

Endoparasites of two species of forage fish from the Três Marias reservoir, Brazil: new host records and ecological indices*

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ABSTRACT. de Albuquerque M.C., dos Santos-Clapp M.D. & Brasil-Sato M. de C. **Endoparasites of two species of forage fish from the Três Marias reservoir, Brazil: new host records and ecological indices.** [Endoparasitos de duas espécies de peixes forrageiros do reservatório de Três Marias, Brasil: novos registros de hospedeiros e seus índices ecológicos.] *Revista Brasileira de Medicina Veterinária*, 38(supl. 3):139-145, 2016. Programa de Pós-Graduação em Ciências Veterinárias, Anexo 1, Instituto de Veterinária, Universidade Federal Rural do Rio de Janeiro, BR 465, km 7, *Campus Seropédica*, RJ, Brasil, 23897-970. E-mail: marciabiologia@hotmail.com

Tetragonopterus chalceus and *Triportheus guentheri* are important forage fish from the Três Marias reservoir, which is located on the upper São Francisco river, State of Minas Gerais, Brazil. Here, their endoparasitic fauna was investigated for the first time. These two fish species have similar diets, despite different foraging strategies. This similarity is reflected in the findings regarding their parasite communities, which indicate overlapping of niches between these species. The qualitative similarity between the two parasite communities was evident (Jaccard index = 0.78), however the quantitative similarity was slight (Sorenson index = 0.28). The community of *T. chalceus* was richer but less diverse (13 species; $H' = 0.43$) than that of *T. guentheri* (12 species; $H' = 0.86$). Both fish species were found to be parasitized by plerocercoids of Proteocephalidea (Eucestoda); larvae of *Contracaecum* sp., *Hysterothylacium* sp., *Goezia* sp., *Procamallanus* (*Spirocamallanus*) sp., *Spiroxys* sp., *Rhabdochona* sp. and *Cystidicoloides fischeri*; adult specimens of *Procamallanus* (*Spirocamallanus*) *saofranciscencis* (Nematoda); spores of *Henneguya* sp. (Myxozoa); and oocysts of *Calyptospora* sp. (Apicomplexa). In addition to these, *Creptotrema creptotrema* (Digenea) and *Spinitectus rodolphiheringi* (Nematoda) were also present in *T. chalceus*; and larvae of *Procamallanus* (*Spirocamallanus*) sp. (Nematoda) were found in *T. guentheri*. *Procamallanus saofranciscencis* and plerocercoids of Proteocephalidea were the parasites with highest prevalence and highest mean abundance, respectively, in the community of *T. chalceus*. Larvae of *Rhabdochona* sp. had the highest prevalence and mean abundance in the parasite community of *T. guentheri*. *Tetragonopterus chalceus* and *T. guentheri* constituted new hosts for plerocercoids of Proteocephalidea, larvae of the nematodes *Goezia* sp., *Spiroxys* sp. and *C. fischeri* and spores of *Henneguya* sp.; *T. chalceus* was a new host for *S. rodolphiheringi*; and *T. guentheri* was a new host for larvae of *Hysterothylacium* sp.

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RESUMO. *Tetragonopterus chalceus* e *Triporthus guentheri*, importantes peixes forrageiros do reservatório de Três Marias, alto rio São Francisco, MG, Brasil, tiveram suas faunas endoparasitárias investigadas pela primeira vez. O consumo de itens alimentares em comum (dietas semelhantes) e estratégias distintas de forrageamento dos hospedeiros refletiram nos resultados de suas comunidades parasitárias que indicaram sobreposição de nichos entre os peixes. Houve destacável similaridade qualitativa (Jaccard index = 0,78) e discreta similaridade quantitativa (Sorenson index = 0,28) entre as duas comunidades parasitárias, sendo a comunidade de *T. chalceus* mais rica e menos diversa (13 espécies, $H' = 0,43$) do que a de *T. guentheri* (12 espécies, $H' = 0,86$). As duas espécies de peixes estavam parasitadas por plerocercoides de Proteocephalidea (Eucestoda), larvas de *Contracaecum* sp., *Hysterothylacium* sp., *Goezia* sp., *Procamallanus* (*Spirocamallanus*) sp., *Spiroxys* sp., *Rhabdochona* sp., *Cystidicoloides fischeri* e espécimes adultos de *Procamallanus* (*Spirocamallanus*) *saofranciscencis* (Nematoda), esporos de *Henneguya* sp. (Myxozoa), e oocistos de *Calyptospora* sp. (Apicomplexa). Além dessas espécies, em *T. chalceus* foram encontradas *Creptotrema creptotrema* (Digenea) e *Spinictectus rodolphiheringi* (Nematoda); e em *T. guentheri* foram encontradas larvas de *Procamallanus* (*Spirocamallanus*) sp. (Nematoda). *Procamallanus saofranciscencis* e os plerocercoides de Proteocephalidea foram os parasitos de maior prevalência e abundância média, respectivamente, na comunidade de *T. chalceus*; as larvas de *Rhabdochona* sp. tiveram a prevalência e a abundância média mais elevadas na comunidade parasitária de *T. guentheri*. *Tetragonopterus chalceus* e *T. guentheri* constituem novos hospedeiros dos plerocercoides de Proteocephalidea, dos nematoides larvais *Goezia* sp., *Spiroxys* sp. e *C. fischeri* e dos esporos de *Henneguya* sp.; *T. chalceus* constitui novo hospedeiro de *S. rodolphiheringi*, e *T. guentheri* novo hospedeiro de larvas de *Hysterothylacium* sp.

