

Monogeneans (Dactylogyridae) parasitizing gills of *Salminus hilarii* from a Neotropical reservoir, Brazil

Monogenéticos (Dactylogyridae) parasitando brânquias de *Salminus hilarii* de uma represa Neotropical, Brasil

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Received August 13, 2013

Accepted November 1, 2013

Abstract

With the aim of creating an inventory of the metazoan gill parasites of *Salminus hilarii* in the Taquari River, state of São Paulo, Brazil, five species of monogeneans (*Anacanthorus contortus*, *A. bicuspidatus*, *Annulotrematoides parisellei*, *Jainus iocensis* and *Tereancistrum arcuatus*) are reported the first time for this host. A total of 28 fish were sampled quarterly between April 2011 and January 2012, with 10 hosts in a lentic ecosystem and 18 in a lotic ecosystem. Quantitative ecological descriptors (prevalence, intensity of infestation and abundance) were calculated for the purpose to comparing the two ecosystems sampled (lentic and lotic ecosystems). However, no quantitative difference between the lentic and lotic ecosystems was observed. The present study has made available a checklist for species of the genus *Anacanthorus* and their hosts and geographical distribution in the Neotropical region up to the present time.

Keywords: Ectoparasite, Monogenea, freshwater fish, Taquari River.

Resumo

Com o objetivo de inventariar os metazoários parasitos de brânquias de *Salminus hilarii* do rio Taquari, estado de São Paulo, Brasil, cinco espécies de monogenéticos (*Anacanthorus contortus*, *A. bicuspidatus*, *Annulotrematoides parisellei*, *Jainus iocensis*, e *Tereancistrum arcuatus*) foram registradas pela primeira vez para o presente hospedeiro. Um total de 28 peixes foi amostrado trimestralmente entre abril/2011 e janeiro/2012, com 10 hospedeiros no ecossistema lêntico e 18 no ecossistema lótico. Os descritores ecológicos quantitativos (prevalência, intensidade de infestação e abundância) foram calculados com o objetivo de comparar os dois ecossistemas amostrados (ecossistema lêntico *versus* ecossistema lótico). No entanto, nenhuma diferença quantitativa desses foi verificada entre os ecossistemas lêntico e lótico. O presente estudo disponibiliza uma lista de espécies do gênero *Anacanthorus*, os hospedeiros e distribuição geográfica na região Neotropical até o presente momento.

Palavras-chave: Ectoparasito, Monogenea, peixe de água doce, rio Taquari.

Introduction

Monogeneans included in Dactylogyridae are primarily parasites of the gills of marine and freshwater fish. The class Monogenea is the most diversified group and contains the largest number of species parasitizing Neotropical fish (BOEGER; VIANNA, 2006). Specific monogeneans are common helminths parasitizing bony fish worldwide (AKOLL et al., 2012), which is a factor justifying the importance of taxonomic knowledge of species of this class.

Eiras et al. (2011) highlighted the increasing numbers of studies on monogeneans. However, the high number of monogenean species does not necessarily imply that this group has more species than other groups. This may simply have occurred because monogeneans have been more intensively studied than other groups.

Salminus hilarii Valenciennes, 1850, is a freshwater fish popularly known as “tabarana” in Brazil, and is considered to be a migratory species over large distances (BARBIERI et al., 2004). The geographical distribution of this species covers the main Brazilian river basins (Paraná, São Francisco, Tocantins,

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Amazon and Orinoco) (AGOSTINHO et al., 2007; GRAÇA; PAVANELLI, 2007).

The present study underscores and broadens the importance of taxonomic knowledge of species of this parasite group. This is the first study to record occurrences of monogeneans at species level, parasitizing the gills of *S. bilarii*. Kohn et al. (1985) identified one nematode, two digenean, and two monogenean parasites of *S. bilarii*, but the last ones were only identified at superfamily level (Dactylogyridae).

The Taquari River, located in the state of São Paulo, is a tributary of the Paranapanema River, which is influenced by the Jurumirim reservoir. From studies on gill parasites of *S. bilarii* in this context, occurrences of five monogenean species were reported and their quantitative parameters were compared between lentic and lotic ecosystems.

