Community of parasites in Triportheus curtus and Triportheus angulatus (Characidae) from a tributary of the Amazon River system (Brazil)

Marcos Sidney Brito Oliveira, Raissa Alves Gonçalves & Marcos Tavares-Dias

Published online: 25 Feb 2016.

Submit your article to this journal

Article views: 15

View related articles

View Crossmark data

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Community of parasites in *Triportheus curtus* and *Triportheus angulatus* (Characidae) from a tributary of the Amazon River system (Brazil)

Marcos Sidney Brito Oliveira[a], Raissa Alves Gonçalves[a,b] and Marcos Tavares-Dias[b,c]

[a]Universidade Federal do Oeste do Pará (UFOPA), Programa de Pós-Graduação em Recursos Aquáticos e Continentais Amazônicos (RACAM), Santarém, PA, Brazil; [b]Universidade do Estado do Amapá (UEAP), Macapá, AP, Brazil; [c]Embrapa Amapá, Aquicultura e Pesca, Laboratório de Sanidade de Organismos Aquáticos, Macapá, AP, Brazi

ABSTRACT

The present study compared the community of parasites in populations of *Triportheus angulatus* and *T. curtus* from a tributary of the Amazon River in northern Brazil. All hosts had one or more parasite species, 862,687 parasites were collected from *T. curtus* and 302,008 from *T. angulatus*. Species richness of parasites, Shannon diversity index and evenness index were higher for *T. angulatus*. The parasite communities of both hosts was similar (99%) and composed by *Ichthyophthirius multifiliis*, *Anacanthorus pitophallus*, metacercariae and *Procamallanus* (*Spirocamallanus*) *inopinatus*, with dominance of *I. multifiliis*. However, low infection level by *Piscinodinium pillulare*, *Dolops* sp. and *Contracaecum* larvae occurred only in *T. angulatus*, and *Spironucleus* sp. was found only in *T. curtus*. There were differences in the prevalence, intensity and mean abundance for some parasites of both hosts. There was aggregated dispersion of parasites in both hosts, but the infection of *P.* (*S.*) *inopinatus* in *T. angulatus* showed a random dispersion. For *T. angulatus* and *T. curtus*, the diversity and abundance of parasites were influenced by the host size. This was the first report of these parasite species for *T. curtus*, as well as of *I. multifiliis*, *P. pillulare*, *Dolops* sp., *P.* (*S.*) *inopinatus* and *Contracecum* sp. for *T. angulatus*.

Introduction

The Igarapé Fortaleza basin, a major tributary of the Amazon River system in the eastern Amazon, is located in the municipalities of Macapá and Santana, State of Amapá (Brazil). This basin features large areas of wetlands along its main course, with very peculiar characteristics, since they are strongly influenced by high rainfall in the Amazon region and tides of the Amazon River (Takyama et al. 2004; Bittencourt et al. 2014). Such wetlands are the habitat of several species of aquatic plants and birds, besides serving as refuge for many fish species, including the *Triportheus* species, popularly known as freshwater sardines.

Triportheus species are Characidae widely distributed in Bolivia, Colombia, Peru, Argentina, Ecuador, Venezuela and Brazil (Santos et al. 2006; Froese & Pauly 2015). Currently, 19 species are known, including *Triportheus angulatus* Spix & Agassiz, 1829 and *T. curtus* Garman, 1890 (Froese & Pauly 2015). Both are pelagic fish, form schools, and both have diurnal activity and total spawning (Soares et al. 2011). During the dry season, *T. angulatus* and *T. curtus* migrate to search food, and during the rainy season they migrate for reproduction (Soares et al. 2011). Both species are omnivorous, thus feed on seeds, fruits, insects and small invertebrates (Santos et al. 2006; Soares et al. 2011; Froese & Pauly 2015) but mainly on microcrustaceans (Pereira et al. 2011). Variation in the diet of *T. angulatus* and *T. curtus* is related to the abundance and availability of food items in accordance with the phases of the Amazonian hydrological cycle (Yamamoto et al. 2004; Pereira et al. 2011).

According to the national statistics, several *Triportheus* species are important for fishing in some Brazilian states (Amazonas, Rondônia, Roraima, Maranhão, Pará, Ceará, Pernambuco, Rio Grande do Norte, Paraiba and Bahia), which produced 3391.1 tons in 2011 (MPA 2013). Although *Triportheus* species do not appear in these statistics in the State of Amapá, they are commonly found in open-air markets. Yet, there are no reports on the parasite communities of *T. angulatus* and *T. curtus*, nor of other *Triportheus* species.