PALAVRAS-CHAVE. Comportamento, biodiversidade, peixes de água doce.

INTRODUCTION

The hydrographic basin of the São Francisco River has unquestionable importance for Brazil because it provides water for the semi-arid region,

has economic potential and has made a historical contribution to the entire country (Brasil 2006). The Três Marias reservoir, located in the upper third of this basin (Britski et al. 1988), is a priority area for biodiversity conservation (Costa et al. 1998) and was the location for collecting fish for the present study.

Over recent years, knowledge of the endoparasite fauna of fish in the São Francisco basin has increased (Brasil-Sato 2003). For most of these species of fish parasites, it was the first time that they had been recorded (Santos et al. 2009, Albuquerque & Brasil-Sato 2010, Eiras et al. 2010, Monteiro et al. 2010, Monteiro & Brasil-Sato 2014a, b, Marques et al. 2015, Monteiro et al. 2015). To further expand this knowledge, the endoparasite fauna of two species of fish, *Tetragonopterus chalceus* Spix and Agassiz, 1829 (Characiformes, Characidae) and *Triporthus guentheri* (Garman, 1890) (Characiformes, Triporthidae), were investigated in the present study.

Tetragonopterus chalceus occurs in the Amazon, Orinoco and São Francisco river basins (Reis et al. 2003). For *T. guentheri*, the São Francisco river is its type locality and its only known distribution (Reis et al. 2003, Malabarba 2004).

The only records of parasites of these two fish species in Brazil are from the Três Marias reservoir. Moreira et al. (1994) recorded larvae of *Heterotyphlum* sp. in *T. chalceus* (= larvae of *Hysterothylacium* sp., according to Brasil-Sato & Santos 2005); adults of *Procamallanus* (*Spirocamallanus*) *saofranciscencis* Moreira, Oliveira and Costa, 1994, and larvae of *Contracaecum* sp. in *T. chalceus* and *T. guentheri*; and larvae of *Procamallanus* (*Spirocamallanus*) sp. in *T. guentheri*. Albuquerque & Brasil-Sato (2009) recorded *Creptotrema creptotrema* Travassos, Artigas and Pereira, 1928, in *T. chalceus*. Albuquerque & Brasil-Sato (2010) reported the presence of oocysts of *Calyptospora* sp. (Apicomplexa) in *T. chalceus* and *T. guentheri*. Costa et al. (2011) cited the occurrence of *Rhabdochona* sp. larvae in *T. chalceus* and *T. guentheri*.

There have also been reports of parasites of *Triporthus* spp., from different basins (Agarwal & Kritsky 1998, Iannaccone et al. 2000, Kohn et al. 2007, Santos et al. 2008, Abdallah et al. 2012, Costa-Pereira et al. 2014, Oliveira et al. 2016).

In addition to contributing towards knowledge of parasite diversity among fish in the São Francisco river basin, the present study had the aim of providing and comparing ecological data on the component species of two endoparasitic communities.

MATERIALS AND METHODS

The fish specimens were collected from the Três Marias reservoir (18°12'59" S 45°17'34" W), upper São Francisco river in the State of Minas Gerais, Brazil. The fish were caught with the aid of gillnets that had been placed the night before by fishermen of the "Estação de Hidrobiologia e Piscicultura" of the "Companhia de Desenvolvimento dos Vales do São Francisco e do Parnaíba" (EPT/CODEVASF). Samples were collected in July 2007 (dry period) and in January 2008 (wet period).

The parasite specimens were collected, fixed and processed for identification in accordance with methodologies that are used for studies on fish parasites. Parasite identification and classification was done in accordance with the specific literature.