Materials and Methods

Study area

The Jurumirim dam (23° 12' 17" S and 49° 13' 19" W) is the first of a cascade of dams on the Paranapanema River. The reservoir behind this dam is operated such that it regulates others further downstream. The dam was built in the late 1950s and operations began in 1962 (HENRY; NOGUEIRA, 1999). The Taquari River (23° 15' 12" S and 49° 12' 34" W), located in the state of São Paulo, is the second largest tributary of the Jurumirim reservoir (HENRY et al., 1999) (Figure 1).

Fish collection and laboratory procedure

Twenty-eight specimens of *S. bilarii* from the Taquari River were collected between April 2011 and January 2012 in order to study monogenean parasites. The fish were collected using nylon monofilament gillnets with mesh sizes of 3 to 14 cm and with standardized effort. Nets were deployed at 5:00 pm and gathered in at 7:00 am the following day (total exposure time: 14 h). Limnological parameters such as temperature (°C), pH and dissolved oxygen ($\text{mg O}_2\cdot\text{L}^{-1}$) were measured with aid of a multi-parameter analyzer. Individuals were measured in terms of standard length (L_s , to the nearest 0.1 mm) and weight (to the nearest 0.1 g). The gills were frozen and subsequently removed and placed in vials containing 5% formalin solution. The parasites collected were preserved in alcohol 70%. Some parasite specimens were mounted unstained in Hoyer's medium in order to study the sclerotized structures, while others were stained with Gomori's trichrome to observe internal organs (EIRAS et al., 2006).

Hierarchical levels of study and statistical analysis

In accordance with Bush et al. (1997), the following community descriptors were calculated at the infracommunity level: prevalence (%), mean intensity of infestation and mean abundance for each parasite species. After checking the assumptions of normality (Lilliefors test), Pearson's linear correlation (r) was applied to examine the relationships between parasite abundance and the limnological parameters. The Mann-Whitney U test

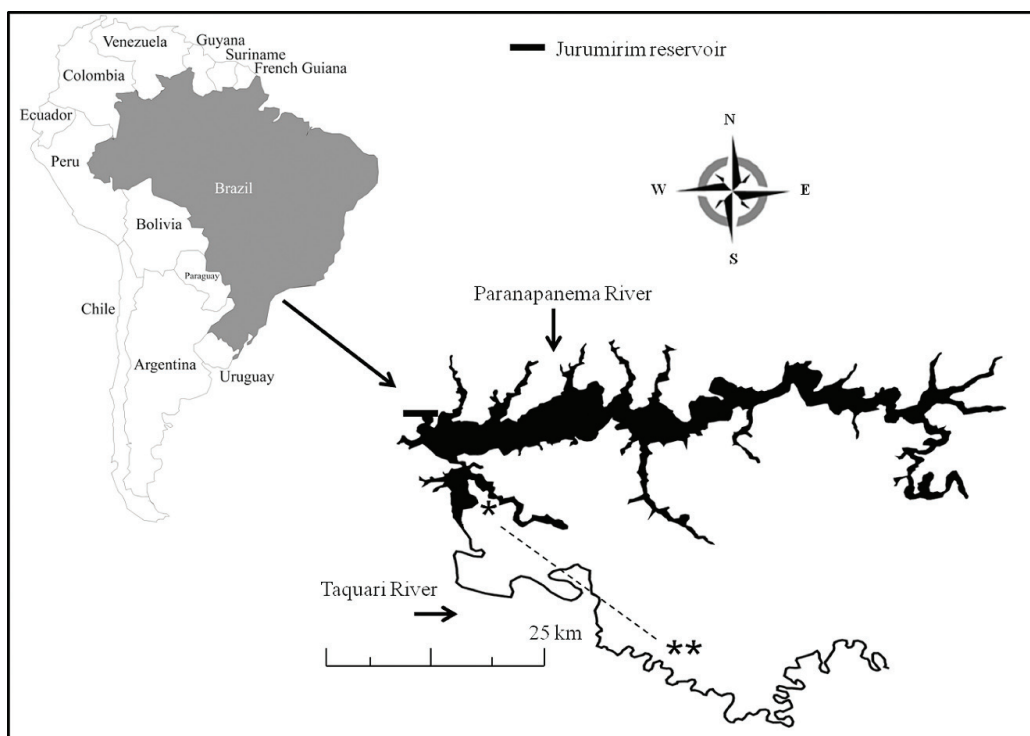


Figure 1. Jurumirim reservoir on the upper Paranapanema River, Brazil. Sampling areas: *lentic and ** lotic ecosystems in the Taquari River (arrow). Source: satellite image from Google Earth Digital Globe

