Abstract

The endoparasite fauna of *Astyanax fasciatus* from the upper São Francisco river was investigated and ecological parameters and morphological and morphometric data on the parasites are presented. A total of 74 specimens of banded astyanax were collected downstream from the Três Marias dam, municipality of Três Marias, Minas Gerais (18°12'32"S, 45°15'41"W) in January 2011 and January 2012. Eleven taxa of Nematoda were found: *Contracaecum* sp.; *Hysterothylacium* sp.; *Goezia* sp.; *Brevimulticaecum* sp.; *Procammallanus* sp.; *Procammallanus (Spirocammallanus) saofranciscensis*; *Cystidicoloides* sp.; *Spinitectus rodolphiheringi*; *Rhabdochona* sp.; *Spiroxys* sp.; and *Eustrongylides* sp.. The fauna of *A. fasciatus* consisted of by larval specimens of *Contracaecum* sp., *Hysterothylacium* sp., *Brevimulticaecum* sp., *Cystidicoloides* sp., and *Spiroxys* sp., and by adult specimens of *P. saofranciscensis*, whose prevalence was greater than 10%. Thus, this fish acts as an intermediate host of some species of larval nematodes especially, Anisakidae and Acanthocheilidae (*Brevimulticaecum* sp., new host record and new locality). It participates in transmitting species such *Rhabdochona* sp. to carnivorous fish and also acts as a definitive host for *P. saofranciscensis* and *S. rodolphiheringi* in the upper São Francisco river.

Keywords: Anisakidae, *Brevimulticaecum* sp., endoparasites, nematodes.

Resumo

A fauna endoparasitária de *Astyanax fasciatus* do alto rio São Francisco foi investigada e os parâmetros ecológicos e os dados morfométricos e morfológicos dos parasitos apresentados. Um total de 74 espécimes de lambaris foi coletado à jusante da barragem de Três Marias, município de Três Marias, Minas Gerais (18°12'32"S, 45°15'41"W), em janeiro de 2011 e de 2012. Onze táxons de Nematoda foram encontrados: *Contracaecum* sp., *Hysterothylacium* sp., *Goezia* sp., *Brevimulticaecum* sp., *Procammallanus* sp., *Procammallanus (Spirocammallanus) saofranciscensis*, *Cystidicoloides* sp., *Spinitectus rodolphiheringi*, *Rhabdochona* sp., *Spiroxys* sp. e *Eustrongylides* sp.. A fauna de *A. fasciatus* foi caracterizada por espécimes larvais de *Contracaecum* sp., *Hysterothylacium* sp., *Brevimulticaecum* sp., *Cystidicoloides* sp., *Spiroxys* sp. e por espécimes adultos de *P. saofranciscensis*, cuja prevalência foi maior que 10%. Assim, o lambari atua como hospedeiro intermediário de algumas espécies de nematoides larvais, especialmente, Anisakidae e Acanthocheilidae (*Brevimulticaecum* sp., novos hospedeiro e localidade); participa na transmissão de espécies como *Rhabdochona* sp., para peixes carnívoros, e atua também como hospedeiro definitivo para *P. saofranciscensis* e *S. rodolphiheringi* no alto Rio São Francisco.

Palavras-chave: Anisakidae, *Brevimulticaecum* sp., endoparasitos, nematoides.

Introduction

Astyanax fasciatus (Cuvier, 1819) is popularly known as the banded astyanax and it is an abundant species in several drainage basins in the Americas (FROESE & PAULY, 2013). It is classified as a foraging species, and it is well distributed along the São

Francisco river (BUCKUP et al., 2007), serving as an important food source for larger fish. Although banded astyanax do not have significant commercial value, they are often eaten as snacks, especially by the riverine population, and they are also used as bait for sport fishing (SANTOS et al., 1995).

Larval specimens of *Spiroxys* sp. were found in *A. fasciatus* in Mexico (MORAVEC, 1998). With regard to the same host species on the Nicaraguan coast, Aguirre-Macedo et al. (2001)

*Corresponding author: Marília Carvalho Brasil-Sato. Departamento de Biologia Animal, Universidade Federal Rural do Rio de Janeiro – UFRRJ, Rodovia BR 465, Km 7, CP 74539, CEP 23851-970, Seropédica, RJ, Brasil. e-mail: mcbsato@ufrjr.br

identified larvae of *Brevimulticaecum* sp., *Contraecaecum* sp. and *Spiroxys* sp. Subsequently, Salgado-Maldonado (2008) also discovered *Procamallanus neocaballeroi* (Caballero-Deloya, 1977) and *Procamallanus rebecca* (Andrade-Salas, Pineda-López, & García-Magaña, 1994) in Central America.