In Brazil, the monogeneans *Anacanthorus acuminatus*, *A. andersoni*, *A. carinatus*, *A. chelophorus*, *A. chaunophallus*, *A. cornutus*, *A. euryphallus*, *A. glyptophallus*, *A.

lygophallus, *A. nanus*, *A. pithophallus*, *A. tricornis*, *A. falci-ferum* and *A. falcunlum* (Kritsky et al. 1992; Thatcher 2006; Cohen et al. 2013), *Ancistrohaptor falcunculum* (Agarwal & Kritsky 1998) and the nematodes *Procamallanus* (*Spirocamallanus*) sp. and *P.* (*Procamallanus*) *peraccuratus* are known to parasitize *T. angulatus* (Kohn et al. 2011). For *T. angulatus* from the Lake Yarinacocha in Peru, Iannacone et al. (2000) reported infection by *Procamallanus* (*Spirocamallanus*) *inopinatus* with a prevalence of 29.8% and a mean intensity of 1.5 parasites/fish. However, there is no information about the parasitic fauna of *T. curtus*.

Studies on the community of parasites in fish increase knowledge about the parasite–host–environment relationship and strategies used by different parasitic taxa (Muñoz et al. 2006; Longshaw et al. 2010; Alarcos & Timi 2012; Bittencourt et al. 2014; Tavares-Dias et al. 2014), as well as the biodiversity of ecosystems (Bittencourt et al. 2014; Tavares-Dias et al. 2014). The parasites can directly influence the population structure when causing mortality, or indirectly by reducing the growth rate and feeding, reproduction, as well as swimming speed, which enhances the risk of predation (Zrncic et al. 2009; Longshaw et al. 2010; Morley 2012). Consequently, the parasites can affect crop production (Tavares-Dias et al. 2001a, 2001b) and fishing, interfering with the fish quality and hampering its commercialization (Tavares-Dias et al. 2014). Moreover, for two species of fish that inhabit the same biotope and, apparently, share the same ecological conditions, feeding habit and geographical location (sympatry), a similar parasite community could be expected (Muñoz et al. 2006; Alarcos & Timi 2012). Thus, this study aimed at comparing the community of parasites in populations of *T. angulatus* and *T. curtus* from a tributary of the Amazon River system in northern Brazil.

Materials and methods

Study site

Specimens of *Triportheus angulatus* and *Triportheus curtus* were caught from July to December 2011 in Igarapé Fortaleza basin (0°02′34.4″ S, 55°05′52.18″ W), a tributary of the Amazon River system in the region of Macapá, State of Amapá (eastern Amazon, Brazil) for parasitological analysis. Fish were caught with different gillnets (ICMBio: 23276-1) and transported on ice to the Laboratory of Aquatic Organism Health of the Embrapa Amapá (Macapá). This study was conducted according to the principles adopted by the Brazilian College of Animal Experimentation (COBEA).

Procedures and analyses of parasites

After measuring body weight (g) and total length (cm), each fish was necropsied for parasitological examination. The mouth, opercula, gills and gastrointestinal tract of each fish were examined to collect ecto- and endoparasites. The collection, fixation, conservation, counting, and staining of parasites for identification followed previous recommendations (Tavares-Dias et al. 2001a, 2001b; Eiras et al. 2006). The ecological terms used were those recommended by Bush et al. (1997).

The Shannon index (*H*), evenness (*E*), Berger–Parker dominance index (d), species richness and frequency of dominance (percentage of infracommunities in which a parasite species was numerically dominant (Rohde et al. 1995; Magurran 2004) were calculated to evaluate the community of parasites using the software Diversity (Pisces Conservation Ltd, Lymington, UK). The variance-to-mean ratio (ID), and index of discrepancy of Poulin (D) were calculated using the software Quantitative Parasitology 3.0 to detect the distribution pattern of the parasite infracommunity (Rózsa et al. 2000) for species with prevalence > 10%. The ID significance for each infracommunity was tested using the *d*-statistics (Ludwig & Reynolds 1988). Similarity measurements between *T. angulatus* and *T. curtus* were based on the Jaccard index (J), based on presence–absence data (qualitative similarity), and the Morisita index (S_M), a quantitative similarity index that takes into account differences in abundance among the shared parasite species (Ludwig & Reynolds 1988; Magurran 2004). These similarity indices were calculated using the Past software (Hammer et al. 2001).

Data on weight and total length were used to calculate the relative condition factor of hosts (Kn) (Le-Cren 1951). The Spearman correlation coefficient (*rs*) was used to determine possible correlations of the abundance of parasites with the length, weight and Kn of hosts, as well as of hosts length with the species richness, *HB, E* and *d*. For comparison of prevalence between *T. angulatus* and *T. curtus* the chi-square test (χ^2) was used, followed by the Yates correction. The mean intensity, mean abundance, species richness, *H, E* and *d* between both hosts were compared by using the Mann–Whitney *U*-test (Zar 2010).

Results

A total of 31 specimens of *T. angulatus* (17.0 ± 1.7 cm and 47.4 ± 1.7 g) were examined and 100% were infected with *Ichthyophthirius multifiliis* Fouquet, 1876; *Piscinoodinium pillulare* (Schäperclaus, 1954) Lom, 1981; *Anacanthorus*

Table 1. Parasites in *Triportheus* spp. from the Igarapé Fortaleza basin, Amazon River system, Amapá state, Brazil.