Voucher specimens of *T. chalceus* (MZUSP 95151) and *T. guentheri* (MZUSP 95152) were deposited in the "Museu de Zoologia" of the "Universidade de São Paulo" (MZUSP), São Paulo, Brazil. Voucher specimens of helminths were deposited in the "Coleção Helminológica" of the "Instituto Oswaldo Cruz" (CHIOC) in the State of Rio de Janeiro, Brazil, and the deposit numbers of the parasites are presented in tables as results.

In the present study, the term "parasite community" and the parasite indexes [prevalence (P), mean intensity (MI) and mean abundance (MA)] are used in accordance with Bush et al. (1997). The parasite species were classified within the community according to their importance value (IV) (Bush & Holmes 1986).

The endoparasitic communities were characterized in terms of species richness, which relates to the number of species found; and Shannon-Wiener parasite diversity (H'), which is based on the proportional abundance of species (heterogeneity index) in random samples. The similarity coefficients that were used to compare diversity in the two hosts studied were the Jaccard index (qualitative evaluation) and Sorenson index (quantitative evaluation) (Magurran 1988).

The DivEs software was used to calculate the mean parasite abundance, mean parasite intensity and Shannon-Wiener parasite diversity (Rodrigues 2005).

RESULTS

A total of 146 fish specimens were examined [*T. chalceus*: total collected (n) = 63; total length (TL): 9.5 ± 0.9 cm (7.4 to 11.5 cm); body weight (BW): 16.8 ± 5.6 g (8.0 to 34.0 g); *T. guentheri*: n = 83, TL: 13.8 ± 1.2 cm (10.5 to 17.2 cm), BW: 33.4 ± 8.2 g (14.0 to 48.1 g)].

Component parasite community *Tetragonopterus chalceus*

A total of 3147 specimens of endoparasites were collected from the 63 *T. chalceus* specimens examined. Out of this total, 3045 (96.7%) were helminths, two (0.1%) were myxozoans and 100 (3.2%) were protozoans. Among the metazoan helminths, there

were 373 adult specimens (12.2%) and 2672 larvae (87.7%). All the fish were parasitized with at least one parasite specimen.

The endoparasite species were distributed into five taxonomic groups: Digenea: adults of *C. creptotrema*; Eucestoda: plerocercoids of Proteocephalidea; Nematoda: adults of *P. (Spirocamallanus) saofranciscensis* and *Spinitectus rodolphiheringi* Vaz & Pereira, 1934; larvae of *Contracaecum* sp., *Hysterothylacium* sp., *Goezia* sp., *Procamallanus (Spirocamallanus)* sp., *Spiroxys* sp., *Rhabdochona* sp. and *Cystidicoloides fischeri* (Travassos, Artigas & Pereira, 1928); Myxozoa: *Henneguya* sp.; and Protozoa (Apicomplexa): *Calyptospora* sp. (Table 1).

The parasites that presented prevalence greater than 10% were: *P. saofranciscensis* (82.5%), plerocercoids of Proteocephalidea (60.3%), *C. creptotrema* (46.0%), *Hysterothylacium* sp. (34.90%), *Spiroxys* sp. (30.2%) and *Contracaecum* sp. (17.5%). The parasites that presented lowest prevalence were, respectively, *C. fischeri* (9.5%), *Rhabdochona* sp. (7.9%), *Calyptospora* sp. (6.3%), *Procamallanus* sp. (3.2%), *Henneguya* sp. (3.2%), *S. rodolphiheringi* (1.6%) and *Goezia* sp. (1.6%).

The classification according to importance value indicated that there was one central species (*P. saofranciscensis*), three secondary species (*C. creptotrema*, plerocercoids and *Hysterothylacium* sp.) and nine other satellite species.

The prevalence, mean intensity, mean abundance, amplitude of intensity of infection, importance value, infection site and deposit number of the parasites can be seen in Table 1.

Triporthus guentheri

In the 83 specimens of *T. guentheri* analyzed, 1095 specimens of endoparasites were found. Among these, 964 (88.0%) were helminths, 11 (1.0%) were myxozoans and 120 (10.9%) were protozoans. Among the helminths, there were eight adults (0.8%) and 956 larvae (99.2%). In total, 90.0% of the fish were parasitized by at least one parasite specimen.

The parasites recorded were: Eucestoda: plerocercoids of Proteocephalidea; Nematoda: adults of *P. saofranciscensis* and larvae of *Contracaecum* sp., *Hysterothylacium* sp., *Goezia* sp., *Procamallanus* sp., *Procamallanus (Spirocamallanus)* sp., *Spiroxys* sp., *Rhabdochona* sp. and *C. fischeri*; Myxozoa: spores of *Henneguya* sp.; and Protozoa (Apicomplexa): oocysts of *Calyptospora* sp.