In the upper São Francisco river, Moreira et al. (1994) recorded occurrences of larvae of *Contraecaecum* sp. and described *Procamallanus saofranciscensis* (Moreira et al., 1994) in *A. fasciatus*. Brasil-Sato (2003) further listed occurrences of several species of adult parasitic nematodes in fish in the São Francisco river basin: *Cosmoxynema vianai* Travassos, 1948; *Cosmoxynemoides aguirrei* Travassos, 1948; *Cucullanus pinnai* Travassos, Artigas & Pereira, 1928; *Neocucullanus neocucullanus* Travassos, Artigas & Pereira, 1928; *Procamallanus freitasi* Moreira, Oliveira & Costa, 1991; *Procamallanus inopinatus* Travassos, Artigas & Pereira, 1928; *P. saofranciscensis*, *Rondonia rondoni* Travassos, 1920; *Travassosnema travassosi* Costa, Moreira & Oliveira, 1991; *Travnema araujo* Fernandes, Campos & Artigas, 1983; and *Travnema travnema* Pereira, 1928. Larval specimens of several nematode species were also listed by Brasil-Sato (*op. cit.*): *Contraecaecum* sp., *Cucullanus* sp., *Dichelyne* sp., *Eustrongylides* sp., *Goezia* sp., *Hysterothylacium* sp. and *Philometra* sp. In addition, Santos et al. (2009) identified larval specimens of *Spiroxys* sp. in three species of carnivorous fish: *Pygocentrus piraya* (Cuvier, 1819); *Serrasalmus brandtii* Lütken, 1875; and *Cichla kelberi* Kullander & Ferreira, 2006, in the Três Marias Reservoir. Finally, larval specimens of *Rhabdochona* sp. were found in *Conorhynchus conirostris* Valenciennes, 1840, by Brasil-Sato & Santos (2005).

The aims of this study were to investigate parasitism in *A. fasciatus* and contribute towards enriching knowledge of the ichthyoparasitology of the São Francisco river. Thus, it had the specific objectives of recording the species of parasitic nematodes of banded astyanax and also measuring their parasitic parameters (prevalence, mean intensity and mean abundance).

Materials and Methods

A total of 74 specimens of *A. fasciatus* were provided by technical staff of the regional development company CODEVASF in Três Marias, Minas Gerais, under authorization from the State Forestry Institute of Minas Gerais (IEF-MG). These fish were collected in the upper São Francisco river, located in the municipality of Três Marias, in the state of Minas Gerais (18°12'32"S, 45°15'41"W) in January 2011 and January 2012. The host necropsies and parasite processing procedures followed Eiras et al. (2006). The parasitological descriptors used were those prescribed by Bush et al. (1997). Nematode measurements are presented in millimeters. The measurement ranges are presented in the results tables, and these values are followed by the means and their respective standard deviations. Morphometry was ascertained using a Nikon Alphaphot-2 microscope with a calibrated reticle coupled to the ocular lens. Parasite voucher specimens were deposited in the Helminthological Collection of the Oswaldo Cruz Institute (CHIOC), state of Rio de Janeiro, Brazil. A numbering system was used, as indicated in the results (Table 1). The host voucher

specimen was deposited in the Fish of the Museum, University of São Paulo (MZUSP, 95161), state of São Paulo, Brazil.

Results and Discussion

The parasite fauna of *A. fasciatus* consisted of eleven nematode species, which are presented in Table 1 with their respective parasitic indices. Nine species were represented by larval specimens and had characterized *A. fasciatus* as a noteworthy intermediate host in their parasitic cycles. Five species (*Brevimulticaecum* sp., *Contraecaecum* sp., *Cystidicoloides* sp., *Hysterothylacium* sp. and *Spiroxys* sp.) out of these nine in the larval stage presented prevalence higher than 10%. Two nematode species were represented by adult specimens: *Spinitectus rodolphiheringi* Vaz & Pereira, 1934 and *P. saofranciscensis*. For these *A. fasciatus* was characterized as the definitive host. The prevalence of *P. saofranciscensis* was higher than 10%.