	Fish species									
	Triportheus curtus (n = 33)					*Triportheus angulatus* (n = 31)				
Parasites	P (%)	MI	MA	TNP	SI	P (%)	MI	MA	TNP	SI
Protozoa/Ichthyophthiriidae										
Ichthyophthirius multifiliis	100	26,130	26,130	862,289	Gills	100	9609.3	9609.3	297,887	Gills
Protozoa/Dinoflagellida										
Piscinoodinium pillulare	–	–	–	–	–	58.1	184.8	107.3	3326	Gills
Protozoa/Hexamitidae										
Spironucleus sp.	6.1	1.0	0.1	2	Gills	–	–	–	–	–
Monogenea/Dactylogyridae										
Anacanthorus pitophallus	97.0	10.2	9.8	325	Gills	96.8	17.7	17.2	532	Gills
Crustacea/Argulidae										
Dolops sp.	–	–	–	–	–	3.2	1.0	0.03	1	Gills
Trematoda/Digenea										
Digenea gen sp.1 (metacercariae)	6.1	1.0	0.1	2	Gills	35.5	19.6	7.0	216	Gills
Digenea gen sp.2 (metacercariae)	3.0	1.0	0.03	1	Intestine	–	–	–	–	–
Nematoda/Camallanidae										
Procamallanus (*S.*) *inopinatus*	3.0	48.0	1.5	48	Stomach	–	–	–	–	–
Procamallanus (*S.*) *inopinatus*	6.1	1.0	0.06	2	Cecum	16.1	2.0	0.3	10	Cecum
Procamallanus (*S.*) *inopinatus* (larvae)	–	–	–	–	–	3.2	1.0	0.03	1	Liver
Procamallanus (*S.*) *inopinatus* (larvae)	–	–	–	–	–	19.3	2.0	0.4	12	Intestine
Procamallanus (*S.*) *inopinatus* (adults)	39.4	1.4	0.5	18	Intestine	35.5	1.9	0.7	21	Intestine
Nematoda/Anisakidae										
Contracaecum sp. (larvae)	–	–	–	–	–	3.3	2.0	0.1	2	Intestine

Abbreviations: P, prevalence; MI, mean intensity; MA, mean abundance; TNP, total number of parasites; SI, site of infection.

pitophallus Kritsky, Boeger & Van Every, 1992; *Dolops* sp. *Procamallanus* (*Spirocamallanus*) *inopinatus* Travassos, Artigas & Pereira, 1928; Digenea undetermined and *Contracaecum* sp. A total of 33 specimens of *T. curtus* (14.6 ± 4.0 cm and 38.0 ± 26.3 g) were examined and 100% were infected with *I. multifiliis*, *Spironucleus* sp., *A. pitophallus*, Digenea undetermined and *P.* (*S.*) *inopinatus*. There was a similar dominance of *I. multifiliis* in the gills of *T. angulatus* and *T. curtus* (Table 1). Only one specimen of *Dolops* sp. was found on the gills of *T. angulatus*. Parasites found showed an aggregated dispersion, except for *P.* (*S.*) *inopinatus* in the pyloric cecum of *T. angulatus* that showed a random dispersion (Table 2).

The prevalence of *I. multifiliis* was similar in the gills of *T. angulatus* and *T. curtus* but the mean intensity and mean abundance were higher ($U = 215.0$, $p = 0.0001$) in *T. curtus*. For *T. angulatus* and *T. curtus* there were no differences in prevalence ($\chi^2 = 0.002$, $p = 0.5004$) of *Anacanthorus pitophallus*, but the mean intensity ($U = 331.0$, $p = 0.0358$) and mean abundance ($U = 363.5$, $p = 0.0468$) were higher in the gills of *T.*

angulatus. The prevalence of metacercariae of Digenea gen. sp. ($\chi^2 = 8.549$, $p = 0.009$) and mean abundance ($U = 353.0$, $p = 0.033$) were higher in *T. angulatus* compared to *T. curtus*, while the mean intensity ($U = 21.0$, $p = 0.111$) was similar in both hosts. Similar prevalence ($\chi^2 = 1.663$, $p = 0.3740$), mean intensity ($U = 6.00$, $p = 0.857$) and mean abundance ($U = 459.0$, $p = 0.481$) of *P.* (*S.*) *inopinatus* were observed in the pyloric caeca of *T. angulatus* and *T. curtus*. In the intestines of both hosts, prevalence ($\chi^2 = 0.963$, $p = 0.465$), mean intensity ($U = 41.5$, $p = 0.082$) and mean abundance ($U = 501.5$, $p = 0.893$) of *P.* (*S.*) *inopinatus* were also similar.