Eight species presented prevalence greater than 10%: *Rhabdochona* sp. (43.4%), *Hysterothylacium* sp.

(39.8%), *C. fischeri* (27.7%), *Spiroxys* sp. (26.5%), *Contraecaecum* sp. (22.9%), *Procammallanus* (S.) sp. (16.9%), *Procammallanus* sp. (15.7%) and *Henneguya* sp. (10.8%). The other four species presented prevalences of between 1.2% and 8.4%.

In this community, there were two secondary species (*Hysterothylacium* sp. and *Rhabdochona* sp.) and all the others were satellite species.

The prevalence, mean intensity, mean abundance, amplitude of intensity of infection, importance value, infection site and deposit number of the parasites can be seen in Table 2.

Diversity and similarity

The Shannon-Wiener diversity values for the communities in *T. chalceus* and *T. guentheri* were $H' = 0.43$ and $H' = 0.86$, respectively. The richness of these endoparasite communities was 13 and 12 species, respectively.

The Jaccard qualitative similarity between the two parasite communities was 0.78 and the Sorenson quantitative similarity was 0.28.

DISCUSSION

Studies on parasite fauna provide data on host behavior and habitats (Moser 1991). The presence

and quantities of given parasite species in their hosts provide clues regarding the structure of the food chain and the hosts' food preferences and foraging strategies (Price 1990).

Gomes & Verani (2003) studied the diet of *T. chalceus* and *T. guentheri* in the Três Marias reservoir and noted that insects were their preferred food. The parasitological data presented here confirm this information, considering that parasites provide an indication of diet over a longer period of time (Williams et al. 1992). High prevalences of nematode larvae were recorded in both fish of this study and these parasites are carried by aquatic insects, through the food web. Ephemeroptera, which form an important part of the diet of *T. chalceus* and *T. guentheri*, are the first intermediate hosts of nematodes (Gomes & Verani 2003). These fish become infected with the second or third larval stage of these helminths. The larvae generally become established in the celom, but they may also be found in other parts of fish, such as the intestine and stomach (Moravec 1998), as was seen in the present study.

The endoparasitic community of *T. chalceus* was richer than that of *T. guentheri*, but there was evident similarity regarding the parasite species accu-

Table 1. Prevalence (P%), mean intensity (MI), mean abundance (MA) with the corresponding standard deviation (SD), deposit number in the Helminthological Collection of the Oswaldo Cruz Institute (CHIOC); infection intensity amplitude (IA); importance value (IV); Ce = central; Se = secondary; Sa = satellite; and sites of infection (SI): C = celom; IC = intestinal cecum; S = stomach; L = liver; I = intestine; K = kidney of the endoparasites of *Tetragonopterus chalceus* Spix and Agassiz 1829 in the Três Marias reservoir, upper São Francisco river, State of Minas Gerais, Brazil.

Parasite	P (%)	MI ± SD	MA ± SD	IA	IV	SI
Digenea Adults <i>Creptotrema creptotrema</i> CHIOC 36995, 35584	46.0	8.60 ± 9.55	3.90 ± 7.76	1-43	Se	C, I
Eucestoda Larvae <i>Plerocercoids of Proteocephalidea</i> CHIOC 35569	60.3	63.10 ± 39.25	38.10 ± 43.39	5-100	Se	C, L, I
Nematoda Adults <i>Procammallanus (Spirocamallanus) saofranciscensis</i> CHIOC 35578	82.5	2.40 ± 2.24	2.00 ± 2.30	1-8	Ce	IC, I
Larvae <i>Spinitectus rodolphiheringi</i> <i>Contraecaecum</i> sp. CHIOC 35575	1.6	1.00	0.02 ± 0.13	1	Sa	I
<i>Hysterothylacium</i> sp. CHIOC 35576	17.5	5.50 ± 7.17	1.00 ± 3.64	1-20	Sa	C, S, I
<i>Goezia</i> sp. <i>Procammallanus (Spirocamallanus)</i> sp. CHIOC 35577	34.9	6.30 ± 6.26	2.20 ± 4.76	1-20	Se	C, S, I
<i>Spiroxys</i> sp. CHIOC 35580	1.6	1.00	0.02 ± 0.13	1	Sa	S
<i>Rhabdochona</i> sp. CHIOC 35581	3.2	2.00 ± 1.00	0.06 ± 0.39	1-3	Sa	I, S
<i>Cystidicoloides fischeri</i> CHIOC 35579	30.2	2.00 ± 1.26	0.60 ± 1.15	1-6	Sa	C, IC, S, I
<i>Henneguya</i> sp. Spores	7.9	5.40 ± 5.46	0.40 ± 2.12	1-16	Sa	S, I
Apicomplexa Oocysts <i>Calyptospora</i> sp.	9.5	1.00	0.10 ± 0.29	1	Sa	I, S
	3.2	1.00	0.03 ± 0.18	1	Sa	K
	6.3	25.00	1.60 ± 6.10	25	Sa	L, I