The results from the morphometric analysis, i.e. characterization of the peculiarities of nematode species identified in *A. fasciatus* in this study, are shown in Tables 2-5. Exceptionally, the data on *Goezia* sp. were based on a single specimen (n = 1; P = 1.35%) that was found in the stomach. Its measurements in millimeters (length × width) were as follows: body, 1.723 × 0.105; esophagus, 0.208 × 0.025; ventriculus, 0.028 × 0.025; nerve ring from the anterior extremity, 0.108; spines of the ventricular appendix region, 0.005; distance between the ring spines of the ventricular appendix region, 0.006; ventricular appendix, 0.743; cecum appendix, 0.088; and tail, 0.058. In the same region of Brazil, Santos-Clapp & Brasil-Sato (2014) also observed larvae of *Goezia* sp. in *C. kelberi*, showing low prevalence (1.8%). Four species have been described in Brazil: *G. spinulosa* in *Arapaima gigas* from Mexiana Island, Amazon river, state of Pará (SANTOS & MORAVEC, 2009) and from the Araguaia river, state of Mato Grosso do Sul (MENEZES et al., 2011); *Astronotus ocellatus*, *Micropterus salmoides* and *Pseudoplatystoma corruscans* from the Araguaia and Amazon rivers (Pará) (MORAVEC, 1998); *G. brasiliensis* in the characid *Brycon hilarii* and in *Pseudoplatystoma corruscans* from the Paraná river, Foz do Iguaçu and *G. breviceca* in *Brycon hilarii* from the Paraná river, Foz do Iguaçu (MORAVEC et al., 1994; MORAVEC, 1998); and *G. leporini* in *Leporinus macrocephalus* from Batatais, state of São Paulo (MARTINS & YOSHITOSHI, 2003).

Differing from our study, Santos & Moravec (2009) and Martins & Yoshitoshi (2003) found high prevalences of adults and larvae in the species *G. spinulosa* (90%) and *G. leporini* (65%), respectively. Massive presence of these species gives rise to attacks mainly on the stomach, causing gross lesions and high mortality among the fish.

With regard to *S. rodolphiheringi*, one male, one female, and one juvenile were found in *A. fasciatus*. Their measurements and features were in line with what was reported by Moravec (1998). In the São Francisco river, adult specimens of *S. rodolphiheringi* were found in *Franciscodoras marmoratus* (Reinhardt, 1874) (SANTOS & BRASIL-SATO, 2004). Thus, the presence of adult specimens of *S. rodolphiheringi* in *A. fasciatus* increases the list of known hosts in the São Francisco basin.

In this study, the features of *P. saofranciscensis* specimens in *A. fasciatus*, as well as their measurements, were equivalent to what

Table 1. Prevalence (%), mean intensity (MI), mean abundance (MA), and their respective standard deviations (SD), followed by amplitude (A), importance of values (IV), and site of infection for nematodes found in *Astyanax fasciatus* (Cuvier, 1819) of the upper São Francisco river, State of Minas Gerais, Brazil.

Nematode species	P(%)	MI ± SD	MA ± SD	A	IV	Site
Larval specimens						
Anisakidae						
<i>Contracaecum</i> sp. CHIOC n. 37853	58.11	5.70 ± 10.17	3.31 ± 8.22	1-57	Se	AC, E, F, AI, PI
<i>Goezia</i> sp.	1.35	1.00	0.01 ± 0.12	1	Sa	E
Rhaphydascaridae						
<i>Hysterothylacium</i> sp. CHIOC n. 37854	59.46	4.16 ± 3.89	2.47 ± 3.62	1-19	Se	AC, E, F, IC, AI, PI
Acanthocheilidae						
<i>Brevimulticaecum</i> sp. CHIOC n. 37851	10.81	1.88 ± 2.10	0.20 ± 0.88	1-7	Sa	AC, IC
Camallanidae						
<i>Procamallanus</i> sp.	1.35	3.00	0.04 ± 0.35	3	Sa	AC
Cystidicolidae						
<i>Cystidicoloides</i> sp. CHIOC n. 37852	12.16	1.22 ± 0.44	0.15 ± 0.43	1-2	Sa	AC, AI
<i>Spinitectus rodolphiheringi</i> *	1.35	1.00	0.01 ± 0.12	1	Sa	E
Rhabdochonidae						
<i>Rhabdochona</i> sp.**	5.41	8.75 ± 11.03	0.47 ± 2.99	1-25	Sa	AC, IC, AI
Gnathostomatidae						
<i>Spiroxys</i> sp. CHIOC n. 37860	22.97	3.59 ± 7.62	0.82 ± 3.88	1-33	Sa	AC, E, F, IC
Dioctophymatidae						
<i>Eustrongylides</i> sp.	1.35	1.00	0.01 ± 0.12	1	Sa	AC
Adult specimens						
<i>Procamallanus saofranciscensis</i> CHIOC n. 37857 (male) CHIOC n. 37858 (female)	21.62	1.06 ± 0.25	0.23 ± 0.45	1-2	Sa	IC, AI
<i>Spinitectus rodolphiheringi</i>	2.70	1.00	0.03 ± 0.16	1	Sa	E