The parasite communities of *T. angulatus* and *T. curtus* were similar and composed by ectoparasites and endoparasites (Table 3). In *T. angulatus*, there was predominance of hosts infected with two, four and five species of parasites, while in *T. curtus*, there was predominance of hosts infected by two and three parasite species (Figure 1). Species richness of parasites, Shannon index and evenness were

Table 2. Index of dispersion (ID), *d*-statistics, discrepancy index (D) and frequency of dominance (FD) for infracommunities of parasites in *Triportheus* spp. from the Igarapé Fortaleza basin, Amazon River system, Amapá state (Brazil).

Hosts	*Triportheus curtus*				*Triportheus angulatus*			
Parasites	ID	*d*	D	FD	ID	*d*	D	FD
Ichthyophthirius multifiliis (gills)	1.577	2.109	0.371	0.999	2.409	4.341	0.409	0.986
Piscinoodinium pillulare (gills)	–	–	–	–	3.002	5.739	0.559	0.011
Anacanthorus pitophallus (gills)	1.988	3.442	0.308	–	1.681	2.361	0.332	0.001
Digenea sp. metacercariae (gills)	–	–	–	–	2.300	4.066	0.737	0.001
Procamallanus (*S.*) *inopinatus* (intestine)	–	–	–	–	1.945	3.122	0.674	-
Procamallanus (*S.*) *inopinatus* (cecum)	–	–	–	–	1.178	0.726	0.833	-

Table 3. Community composition of ectoparasites and endo-parasites of *Triportheus* spp. from the Igarapé Fortaleza basin, Amazon River system, Amapá state (Brazil).

Characteristics	*Triportheus curtus* (n = 33)	*Triportheus angulatus* (n = 31)
Prevalence (%) of parasites	100	100
Total number of parasites	862,687	302,008
Ectoparasite species	4	5
Percentage of ectoparasites	99.9	99.9
Endoparasite species	2	2
Percentage of endoparasites	0.1	0.1
Endoparasite species (adults)	1	1
Endoparasite species (larvae)	2	2
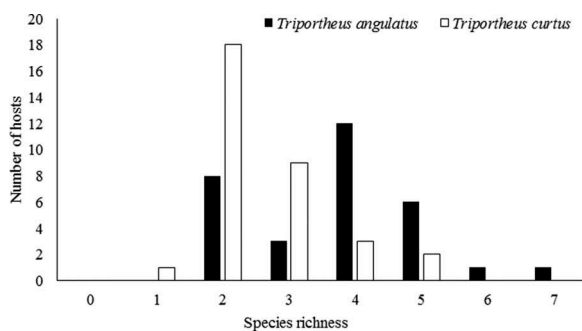
Figure 1. Species richness of parasites for two *Triportheus* species from the Igarapé Fortaleza basin, Amazon River system, Amapá state (Brazil).

higher for *T. angulatus*, while the Berger–Parker dominance index was higher for *T. curtus* (Table 4).

The Jaccard index (J = 0.60) and Morisita similarity index (S_M = 0.99) demonstrated a high similarity between the parasite communities of *T. angulatus* and *T. curtus*. Total length of *T. angulatus* was negatively correlated with Shannon index (rs = −0.385, p = 0.032) and parasite species richness (rs = −0.372, p = 0.039). In *T. curtus*, total length was also

negatively correlated with Shannon index (rs = −0.493, p = 0.003), but not with parasite species richness (rs = −0.039, p = 0.829).

For *T. angulatus*, the Kn was 0.999 ± 0.052 and for *T. curtus* the Kn was 0.997 ± 0.098, and these mean values did not differ (H = 3.899, p = 0.142) from the standard values (Kn = 1.000), indicating good body conditions for both hosts.

In *T. angulatus*, there was a positive correlation between total length and weight with abundance of *I. multifiliis* and between Kn and abundance of *P. (S.) inopinatus*. However, there was a negative correlation between length and weight with the abundance of Digenea metacercariae. Moreover, the abundance of *P. pilullare* showed positive correlation with Kn. In *T. curtus*, the Kn was 0.999 ± 0.052, and only the abundance of *I. multifiliis* was correlated with the length and weight of the host (Table 5).

Discussion

Aspects of the parasite communities

Host fish that are phylogenetically close tend to present parasite diversity and species richness of greater similarity than those of unrelated host species (Muñoz et al. 2006; Alarcos & Timi 2012). Congeneric hosts such as *T. angulatus* and *T. curtus* have similar ecology, and thus can overlap in space and time. Thereby, the similar parasite communities of *T. angulatus* and *T. curtus* were characterized by high prevalence and high abundance of ectoparasites and low prevalence, low abundance of endoparasites, with low diversity and low species richness. Similar findings have been reported for other fish species also from the Amazon River system in Brazil (Pinheiro et al. 2013; Tavares-Dias et al. 2013, 2014). The endoparasite communities were similar between *T. angulatus* and *T. curtus*, as expected. Moreover, the ectoparasite communities

Table 4. Descriptors of diversity for communities of parasites of *Triportheus* spp. from the Igarapé Fortaleza basin, Amazon River system, Amapá state (Brazil).