Table 2. Prevalence (P%); mean intensity (MI); mean abundance (MA) with the corresponding standard deviation (SD); deposit number in the Helminthological Collection of the Oswaldo Cruz Institute (CHIOC); infection intensity amplitude (IA); importance value (IV); Ce = central; Se = secondary; Sa = satellite; and sites of infection (SI): C = celom; IC = intestinal cecum; S = stomach; L = liver; I = intestine; K = kidney of the endoparasites of *Triporthesus guentheri* (Garman 1890) in the Três Marias reservoir, upper São Francisco river, State of Minas Gerais, Brazil.

Parasite		P (%)	MI ± SD	MA ± SD	IA	IV	SI
Eucestoda	<i>Plerocercoids of Proteocephalidea</i>	7.2	38.20 ± 43.87	2.80 ± 15.39	2–100	Sa	C, I
Larvae	CHIOC 35569						
Nematoda	<i>Procamallanus (Spirocamallanus)</i>	8.4	1.40 ± 0.35	0.10 ± 0.33	1–2	Sa	S, I
Adults	<i>saofranciscensis</i>						
	CHIOC 35578						
Larvae	<i>Contractaecum</i> sp.	22.9	2.20 ± 2.00	0.50 ± 1.33	1–10	Sa	C, IC, S
	CHIOC 35575						
	<i>Hysterothylacium</i> sp.	39.8	5.80 ± 8.84	2.30 ± 6.35	1–35	Se	C, IC, S, I
	CHIOC 35576						
	<i>Goezia</i> sp.	1.2	1.00	0.01 ± 0.11	1	Sa	C
	<i>Procamallanus</i> sp.	15.7	3.00 ± 3.11	0.50 ± 1.65	1–12	Sa	IC, I
	CHIOC 35577						
	<i>Procamallanus (Spirocamallanus)</i> sp.	16.9	3.30 ± 3.40	0.60 ± 1.86	1–12	Sa	C, IC, S
	<i>Spiroxys</i> sp.						
	CHIOC 35580	26.5	2.50 ± 3.63	0.70 ± 2.16	1–18	Sa	C, IC, S
	<i>Rhabdochona</i> sp.						
	CHIOC 35581	43.4	8.50 ± 11.81	3.70 ± 8.85	1–57	Se	C, S, IC, I
	<i>Cystidicoloides fischeri</i>						
	CHIOC 35579	27.7	2.00 ± 1.12	0.60 ± 1.10	1–5	Sa	C, IC, S, I
Myxozoa	<i>Henneguya</i> sp.	10.8	1.20 ± 0.42	0.10 ± 0.40	1–2	Sa	K
Spores							
Apicomplexa	<i>Calyptospora</i> sp.	7.2	20.00 ± 8.45	1.40 ± 5.66	2–25	Sa	L, I
Oocysts							

mulated (Jaccard qualitative similarity). This confirms that these fish species have preferences for similar food items and indicates that there is overlapping of niches between these species. However, there is not competition because *T. chalceus* and *T. guentheri* present different foraging strategies. *Tetragonopterus chalceus* explores the water column more intensely and seeks food items associated with vegetation close to the edges of the reservoir, while *T. guentheri* consumes items associated with the water surface (Gomes & Verani 2003). Moreover, *T. guentheri* utilizes a cruiser foraging strategy and accumulates more specimens of endoparasites than *T. chalceus*, which uses an ambush foraging strategy to encounter with a resource. Fish with a cruiser foraging behaviour are constantly on the move through the environment, have little time to pause and consume several prey per day. On the other hand, fish with an ambush foraging behaviour examines the scene meticulously during long pauses, make attacks of short duration and have less likelihood of encountering prey every day (Campbell & Lewis 2002). It is known that when fish consume taxonomically diverse prey, there is greater acquisition of endoparasites (Humphrey et al. 1978, Hood & Welch 1980, Esch 1983).