Sa = satellite species; Se = secondary species; AC = abdominal cavity; E = stomach; F = liver; IC = intestinal cecum; AI = anterior intestine; PI = posterior intestine. Developmental stages: *juvenile; **larval and juvenile.

was presented by Moravec (1998). *Procamallanus saofranciscensis* was identified in fish of the families Characidae (VICENTE & PINTO, 1999) and Acestrorhynchidae (MOREIRA et al., 1994) in the upper São Francisco river. Larval specimens of *Procamallanus* sp., which had already been identified in this basin, have also been found in Characidae (VICENTE & PINTO, 1999) and Pimelodidae (BRASIL-SATO & SANTOS, 2005). Based on the presence of the larval specimens (*Procamallanus* sp.) and adults of *P. saofranciscensis* in *A. fasciatus*, it can be seen that this foraging fish takes part in the cycle of these species as intermediate and definitive hosts, respectively, and this enlarges the list of hosts for this nematode group in the São Francisco basin.

Larval specimens of *Cystidicoloides* sp. had already been found in *Leporinus friderici* (Bloch, 1794) in the upper Paraná river by Takemoto et al. (2009). Thus, *A. fasciatus* is a new host and enlarges the list of the known intermediate hosts of *Cystidicoloides* sp. in the São Francisco basin.

In this study, larval specimens of *Rhabdochona* sp. were also found in *A. fasciatus*. They had previously been found in *C. conirostris* by Brasil-Sato & Santos (2005). The results obtained in *A. fasciatus* in this study indicate that foraging fish play a role as

intermediate hosts for some species of *Rhabdochona* Railliet, 1916, thus enlarging the list of hosts in the upper São Francisco river.

Larval specimens of *Spiroxys* sp. were identified in *A. fasciatus* in Mexico (Moravec, 1998). In the upper São Francisco river, Santos et al. (2009) and Santos-Clapp & Brasil-Sato (2014) reported occurrences of these larvae in the carnivorous fish *Cichla kelberi* Kulander & Ferreira, 2006). In the present study, these larvae were also found in *A. fasciatus*, thus showing that this fish acts as an intermediate host for these parasites.

The occurrences of larval specimens of *Hysterothylacium* sp., *Eustrongylides* sp. and *Goezia* sp. in *A. fasciatus* enlarges the list of hosts in the São Francisco river, especially given that occurrences of these species had already been identified in several families of fish in the upper São Francisco river (BRASIL-SATO, 2003; SANTOS-CLAPP & BRASIL-SATO, 2014).

Larvae of *Brevimulticaecum* sp. were first described in fish by Moravec et al. (1997), but Bruce et al. (1994) asserted that fish rarely act as intermediate hosts for *Brevimulticaecum* sp. According to Moravec (1998), amphibians are intermediate hosts for *Brevimulticaecum* spp. and, as Bruce et al. (1994) stated, the most common definitive hosts are reptiles. In the Neotropical region

Table 2. Morphometry of the larval specimens of the *Contraecaecum* sp., *Hysterothylacium* sp., and *Brevimulticaecum* sp. in *Astyanax fasciatus* (Cuvier, 1819) of the upper São Francisco river, State of Minas Gerais, Brazil.

Character of nematodes	<i>Contraecaecum</i> sp. Larval specimens (n=10)			<i>Hysterothylacium</i> sp. Larval specimens (n=10)			<i>Brevimulticaecum</i> sp. Larval specimens (n=10)		
	X ± SD	Min.	Max.	X ± SD	Min.	Max.	X ± SD	Min.	Max.
Body ^L	3.520 ± 0.833	2.750	4.550	1.695 ± 0.114	1.568	1.833	3.563 ± 0.722	2.155	4.616
Body ^W	0.140 ± 0.038	0.093	0.197	0.062 ± 0.022	0.012	0.078	0.091 ± 0.019	0.050	0.118
Esophagus ^L	0.259 ± 0.041	0.201	0.309	0.167 ± 0.016	0.143	0.183	0.442 ± 0.088	0.303	0.550
Esophagus ^W	0.027 ± 0.013	0.015	0.042	*	*	*	0.018 ± 0.002	0.015	0.020
Ventriculus ^L	0.055 ± 0.018	0.041	0.083	0.026 ± 0.021	0.015	0.064	0.046 ± 0.007	0.035	0.053
Ventriculus ^W	0.023 ± 0.011	0.011	0.032	0.024 ± 0.003	0.020	0.028	0.036 ± 0.005	0.025	0.043
Ventricular appendix ^L	0.559 ± 0.120	0.367	0.682	0.821 ± 0.074	0.713	0.880	-	-	-
Ventricular appendix ^W	*	*	*	*	*	*	-	-	-
Nerve ring	0.182 ± 0.030	0.144	0.220	0.115 ± 0.010	0.105	0.125	0.124 ± 0.027	0.090	0.153
Excretory	*	*	*	0.111 ± 0.009	0.100	0.125	0.166 ± 0.014	0.143	0.185
Intestinal caecum ^L	0.314 ± 0.101	0.227	0.482	0.027 ± 0.001	0.025	0.028	0.215 ± 0.064	0.113	0.370
Intestinal caecum ^W	*	*	*	*	*	*	0.029 ± 0.006	0.018	0.038
Tail	0.102 ± 0.022	0.074	0.130	0.052 ± 0.003	0.048	0.055	0.089 ± 0.014	0.075	0.113
Tooth	*	*	*	*	*	*	0.004 ± 0.001	0.003	0.004