Diversity indices	*Triportheus angulatus*	*Triportheus curtus*	U	p
Mean species richness	3.8 ± 1.4 (2–8)	2.6 ± 0.99 (1–5)	285.5	0.0009
Mean index of Shannon (H)	0.239 ± 0.303 (0.0003– 1.093)	0.007 ± 0.009 (0.001–0.046)	199.0	0.0001
Mean evenness (E)	0.104 ± 0.130 (0.0001– 0.561)	0.003 ± 0.004 (0–0.022)	210.0	0.0001
Mean index of Berger–Parker (d)	0.925 ± 0.120 (0.5–1.0)	0.999 ± 0.001 (0.9–1.0)	201.0	0.0001

U = Mann–Whitney.

Table 5. Spearman correlation coefficient (*rs*) of the abundance of parasites with the total length, body weight and Kn of *Triportheus* spp. from the Igarapé Fortaleza basin, Amazon River system, Amapá state (Brazil).

	Triportheus angulatus						*Triportheus curtus*					
Hosts	Length		Weight		Kn		Length		Weight		Kn	
Parasite species	rs	p	rs	p	rs	p	rs	p	rs	p	rs	p
Ichthyophthyrius multifiliis	0.432	0.015	0.356	0.049	0.052	0.780	0.649	0.0001	0.662	0.0001	0.218	0.224
Piscinoodinium pilullare	0.021	0.909	0.286	0.119	0.433	0.015	–	–	–	-	-	-
Anacanthorus pitophallus	−0.024	0.898	0.199	0.283	0.338	0.062	0.052	0.772	0.107	0.553	0.149	0.408
Digenea gen. sp. metacercariae	−0.474	0.002	−0.388	0.031	−0.086	0.646	–	–	–	-	-	-
Procamallanus (*S.*) *inopinatus* (cecum)	0.142	0.446	0.129	0.489	0.028	0.879	–	–	–	-	-	-
Procamallanus (*S.*) *inopinatus* (intestine)	−0.148	0.462	0.010	0.957	0.363	0.045	−0.130	0.469	−0.044	0.809	0.091	0.614

showed differences between *T. angulatus* and *T. curtus*, because *P. pilullare* and *Dolops* sp. occurred only in the gills of *T. angulatus* and *Spironucleus* sp. only in *T. curtus*, indicating that the hosts had had contact with different infective forms of these ectoparasites with a direct cycle.

The mostly aggregated dispersion of parasites in *T. angulatus and T. curtus* is a pattern also reported for other fish species (Rohde et al. 1995; Guidelli et al. 2003; Tavares-Dias et al. 2013), and is caused mainly by magnitude of the size of the ecological niche, immunological heterogeneity of the host population, and environment (Guidelli et al. 2003; Tavares-Dias et al. 2013). However, the random dispersion of *P.* (*S.*) *inopinatus* in the pyloric cecum of *T. angulatus* is similar to the infection by *Contracaecum* larvae in *Hemisorubim platyrhynchos* (Guidelli et al. 2003). A random dispersion pattern is common in species of parasites with greater pathogenicity and reduced ability to colonize hosts (Guidelli et al. 2003). Gaines et al. (2012) reported pathogenicity of *P.* (*S.*) *inopinatus* in *Arapaima gigas* by causing necrosis, desquamation, inflammation, cytolysis and formation of fibrous capsules in the intestine of the host. In contrast to this, we did not find clinical signals of pathology in *T. angulatus*, probably due to low abundance of *P.* (*S.*) *inopinatus*. The lack of correlation between abundance of the monogenean *A. pitophallus* in *T. curtus* and *T. angulatus* and host size is similar to the lack of correlation between the intensity of *Gonocleithrum aruane* in *Osteoglossum bicirrhosum* and *Gussevia asota* in *Astronotus ocellatus* and host size, and is probably due to the behavior and physiology of these hosts (Tavares-Dias et al. 2014).

Aspects of the parasite infracommunities

The low prevalence of *Dolops* sp. in the gills of *T. angulatus* was similar to the situation described for *T. elongatus* from Janauacá Lake (prevalence of *Dolops* sp.: 9.0%) (Malta 1984). The low abundance of *Dolops* sp. did not allow species identification, but nine *Dolops* species have been listed for different Brazilian fish and most of these parasites have a wide distribution in the hydrographic basins (Luque et al. 2013). However, no species was identified parasitizing *Triportheus* species, thus this is the first report of the genus *Dolops* for *T. angulatus*.

Piscinoodinium pilullare and *I. multifiliis* are protozoans with direct life cycles, and have no parasitic specificity, and thereby are common in fish species from the Igarapé Fortaleza basin, an environment with strong urban eutrophication (Pinheiro et al. 2013; Tavares-Dias et al. 2013; Bittencourt et al. 2014). *Ichthyophthirius multifiliis* showed higher abundance in *T. curtus*, but for both hosts the positive correlation between abundance and host size indicates an accumulation of this protozoan on the gills of these hosts (Pinheiro et al. 2013; Tavares-Dias et al. 2013). Moreover, the positive correlation of *P. pilullare* abundance with Kn of *T. angulatus*, indicated that fish with better body conditions support higher parasite load.