Tetragonopterus chalceus and *T. guentheri* are food for macro-zoophagous fish of commercial impor-

tance, such as: *Acestrorhynchus britskii* Menezes, 1969, *Acestrorhynchus lacustris* Lütken, 1875, *Cichla kelberi* Kullander & Ferreira, 2006, *Serrasalmus brandtii* (Lütken, 1875), *Pygocentrus piraya* (Cuvier, 1819), *Leporinus obtusidens* (Valenciennes, 1837), *Leporinus piau* Fowler, 1941, *Leporinus reinhardtii* Lütken, 1874, *Leporinus taeniatus* Lütken, 1875, and *Schizodon knerii* (Steindachner, 1875) (Gomes & Verani 2003, Alvim & Peret 2004). These piscivores become infected with some species of endoparasites and thus constitute definitive hosts precisely because they feed on *T. chalceus* and *T. guentheri*, which are intermediate or paratenic hosts of helminths such as cestodes and nematodes.

Santos-Clapp & Brasil-Sato (2014) recorded occurrences of *Proteocephalus macrophallus* (Diesing, 1850) and *Proteocephalus microscopicus* Woodland, 1935 (Proteocephalidae) in *C. kelberi* in the Três Marias reservoir. *Tetragonopterus chalceus* and *T. guentheri* were recorded in the present study as intermediate hosts of plerocercoids of Proteocephalidea. As fish that are foraged by *C. kelberi*, both of these species probably participate in the life cycle of these cestodes, especially *T. chalceus*, given that larvae of Proteocephalidea were highly prevalent (> 60%) in its parasite community (and were the most abundant parasite).

Adult specimens of *Procamallanus (Spirocamalla-*

nus) *inopinatus* Travassos, Artigas & Pereira, 1928, were recorded parasitizing *S. brandtii*, *P. piraya*, *L. obtusidens*, *L. piaui*, *L. reinhardtii*, *L. taeniatus* and *S. knerii* in the São Francisco river basin (Brasil-Sato 2003); mature specimens of *Rhabdochona acuminata* (Molin, 1860) were recorded in *A. britskii* and *A. lacustris* (Costa et al. 2011); and adult individuals of *C. fischeri* were recorded in *P. piraya* and *S. brandtii* (Moravec et al. 2008). *Tetragonopterus chalceus* and *T. guentheri*, which are paratenic hosts of these parasite species, form important alternatives (via the trophic route) in maintaining the life cycle of these nematodes in the Três Marias reservoir.

The present study has revealed the biological diversity of the endoparasitic communities of two forage fish species in the São Francisco river basin, which is an important hydrological system in Brazil. These fish species are prey for a variety of aquatic organisms; therefore transmission of the larvae of parasites in these communities to the definitive piscivorous hosts is boosted. Plerocercoids of Proteocephalidea, *Goezia* sp., *Spiroxys* sp., *C. fischeri* and *Henneguya* sp. were recorded for the first time in *T. chalceus* and in *T. guentheri*; *S. rodolphiheringi*, in *T. chalceus*; and *P. saofranciscensis*, *Contracaecum* sp. and *Hysterothylacium* sp. in *T. guentheri*.

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REFERENCES

Abdallah V.D., Azevedo R.K., Carvalho E.D. & Silva R.J. New hosts and distribution records for nematode parasites of freshwater fishes from São Paulo state, Brazil. *Neotrop. Helminthol.*, 6:43-57, 2012.

Agarwal N. & Kritsky D.C. Neotropical Monogenoidea. 33. Three new species of *Ancistrohaptor* n. g. (Dactylogyridae, Ancyrocephalinae) on *Triporthus* spp. (Teleostei, Characidae) from Brazil, with checklists of ancyrocephalines recorded from neotropical characiform fishes. *Syst. Parasitol.*, 39:59-69, 1998.

Albuquerque M.C. & Brasil-Sato M.C. *Creptotrema creptotrema* (Digenea) in *Tetragonopterus chalceus* (Characiformes) from the Três Marias Reservoir, Upper São Francisco River, Brazil. *Rev. Bras. Med. Vet.*, 31:265-267, 2009.

Albuquerque M.C. & Brasil-Sato M.C. First report of *Calyptospora* sp. (Apicomplexa, Calyptosporidae) in forage characid fish from the Três Marias Reservoir, São Francisco Basin, Brazil. *Eur. J. Protistol.*, 46:150-152, 2010.

Alvim M.C.C. & Peret A.C. Food resources sustaining the fish fauna in a section of the upper São Francisco river in Três Marias, MG, Brazil. *Braz. J. Biol.*, 64:195-202, 2004.

Brasil. Ministério do Meio Ambiente. Plano de ações estratégicas e integradas para o desenvolvimento do turismo sustentável na Bacia do Rio São Francisco. Programa de revitalização da Bacia Hidrográfica do Rio São Francisco. Distrito Federal. Disponível at: <http://www.mma.gov.br/estruturas/sedr_proecotur/_arquivos/livrosf.pdf>. Accessed on: Dez 21, 2006.