was performed to measure the effects of the lentic and lotic ecosystems on the abundance of each parasite species. Yates' corrected χ^2 together with Spearman's rank correlation (r_s) were also performed on pairs of co-occurring parasite species to investigate possible interspecific associations (i.e. co-operative or antagonistic relationships) (LUDWIG; REYNOLDS, 1988). The Z-test for proportions was performance to check differences in prevalence between infrapopulations of the lentic and lotic ecosystems.

The Berger-Parker index was applied to appraise the numerical dominance trends among parasite species (MAGURRAN, 1988). The variance-to-mean ratio of parasite abundance (dispersion index) and the discrepancy index, computed using the Quantitative Parasitology 3.0 software (RÓZSA et al., 2000), were used to detect distribution patterns of the infrapopulations (POULIN, 1993). The Shannon index (H') was calculated to compared the biological diversity of communities in the lentic and lotic ecosystems (MAGURRAN, 1988). The hierarchical levels and terminology used in this study followed Bush et al. (1997) and Poulin (2004) and the significance level used was $p < 0.05$.

The monogenean species were identified as described by Cohen et al. (2012) and Boeger and Vianna (2006). Voucher specimens were deposited in the Helminthological Collection of the Institute of Biosciences (CHIBB), UNESP, Botucatu, São Paulo, Brazil.

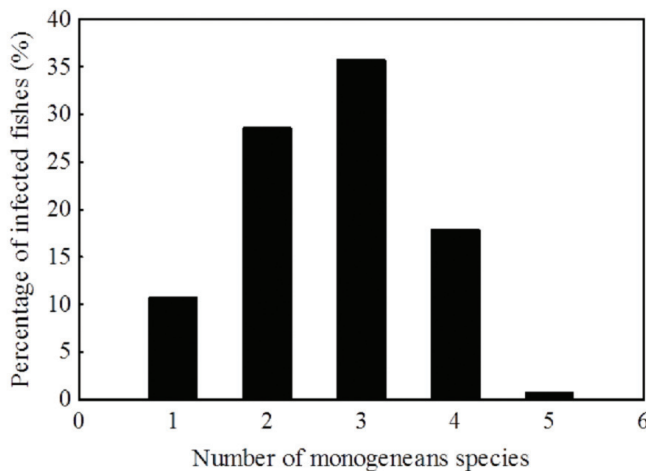


Figure 2. Richness and intensity of infection in communities of monogeneans in the gills of *Salminus hilarii* in the Taquari River, upper Paranapanema River, Brazil.

Table 1. Prevalence (%), total abundance (TA), mean intensity \pm standard error (MI \pm SE) and mean abundance (MA) of monogenean species in *Salminus hilarii* in the Taquari River, upper Paranapanema River, Brazil.

Monogenean species	Lentic ecosystem (n = 10)				Lotic ecosystem (n = 18)			
	%	TA	MI \pm SE	MA	%	TA	MI \pm SE	MA
<i>Anacanthorus contortus</i>	70	109	10.9 \pm 4.6	7.6	94.4	114	6.3 \pm 1.6	5.7
<i>Anacanthorus bicuspidatus</i>	20	9	0.9 \pm 0.6	0.2	16.7	5	0.3 \pm 0.1	0.1
<i>Annulotrematoides parisellei</i>	80	31	3.1 \pm 0.9	2.5	77.8	56	3.1 \pm 0.8	2.5
<i>Jainus iocensis</i>	70	15	1.5 \pm 0.4	1.1	33.3	16	0.9 \pm 0.4	0.3
<i>Tereancistrum arcuatus</i>	70	19	1.9 \pm 0.6	1.3	38.9	45	2.5 \pm 0.7	1.0

Results

A total of 28 fish were captured and all were parasitized by one or more monogenean species (overall prevalence = 100%). About 35% of the fish examined were parasitized by three parasite species (Figure 2). Calculations on the absolute frequencies of the total parasites collected highlighted *Anacanthorus contortus* as the most important numerically (53.2%), followed by *Annulotrematoides parisellei* (20.9%), *Tereancistrum arcuatus* (15.1%), *Jainus iocensis* (7.4%) and *A. bicuspidatus* (3.4%). *Salminus hilarii* is a new host record for all the monogeneans identified.