X = mean; SD = standard deviation; Min. and Max. = minimum and maximum values for the measurement. Characters: L = length; W = width; -lacks; *not measured.

Table 3. Morphometry of *Procamallanus saofranciscensis* Moreira, Oliveira & Costa, 1994 (male and female specimens) and *Procamallanus* sp. (larval specimens) in *Astyanax fasciatus* (Cuvier, 1819) of the upper São Francisco river, State of Minas Gerais, Brazil.

Character of nematodes	<i>Procamallanus saofranciscensis</i> Male specimens (n=10)			<i>Procamallanus saofranciscensis</i> Female specimens (n=7)			<i>Procamallanus</i> sp. Larval specimens (n=3)		
	X ± SD	Mín.	Máx.	X ± SD	Mín.	Máx.	sp. 1	sp. 2	sp. 3
Body ^L	4.410 ± 0.454	3.725	4.998	8.954 ± 3.132	6.250	14.975	1.653	1.260	1.490
Body ^W	0.221 ± 0.033	0.175	0.300	0.321 ± 0.057	0.250	0.425	0.049	0.033	0.045
Buccal Capsule ^L	0.074 ± 0.008	0.063	0.090	0.085 ± 0.026	0.035	0.108	0.048	0.040	0.040
Buccal Capsule ^W	0.074 ± 0.011	0.063	0.084	0.123 ± 0.020	0.103	0.155	0.033	0.150	0.015
Basal ring ^L	0.055 ± 0.008	0.045	0.070	0.078 ± 0.007	0.070	0.090	0.025	0.010	0.010
Basal ring ^W	0.008 ± 0.001	0.008	0.010	0.015 ± 0.001	0.013	0.015	0.008	*	0.013
Spiral number	13.8 ± 1.414	12	16	16 ± 1.155	14	18	*	-	-
Muscular esophagus ^L	0.324 ± 0.020	0.285	0.350	0.396 ± 0.046	0.350	0.468			
Muscular esophagus ^W	0.112 ± 0.013	0.098	0.140	0.139 ± 0.007	0.133	0.150	0.200*	0.138*	0.125*
Glandular esophagus ^L	0.502 ± 0.038	0.452	0.570	0.569 ± 0.045	0.530	0.638			
Glandular esophagus ^W	0.138 ± 0.020	0.098	0.173	0.166 ± 0.013	0.148	0.183			
Nerve ring ^A	0.191 ± 0.011	0.173	0.208	0.217 ± 0.028	0.178	0.248	*	*	*
Excretory pore ^A	0.258 ± 0.026	0.228	0.310	0.313 ± 0.050	0.243	0.390	*	*	*
Spicules ^{La}	0.103 ± 0.015	0.080	0.113	-	-	-	*	*	*
Spicules ^S	0.084 ± 0.017	0.063	0.071				*	*	*
Vulva ^B	-	-	-	3.748 ± 1.564	2.400	6.76	*	*	*
Tail	0.185 ± 0.018	0.155	0.215	0.177 ± 0.024	0.140	0.213	*	*	*

X = mean; SD = standard deviation; Min. and Max. = minimum and maximum values for the measurement. Characters: L = length; W = width; A = distance from the anterior end of body; B = distance from the posterior end of body; La = large; S = small; -lacks; *not measured; *undifferentiated esophagus.