Brasil-Sato M.C. Parasitos de Peixes da Bacia do São Francisco, p. 149-165. In: Godinho H.P. & Godinho A.L. (Eds.). *Águas, Peixes e Pescadores do São Francisco das Minas Gerais*. PUCMINAS, Belo Horizonte, 2003.

Brasil-Sato M.C. & Santos M.D. Metazoan parasites of *Conorhynchos conirostris* (Valenciennes, 1840) an endemic siluriform fish of the São Francisco basin, Brazil. *Rev. Bras. Parasitol. Vet.*, 14:160-166, 2005.

Britski H.A., Sato Y. & Rosa A.B.S. *Manual de identificação de peixes da região de Três Marias (com chaves de identificação para os peixes da Bacia do São Francisco)*. 3rd. ed. CODEVASF- Câmara dos Deputados, Brasília, 1988. 115p.

Bush A.O. & Holmes J.C. Intestinal helminthes of lesser scaup ducks: a interactive community. *Can. J. Zool.*, 64:142-152, 1986.

Bush A.O., Lafferty J.M. & SHOSTAK A.W. Parasitology meets ecology on its own terms: Margolis et al. revisited. *J. Parasitol.*, 83:575-583, 1997.

Campbell J.F. & Lewis E.E. Entomopathogenic nematode: host-search strategies, p. 13-38. In: Lewis E.E., Campbell J.F. & Sukhdeo M.V.K. (Eds.). *The behavioural ecology of parasites*. CAB International, Wallingford, 2002.

Costa C.M.R., Hermann G., Martins C.S., Lins L.V. & Lamas, I.R. (Orgs.). *Biodiversidade em Minas Gerais: um atlas para sua conservação*. Fundação Biodiversistas, Belo Horizonte, 1998. 94p.

Costa D.P.C.C., Albuquerque M.C. & Brasil-Sato M.C. *Rhabdochona (Rhabdochona) acuminata* (Nematoda) em peixes (Characiformes, Acestrohynchidae) do reservatório de Três Marias, alto rio São Francisco, Brasil. *Neotrop. Helminthol.*, 5:16-23, 2011.

Costa-Pereira R., Paiva F. & Tavares L.E.R. Variation in the parasite community of the sardine fish *Triporthus nematurus* (Actinopterygii: Characidae) from the Medalha lagoon in the Pantanal wetland, Brazil. *J. helminthol.*, 88:272-277, 2014.

Eiras J.C., Monteiro C.M. & Brasil-Sato M.C. *Myxobolus franciscoi* sp. nov. (Myxozoa, Myxosporidia, Myxobolidae) a parasite of *Prochilodus argenteus* (Actinopterygii, Prochilodontidae) from the upper São Francisco river, Brazil, with a revision of *Myxobolus* spp. from South America. *Rev. Bras. Zool.*, 27:131-137, 2010.

Esch G.W. The population and community ecology of cestodes. p. 81-137. In: Arme C. & Pappas P.W. *Biology of the Eucestoda*. Academic Press, London, 1983.

Gomes J.H.C. & Verani J.R. Alimentação de espécies do reservatório de Três Marias. p. 195-227. In: Godinho H.P. & Godinho A.L. (Eds.). *Águas, peixes e Pescadores do São Francisco das Minas Gerais*. PUC Minas, Belo Horizonte, 2003.

Hood D.E. & Welch H.E. A seasonal study of the parasites of the red-winged blackbird, *Agelaius phoeniceus* in Manitoba and Arkansas. *Can. J. Zool.*, 58:528-537, 1980.

Humphrey S.P., Courtney C.H. & Forrester D.H. Community ecology of the helminth parasites in brown pelicans. *Wilson Bull.*, 90:587-598, 1978.

Iannaccone J.A., López E.M. & Alvarinho L.F. *Procamallanus (Spirocamallanus) inopinatus* Travassos, Artigas et Pereira, 1928 (Nematoda: Camallanidae) endoparasito de *Triporthus angulatus* (Spix, 1829) (Characidae) en La Laguna de Yarínacochoa, Ucayali-Perú. *Biol. Pesq.*, 28:37-43, 2000.

Kohn A., Fernandes B.M.M. & Cohen, S.C. *South American trematodes parasites of fishes*. Imprinta Express Ltda, Rio de Janeiro, 2007. 318p.

Magurran A.E. *Ecological Diversity and Its Measurement*. Princeton University Press, New Jersey, 1988. 179p.

Malabarba M.C.S.L. Revision of the Neotropical genus *Triporthus* Cope, 1872 (Characiformes: Characidae). *Neotrop. Ichthyol.*, 2:167-204, 2004.