Trophozoites of *Spironucleus* sp. were only found in the gills of *T. curtus* and showed low levels of infection. Similarly, low levels of parasitism were recorded in the gills of *Curimata cyprinoides* also captured in the Igarapé Fortaleza basin (Tavares-Dias et al. 2013). Trophozoites of *Spironucleus* sp. were described in the gallbladder of *Rhamdia quelen* (Tanzola & Vanotti 2008), due to the systemic infection common in spironucleosis. However, the hexamitid species has the intestine as the primary site of infection, an uncommon site of infection in Neotropical fishes (Tanzola & Vanotti 2008; Williams et al. 2011). In general, these parasites are not pathogenic for the natural wild fish populations, but can compromise the immune system of the hosts (Williams et al. 2011). However, no significant signs of disease were observed in *T. curtus*; there was no systemic infection.

Anacanthorus pitophallus, the dominant helminth species in *T. curtus* and *T. angulatus*, had a similar prevalence in both hosts, but both the highest mean intensity and the mean abundance occurred in *T.*

angulatus. As *T. angulatus* and *T. curtus* form schools to migrate together (Santos et al. 2006; Soares et al. 2011; Froese & Pauly 2015), this behavior explains that both species were infected by the same species of Monogenea. However, for *T. angulatus* from central Amazon other monogenoidea species such as *Anacanthorus carinatus, A. acuminatus, A. andersoni, A. chaunophallus, A. chelophurus, A. cornutus, A. euryphallus, A. gyptophallus, A. lygophallus* and *A. nanus* are also known (Kritsky et al. 1992; Thatcher 2006). These results confirm that the environment may favor the presence of monogenoidea species for the same host of different locations.

Metacercariae of Digenea were found in low level of infection in the gills and intestine of *T. curtus*, but there was higher infection in the gills of *T. angulatus*. In general, the transmission of digeneans is related to the life history of hosts, since these parasites need more than one host to complete their life cycle. Digenean species have a mollusk species as primary intermediate host, and subsequently require another secondary intermediate host that may be a fish species that eats mollusks (Morley 2012; Tavares-Dias et al. 2014). Moreover, the digeneans can have piscivorous birds or larger fish as their definitive hosts (Guidelli et al. 2003; Morley 2012). Due to the higher gill infection in *T. angulatus*, this host is likely in direct contact with cercariae of Digenea (Morley 2012) in our study site, especially the smaller individuals, which were most infected. Metacercariae of many digenean species enter the host by active invasion of cercariae and their successful transmission depends on the behavior of these cercariae, as well as the host behavior and environment (Tavares-Dias et al. 2014). As *T. angulatus* and *T. curtus* live near aquatic vegetation (Soares et al. 2011), this behavior seems to have favored the gill infection by metacercariae of digeneans; thereby, these fish are paratenic hosts for such parasites.

Larvae of *Contracaecum* were found only in *T. angulatus* but at low levels of infection in contrast to what was reported for *Astronotus ocellatus* from the Igarapé Fortaleza basin (Bittencourt et al. 2014) and Rio Preto (Tavares-Dias et al. 2014). Such anisakids lack host specificity, and during their larval stage have microcrustacean species as primary hosts (Moravec 2009; Moreira et al. 2009), whereas the adults use piscivorous birds as definitive hosts and fish as parathenic hosts (Moravec 2009; Tavares-Dias et al. 2014). As microcrustaceans are food items shared by *T. angulatus* and *T. curtus*, hosts that overlap in space and time in the Igarapé Fortaleza basin, the absence of *Contracaecum* sp. in *T. curtus* and the low abundance in *T. angulatus* therefore indicates accidental infection.

In *T. curtus* and *T. angulatus*, infection levels by *P. (S.) inopinatus* were similar. The fact that larvae and adults of *P. (S.) inopinatus* were collected from *T. curtus* and *T. angulatus* indicates that they are definitive hosts of this nematode that uses chironomids as intermediate hosts (Moreira et al. 2009; Tavares-Dias et al. 2014). The abundance of *P. (S.) inopinatus* showed a positive correlation with Kn of *T. angulatus*, indicating that hosts with better body condition are feeding more and support higher levels of infection. Consequently, the length of *T. angulatus* showed a negative correlation with species richness of these parasites. Variation in the diet of these two hosts is related to the abundance of microcrustaceans (Yamamoto et al. 2004; Pereira et al. 2011; Froese & Pauly 2015) and mollusks in the environment. This suggests that *T. curtus* and *T. angulatus* from the Igarapé Fortaleza basin are consuming different species of these invertebrates.