(Peru, Venezuela, Nicaragua, Mexico, and Brazil), larvae have been found in the following fish species: *A. fasciatus*; *Gymnotus carapo* Linnaeus, 1758; *Gymnotus inaequilabiatus* (Valenciennes, 1839); *Loricariichthys brunneus* (Hancock, 1828); *Leporinus elongatus* Valenciennes, 1850; *Leporinus lacustris* Amaral Campos, 1945;

L. friderici, *Hemisorubim platyrhynchos* (Valenciennes, 1840); *Hoplias malabaricus* (Bloch, 1794); *Myleus levis* Eigenmann & McAtee, 1907; *Pseudoplatystoma corruscans* (Spix & Agassiz, 1829); *Pygocentrus nattereri* (Cuvier, 1819); *Serrasalmus marginatus* (Valenciennes, 1837); *Sorubim lima* (Bloch & Schneider, 1801);

Table 4. Morphometry of larval specimens of *Cystidicoloides* sp., *Rhabdochona* sp., and *Spiroxys* sp. in *Astyanax fasciatus* (Cuvier, 1819) of the upper São Francisco river, State of Minas Gerais, Brazil.

Character of nematodes	<i>Cystidicoloides</i> sp. Larval specimens (n=10)			<i>Rhabdochona</i> sp. Larval specimens (n=10)			<i>Spiroxys</i> sp. Larval specimens (n=11)		
	X ± SD	Mín.	Máx.	X ± SD	Mín.	Máx.	X ± SD	Mín.	Máx.
Body ^L	4.615 ± 0.579	3.785	5.704	3.409 ± 1.601	1.646	7.164	2.145 ± 0.402	1.725	2.871
Body ^W	0.104 ± 0.027	0.056	0.127	0.078 ± 0.027	0.044	0.127	0.056 ± 0.008	0.043	0.069
Vestibule ^L	0.097 ± 0.015	0.075	0.125	*	*	*	-	-	-
Vestibule ^W	0.004 ± 0.001	0.004	0.005	*	*	*	-	-	-
Prostom	-	-	-	0.022 ± 0.005	0.015	0.030	-	-	-
Vestibule Including prostom	-	-	-	0.087 ± 0.012	0.065	0.103	-	-	-
Pseudolabia	0.008 ± 0.002	0.005	0.010	-	-	-	0.019 ± 0.001	0.018	0.021
Deirids	-	-	-	0.039 ± 0.006	0.034	0.045	0.325 ± 0.030	0.288	0.365
Muscular esophagus ^L	0.214 ± 0.092	0.148	0.380	0.218 ± 0.066	0.138	0.323	0.115 ± 0.026	0.080	0.150
Muscular esophagus ^W	0.223 ± 0.006	0.015	0.038	*	*	*	0.021 ± 0.004	0.015	0.025
Glandular esophagus ^L	1.601 ± 0.417	1.003	2.208	1.212 ± 0.451	0.480	2.080	0.599 ± 0.168	0.212	0.818
Glandular esophagus ^W	0.055 ± 0.020	0.023	0.083	*	*	*	0.046 ± 0.007	0.037	0.058
Nerve ring ^A	0.158 ± 0.010	0.144	0.168	0.132 ± 0.013	0.110	0.150	0.175*	-	-
Excretory pore ^A	0.229 ± 0.054	0.162	0.285	1.157 ± 0.040	0.095	0.200	0.200 ± 0.016	0.175	0.228
Vulva ^B	-	-	-	-	3.100 ¹ _n	-	-	-	-
Tail	0.096 ± 0.014	0.075	0.115	1.139 ± 0.035	0.093	0.185	0.084 ± 0.014	0.063	0.118

Characters: L = length; W = width; A = distance from the anterior end of body; B = distance from the posterior end of body; -lacks; *not measured; *measured near prostom; ¹n = 1.

Table 5. Morphometry of *Spinitectus rodolphiberingi* Vaz & Pereira, 1934 (male, female, and juvenile specimens) in *Astyanax fasciatus* (Cuvier, 1819) of the upper São Francisco river, State of Minas Gerais, Brazil.