Marques T.M., Boeger W.A. & Brasil-Sato M.C. Two new species of *Ergasilus* Nordmann, 1832 (Copepoda: Ergasilidae) and a redescription of *Ergasilus salmini* Thatcher & Brasil-Sato, 2008 from *Salminus*

- brasiliensis* Cuvier and *S. franciscanus* Lima & Britsky (Teleostei: Characidae) in Brazil. *Syst. Parasitol.*, 90:81-89, 2015.
- Monteiro C.M. & Brasil-Sato M.C. A new species of Anacanthoroides and redescription of *Apedunculata discoidea* (Monogenoidea) parasitizing *Prochilodus argenteus* (Actinopterygii) from the São Francisco River, Brazil. *Zootaxa*, 3784:259-266, 2014a.
- Monteiro C.M. & Brasil-Sato M.C. A new species of *Rhinonastes* (Monogenoidea, Dactylogyridae), nasal parasite of *Prochilodus argenteus* (Actinopterygii, Characiformes) from Brazil. *Acta Parasitol.*, 59:540-543, 2014b.
- Monteiro C.M., Cohen, S.C. & Brasil-Sato M.C. New species and reports of dactylogyrids (Monogenoidea) from *Salminus franciscanus* (Actinopterygii: Bryconidae) from the upper São Francisco River, Brazil. *Zootaxa*, 3941:137-143, 2015.
- Monteiro C.M., Kritsky D.C. & Brasil-Sato M.C. Neotropical Monogenoidea. 56. New species of *Anacanthorus* (Dactylogyridae) from the gills of matrinhã, *Brycon orthotaenia* (Characiformes: Characidae), in the Rio São Francisco, Brazil. *Folia Parasitol.*, 57:164-167, 2010.
- Moravec F. *Nematodes of freshwater fishes of the Neotropical Region*. Academia, Praha, 1998. 464p.
- Moravec F., Santos M.D. & Brasil-Sato M.C. Redescription of *Cystidicoloides fischeri* Based on Specimens From Piranhas in Brazil, and Erection of a New Genus (Nematoda: Cystidicolidae). *J. Parasitol.*, 94:889-897, 2008.
- Moreira N.I.B., Oliveira C.L. & Costa H.M.A. *Spirocamallanus inopinatus* (Travassos, Artigas & Pereira, 1928) e *Spirocamallanus saofranciscensis* sp. n. (Nematoda, Camallanidae) em peixes da Represa de Três Marias. *Arq. Bras. Med. Vet. Zootec.*, 46:485-500, 1994.
- Moser M. Parasites as biological tags. *Parasitol. Today*, 7:182-185, 1991.
- Oliveira M.S.B., Gonçalves R.A. & Tavares-Dias M. Community of parasites in *Triporthus curtus* and *Triporthus angulatus* (Characidae) from a tributary of the Amazon River system (Brazil). *Stud. Neotrop. Fauna Environ.*, 51:29-36, 2016.
- Price P.W. Host populations as resources defining parasite community organization. p. 21-40. In: Esch, G.W., Bush, A., Aho, J. *Parasite communities: patterns and process*. Chapman & Hall, New York, 1990.
- Reis R.O., Kullander S. O. & Ferraris Jr. C.J. *Check list of the freshwater fishes of South and Central America*. EDIPUCR, Porto Alegre, 2003. 742p.
- Rodrigues W.C. DivEs: Diversidade de espécies. Versão 2.0. Software e Guia do Usuário, 2005. Disponível at: <<http://www.ebras.bio.br>>. Accessed on: Jun 1, 2008.
- Santos C.P., Gibson D.I., Tavares L.E.R. & Luque J.L. Checklist of Acanthocephala associated with the fishes of Brazil. *Zootaxa*, 1938:1-22, 2008.
- Santos M.D., Albuquerque M.C., Monteiro C.M., Martins A.N., Ederli N.B. & Brasil-Sato M.C. First report of larval *Spiroxys* sp. (Nematoda, Gnathostomatidae) in three species of carnivorous fish. *Panam. J. Aquat. Sci.*, 4:306-311, 2009.
- Santos-Clapp M.D. & Brasil-Sato M.C. Parasite Community of *Cichla kelberi* (Perciformes, Cichlidae) in the Três Marias Reservoir, Minas Gerais, Brazil. *Rev. Bras. Parasitol. Vet.*, 23:367-374, 2014.
- Williams H.H., Mackenzie K. & Mccarthy A.M. Parasites as biological indicators of the population biology, migrations, diet and phylogenetics of fish. *Rev. Fish Biol. Fish*, 2:144-176, 1992.