This study showed that the parasite communities of *T. angulatus* and *T. curtus* were characterized by low abundance of helminths, low species richness, low diversity and evenness, with predominant species of ectoparasites. Body condition of the both hosts was not affected by the moderate parasitism. Moreover, the hosts' size was a factor that influenced the diversity, species richness and abundance of parasites in *T. angulatus*, but only species richness of parasites in *T. curtus*. This is the first record of all these parasites to *T. curtus*, as well as *P. pilullare, I. multifiliis* and *Contracaecum* sp. for *T. angulatus*.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

References

Agarwal N, Kritsky DC. 1998. Neotropical Monogenoidea. 33. The new species of *Ancistrohaptor* n. g. (Dactylogyridae, Ancyrocephalinae) on *Triportheus* spp. (Teleostei, Characidae) from Brazil, with checklists of ancyrocephalines recorded from Neotropical characiform fishes. Systematic Parasitol. 39:59–69.

Alarcos AJ, Timi JT. 2012. Parasite communities in three sympatric flounder species (Pleuronectiformes: Paralichthyidae). Parasitol Res. 110:2155–2166.

Bittencourt LS, Pinheiro DA, Cárdenas MQ, Fernandes BMM, Tavares-Dias M. 2014. Parasites of native Cichlidae populations and invasive *Oreochromis niloticus* in tributary of Amazonas River (Brazil). Braz J Vet Parasit. 23(1):1–11.

Bush AO, Lafferty KD, Lotz JM, Shostak W. 1997. Parasitology meets ecology on its own terms: Margolis et al. Revisited. J Parasitol. 83(4):575–583.

Cohen SC, Justo MCN, Kohn A. 2013. South American Monogenoidea parasites of fishes, amphibians and reptiles. Rio de Janeiro: Oficina de Livros; 663 p.

Eiras JC, Takemoto RM, Pavanelli GC. 2006. Métodos de estudo e técnicas laboratoriais em parasitologia de peixes. Maringá: Eduem; 199 p.

Froese R, Pauly D. 2015. FishBase. World wide web electronic publication. [cited 2015 Apr 20]. Available from: www.fishbase.org/

Gaines APL, Lozano LES, Viana GM, Monteiro PC, Araújo CSO. 2012. Tissue changes in the gut of *Arapaima gigas* (Schinz, 1822), infected by the nematode *Spirocamallanus inopinatus* (Travassos, 1929). Neotrop Helminthol. 6 (2):147–157.

Guidelli GM, Isaac A, Takemoto RM, Pavanelli GC. 2003. Endoparasite infracommunities of *Hemisorubim platyrhynchos* (Valenciennes, 1840) (Pisces: Pimelodidae) of the Baía river, upper Paraná river floodplain, Brazil: specific composition and ecological aspects. Braz J Biol. 63 (2):261–268.

Hammer O, Harper DAT, Ryan PD. 2001. PAST: paleontological statistics software package for education and data analysis. Palaeontol Electron. 4:1–9.

Iannacone JA, López EN, Alvariño LF. 2000. *Procamallanus* (*Spirocamallanus*) *inopinatus* Travassos, Artigas et Pereira, 1928 (Nematoda: Camallanidae) parásito de *Triportheus angulatus* (Spix, 1829) (Characidae) en la laguna de Yarinacocha, Ucayali-Peru. Biol Pesquera. 28:37–43.

Kohn A, Moravec F, Cohen SC, Canzi C, Takemoto RM, Fernandes BMM. 2011. Helminths of freshwater fishes in the reservoir of the hydroelectric power station of Itaipu, Paraná, Brazil. Check List. 7(5):681–690.

Kritsky DC, Boeger WA, Van Every LR. 1992. Neotropical Monogenoidea. 17. *Anacanthorus* Mizelle and Price, 1965 (Dactylogyridae, Nacanthorinae) from characoid fishes of central Amazon. J Helminth Soc Was. 59(1):25–51.

Le-Cren ED. 1951. The length-weight relationship and seasonal cycle in gonadal weight and condition in the perch (*Perca fluviatilis*). J Anim Ecol. 20(2):201–219.

Longshaw M, Frear PA, Nunn AD, Cowx IG, Feist SW. 2010. The influence of parasitism on fish population success. Fish Manag Ecol. 17:426–434.

Ludwig JA, Reynolds JF. 1988. Statistical ecology: a primer on methods and computing. New York: Wiley-Interscience Pub; 337 p.

Luque JL, Vieira FM, Takemoto RM, Pavanelli GC, Eiras JC. 2013. Checklist of Crustacea parasitizing fishes from Brazil. Check List 2013. 9(6):1449–1470.

Magurran AE. 2004. Measuring biological diversity. Oxford (UK): Blackwell Science; 215 p.

Malta JCO. 1984. Os peixes de um lago de várzea da Amazônia central (Lago Janauacá, Rio Solimões) e suas relações com os crustáceos ectoparasitas (Branchiura: Argulidae). Acta Amaz. 14(3–4):355–372.

Ministério da Pesca e Aquicultura - MPA. 2013. Boletim estatístico da pesca e aquicultura 2011. Brasília: MPA; 60 p.