Character of nematodes	<i>Spinitectus rodolphiberingi</i> male (n=1)	<i>Spinitectus rodolphiberingi</i> female (n=1)	<i>Spinitectus rodolphiberingi</i> female juvenile (n=1)
Body ^L	2.450	4.400	1.940
Body ^W	0.069	0.235	0.137
Spine of anterior region	0.008	0.008	0.008
Spine of posterior region	0.004	0.004	0.004
First ring of spines	0.043	0.081	0.053
Vestibule	0.034	0.040	0.035
Muscular esophagus ^L	0.150	0.235	0.110
Muscular esophagus ^W	*	*	*
Glandular esophagus ^L	0.688	1.043	0.680
Glandular esophagus ^W	*	*	*
Nerve ring ^A	0.158	*	*
Excretory pore ^A	*	0.188	0.120
Spicules ^{La}	0.093	-	-
Spicules ^S	0.060	-	-
Vulva ^B	-	0.740	0.295
Eggs oval ^L	-	0.037	-
Eggs oval ^W	-	0.023	-
Tail	0.075	*	0.060

Characters: L = length; W = width; A = distance from the anterior end of body; B = distance from the posterior end of body; La = large; S = small; -lacks; *not measured.

and *Rhamdia guatemalensis* (Günther, 1864) (MORAVEC, 1998; AGUIRRE-MACEDO et al., 2001; VIEIRA et al., 2010). Adult specimens of *Brevimulticaecum regoi* Sprent, 1990, were found in the rays *Potamotrygon motoro* (Müller & Henle, 1841) and *Potamotrygon castexi* Castello & Yagolkowski, 1969, in southeastern Peru (REYDA, 2008). The present study provides the first record of *Brevimulticaecum* sp. larvae parasitizing *A. fasciatus*, and this occurrence widens their known geographical distribution in the Neotropical region for the São Francisco river basin. The minimum and maximum values for the measurements on ten larval specimens of *Brevimulticaecum* sp., followed by their means and standard deviations, are presented in Table 2.

Conclusion

This study highlights occurrences of and quantitative data on eleven species of parasitic nematodes of *A. fasciatus* in the São Francisco river. The most prevalent species characterizing the nematodes fauna of *A. fasciatus* were, in larval form, *Hysterothylacium* sp. and *Contracaecum* sp., followed by *Spiroxyis* sp., *Cystidicoloides* sp., and *Brevimulticaecum* sp; and, in adult form, *P. saofranciscensis*. Except for *Contracaecum* sp. and *P. saofranciscensis*, *A. fasciatus* represents a new host for these nematode species. These results aid in elucidating the biodiversity of parasites in fish in the Neotropical region; they also add to research projects under development in the São Francisco basin.

Acknowledgements

The authors wish to thank Dr Yoshimi Sato and Dr Edson Sampaio, researchers at the Hydrobiology and Fish-farming Station of CODEVASF, in Três Marias, Minas Gerais, for their assistance throughout the research process. The authors also wish to acknowledge the CEMIG/CODEVASF agreement that provided appropriate facilities for producing this article. "The first author was granted a fellowship by the Brazilian National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico, CNPq)".