Moravec F. 2009. Experimental studies on the development of *Contracaecum rudolphii* (Nematoda: Anisakidae) in copepod and fish paratenic hosts. Folia Parasitol. 56 (3):185–193.

Moreira LHA, Takemoto RM, Yamada FH, Ceschini TL, Pavanelli GC. 2009. Ecological aspects of metazoan endoparasites of *Metynnis lippincottianus* (Cope, 1870) (Characidae) from upper Paraná River floodplain, Brazil. Helminthologia. 46:214–219.

Morley NJ. 2012. Cercariae (Platyhelminthes: Trematoda) as neglected components of zooplankton communities in freshwater habitats. Hydrobiologia. 691:7–19.

Muñoz G, Grutter AS, Cribb TH. 2006. Endoparasite communities of five fish species (Labridae: Cheilininae) from Lizard Island: how important is the ecology and phylogeny of the hosts? Parasitology. 132:363–374.

Pereira JO, Silva MT, Vieira LJS, Fugi R. 2011. Effects flood regime on the diet of *Triportheus curtus* (German, 1890) in an Amazonian floodplain lake. Neotrop Ichthyol. 9 (3):623–628.

Pinheiro DA, Tavares-Dias M, Dias MKR, Santos EF, Marinho RGB. 2013. Primeiro registro da ocorrência de protozoários em tamoatá *Hoplosternum littorale* no Brasil. Bol Inst Pesca. 39(2):169–177.

Rohde K, Hayward C, Heap M. 1995. Aspects of the ecology of metazoan ectoparasites of marine fishes. Int J Parasitol. 25(8):945–970.

Rózsa L, Reiczigel J, Majoros G. 2000. Quantifying parasites in samples of hosts. J Parasitol. 86:228–232.

Santos GM, Ferreira EJG, Zuanon JAS. 2006. Peixes comerciais de Manaus. Manaus: Ibama/AM –PróVárzea; 144 p.

Soares MGM, Costa EL, Siqueira-Souza FK, Anjos HDB, Yamamoto KC, Freitas CEC. 2011. Peixes de lagos do médio Rio Solimões. 2nd ed. Manaus: Instituto Piatam; 160 p.

Takyama LR, Silva AQ, Costa WJP, Nascimento HS. Qualidade das águas das ressacas das bacias do Igarapé da Fortaleza e do Rio Curiaú. In: Takiyama LR, Silva AQ, editors. Diagnóstico das ressacas do estado do Amapá: bacias do Igarapé da Fortaleza e Rio Curiaú. Macapá: GEA/SETEC/IEPA; p. 1–22.

Tanzola RD, Vanotti D. 2008. Primer registro del género *Spironucleus* (Diplomonadida: Hexamitidae) en un pez Neotropical. BioScriba. 1(2):73–75.

Tavares-Dias M, Martins ML, Moraes FR. 2001a. Fauna parasitária de peixes oriundos de pesque-pague do município de Franca, São Paulo, Brasil. I. Protozoários. Rev Brasil Zool. 18(1):67–79.

Tavares-Dias M, Moraes FR, Martins ML, Kronka SN. 2001b. Fauna parasitária de peixes oriundos de pesque-pagues do município de Franca, São Paulo, Brasil. II. Metazoários. Rev Brasil Zool. 18(1):81–95.

Tavares-Dias M, Neves LR, Pinheiro DA, Oliveira MSB, Marinho RGB. 2013. Parasites in *Curimata cyprinoides* (Characiformes: Curimatidae) from eastern Amazon, Brazil. Acta Sci Biol Sci. 35(4):595–601.

Tavares-Dias M, Souza TJS, Neves LR. 2014. Parasitic infections in two benthopelagic fish from Amazon, the arowana *Osteoglossum bicirrhosum* (Osteoglossidae) and oscar *Astronotus ocellatus* (Cichlidae). Bioscienc J. 30(2):546–555.

Thatcher VE. 2006. Amazon fish parasites. 2ª ed. Sofia: Pensoft; 507 p.

Williams CF, Lloyd D, Poynton SL, Jorgensen A, Millet COM, Cable J. 2011. *Spironucleus* species: economically-important fish pathogens and enigmatic single-celled eukaryotes. J Aquac Res Dev. doi:10.4172/2155-9546.S2-002

Yamamoto KC, Soares MGM, Freitas CEC. 2004. Alimentação de *Triportheus angulatus* (Spix e Agassiz, 1829) no Lago Camaleão, Manaus, AM, Brasil. Acta Amaz. 34:653–659.

Zar JH. 2010. Biostatistical analysis. 5th ed. Upper Saddle River (NJ): Prentice Hall; p. 944.

Zrncic S, Oraic D, Caleta M, Bulj I, Zanella D, Surmanovic D. 2009. Occurrence of parasites in Cobitidae from Croatia rivers draining into two different watersheds. J Appl Ichthyol. 25(4):447–450.