References

- Aguirre-Macedo ML, Scholz T, Gozález-Solís D, Vidal-Martínez VM, Posel P, Arjona-Torres G, et al. Larval helminths parasitizing freshwater fishes from the Atlantic coast of Nicaragua. *Comp Parasitol* 2001; 68(1): 42-51.
- Brasil-Sato MC. Parasitos de peixes da bacia do São Francisco. In: Godinho HP, Godinho AL. *Águas, peixes e pescadores do São Francisco das Minas Gerais*. Belo Horizonte: PUC Minas; 2003. p. 149-165.
- Brasil-Sato MC, Santos MD. Metazoan parasites of *Conorhynchos conirostris* (Valenciennes, 1840), an endemic siluriform fish of the São Francisco Basin, Brazil. *Rev Bras Parasitol Vet* 2005; 14(4): 160-166. PMID:16445873.
- Bruce NL, Adlard RD, Cannon LRG. Synoptic checklist of ascaridoid parasites (Nematoda) from fish hosts. *Invertebr Taxon* 1994; 8(3): 583-674. <http://dx.doi.org/10.1071/IT9940583>.
- Buckup PA, Menezes NA, Ghazzi MS. *Catálogo das espécies de água doce do Brasil*. Rio de Janeiro: Museu Nacional; 2007.
- 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>.
- Eiras JC, Takemoto RM, Pavanelli GC. *Métodos de estudo e técnicas laboratoriais em parasitologia de peixes*. 2. ed. Maringá: Eduem; 2006.
- Froese R, Pauly D, editors. *FishBase. World Wide Web electronic publication* [online]. 2013 [cited 2013 Jan 8]. Available from: <http://www.fishbase.org>
- Martins ML, Yoshitoshi ER. A new nematode species *Goezia leporini* n. sp. (Anisakidae) from cultured freshwater fish *Leporinus macrocephalus* (Anostomidae) in Brazil. *Braz J Biol* 2003; 63(3): 497-506. PMID:14758709. <http://dx.doi.org/10.1590/S1519-69842003000300016>.
- Menezes RC, Santos SMC, Ceccarelli PS, Tavares LER, Tortelly R, Luque JL. Tissue alterations in the pirarucu, *Arapaima gigas*, infected by *Goezia spinulosa* (Nematoda). *Rev Bras Parasitol Vet* 2011; 20(3): 207-209. PMID:21961749. <http://dx.doi.org/10.1590/S1984-29612011000300005>.
- Moravec F, Kohn A, Fernandes BMM. Two new species of the genus *Goezia*, *G. brasiliensis* sp. n. and *G. brevicocca* sp. n. (Nematoda: Anisakidae), from freshwater fishes in Brazil. *Folia Parasitol (Praha)* 1994; 41(4): 271-278. PMID:7883259.
- Moravec F, Prouza A, Royero R. Some nematodes of freshwater fishes in Venezuela. *Folia Parasitol (Praha)* 1997; 44(1): 33-47. PMID:9188173.
- Moravec F. *Nematodes of freshwater fishes of the Neotropical Region*. Praha: Academia; 1998.
- Moreira NIB, Oliveira CL, Costa HMA. *Spirocamallanus inopinatus* (Travasso, Artigas & Pereira, 1928) e *Spirocamallanus saofranciscensis* sp. n. (Nematoda, Camallanidae) em peixes da represa de Três Marias. *Arg Bras Med Vet Zootec* 1994; 46(5): 485-500.
- Reyda FB. Intestinal helminths of freshwater stingrays in southeastern Peru, and a new genus and two new species of cestode. *J Parasitol* 2008; 94(3): 684-699. PMID:18605776. <http://dx.doi.org/10.1645/GE-1230.1>.
- Salgado-Maldonado G. Helminth parasites of freshwater fishes from Central America. *Zootaxa* 2008; 1915: 29-53.
- Santos CP, Moravec F. *Goezia spinulosa* (Nematoda: Raphidascarididae), a pathogenic parasite of the arapaima *Arapaima gigas* (Osteichthyes). *Folia Parasitol (Praha)* 2009; 56(1): 55-63. PMID:19391331. <http://dx.doi.org/10.14411/fp.2009.009>.
- Santos MD, Albuquerque MC, Monteiro CM, Martins NA, Ederli NB, Brasil-Sato MC. First report of larval *Spiroxyis* sp. (Nematoda, Gnathostomatidae) in three species of carnivorous fish from Três Marias Reservoir, São Francisco River, Brazil. *Panam J Aquat Sci* 2009; 4(3): 306-311.
- Santos MD, Brasil-Sato MC. Parasitos metazoários de *Franciscodoras marmoratus* (Reinhardt, 1874), "serrudo" (Siluriformes: Doradidae) do rio São Francisco, Brasil. *Rev Bras Parasitol Vet* 2004; 13(1): 18-22.
- Santos RA, Giamas MTD, Campos EC, Camara JJC, Vermulm H Jr. Dinâmica da nutrição do Tambiú *Astyanax bimaculatus* Linnaeus, 1758 (Pisces, Characiformes, Characidae), na Represa de Ibitinga, Estado de São Paulo, Brasil. *Bol Inst Pesca* 1995; 22(1): 115-124.
- Santos-Clapp MD, Brasil-Sato MC. Parasite community of *Cichla kelberi* (Perciformes, Cichlidae) in the Três Marias reservoir, Minas Gerais, Brazil. *Rev Bras Parasitol Vet* 2014; 23(3): 367-374. PMID:25271458. <http://dx.doi.org/10.1590/S1984-29612014059>.
- Takemoto RM, Pavanelli GC, Lizama MAP, Lacerda ACF, Yamada FH, Moreira LHA, et al. Diversity of parasites of fish from the Upper

Paraná River floodplain, Brazil. *Braz J Biol* 2009;69(S2 Suppl): 691-705. PMID:19738975. <http://dx.doi.org/10.1590/S1519-69842009000300023>.

Vicente JJ, Pinto RM. Nematóides do Brasil. Nematóides de peixes. Atualização: 1985-1998. *Rev Bras Zool* 1999; 16(3): 561-610. <http://dx.doi.org/10.1590/S0101-81751999000300001>.

Vieira KRI, Vicentin W, Paiva F, Pozo CF, Borges FA, Adriano EA, et al. *Brevimulticaecum* sp. (Nematoda: Heterocheilidae) larvae parasitic in freshwater fish in the Pantanal wetland, Brazil. *Vet Parasitol* 2010; 172(3-4): 350-354. PMID:20684864. <http://dx.doi.org/10.1016/j.vetpar.2010.05.003>.