The component community was composed of five monogenean species totaling 417 specimens. Among these, 183 were collected in a lentic ecosystem and 234 in a lotic ecosystem, with means of 3.36 ± 7.53 and 2.6 ± 4.21 , respectively. Comparing the prevalence and abundance of the component communities of the lotic and lentic ecosystems, no significant difference was observed. Fish from both ecosystems had the same magnitude of species richness and no differences in diversity ($H'_{\text{lentic}} = 1.19$ and $H'_{\text{lotic}} = 1.27$; degrees of freedom = 27; t test = 0.988; $p > 0.05$).

Comparing the component communities, *A. contortus* showed high values for quantitative descriptors in both the lentic and the lotic ecosystems, except for the prevalence values. Among these, *A. parisellei* in the lentic ecosystem stood out with prevalence of 80%. The parasite *A. bicuspidatus* presented the lowest prevalence and *J. iocensis* and *T. arcuatus* presented similar prevalences (Table 1).

Significant covariations of abundance were observed between pairs: *A. contortus* versus *A. bicuspidatus*, *A. contortus* versus *T. arcuatus* and *A. parisellei* versus *T. arcuatus*. Significant associations of prevalence were observed between pairs: *A. contortus* versus *A. bicuspidatus* and *A. parisellei* versus *A. bicuspidatus* (Table 2).

Anacanthorus contortus had the highest dominance frequency at both sites (0.59 and 0.48 in lentic and lotic ecosystems, respectively). All the parasites had a typically aggregated distribution pattern, and *A. bicuspidatus* was the monogenean species that showed the highest discrepancy index values (Table 3).

In relation to the limnological variables (Table 4), the Pearson linear correlation (r) only revealed a statistical difference in the abundance of monogeneans in relation to pH: abundance versus temperature ($R^2 = 0.81$; $p = 0.09$); abundance versus oxygen ($R^2 = 0.15$; $p = 0.61$); and abundance versus pH ($R^2 = 0.89$; $p = 0.05$). Considering the months of May to July to be the dry period and October to January to be the rainy period, greater abundance of monogeneans was observed during the rainy period (Figure 3).

Table 2. Paired associations for monogenean species in *Salminus hilarii* in the Taquari River, upper Paranapanema River, Brazil. Spearman rank correlation (rs). Significant values * $p \leq 0.05$.

Monogenean species	Yates-corrected chi-square (χ^2)				
	1	2	3	4	5
(1) <i>Anacanthorus contortus</i>	—	18.31*	0.11	4.88*	0.79
(2) <i>Anacanthorus bicuspidatus</i>	0.408*	—	18.31*	4.01*	10.62*
(3) <i>Annulotrematoides parisellei</i>	0.284	0.013	—	4.88*	0.79
(4) <i>Jainus iocensis</i>	0.099	-0.007	0.345	—	1.16
(5) <i>Tereancistrum arcuatus</i>	0.489*	0.310	0.475*	-0.115	—

Table 3. Values of variance-to-mean ratio for parasite abundance (ID) and discrepancy index (D) among monogenean parasites of *Salminus hilarii* in the Taquari River, upper Paranapanema River, Brazil.

Monogenean species	ID	D
<i>Anacanthorus contortus</i>	13.256	0.603
<i>Anacanthorus bicuspidatus</i>	3.185	0.868
<i>Annulotrematoides parisellei</i>	3.441	0.520
<i>Jainus iocensis</i>	2.163	0.653
<i>Tereancistrum arcuatus</i>	3.213	0.577

Table 4. Mean values and standard deviations of monthly limnological parameters in the Taquari River, between April 2011 and January 2012.

Months	Temperature (°C)	Oxygen (mg/L)	pH
Apr	18 ± 0.9	9.2 ± 0.8	5.8 ± 0.5
July	15.8 ± 0.5	10 ± 0.0	6.3 ± 0.5
Oct	23.8 ± 0.5	10 ± 0.0	7 ± 0
Jan	25 ± 0.8	8 ± 1	7 ± 0

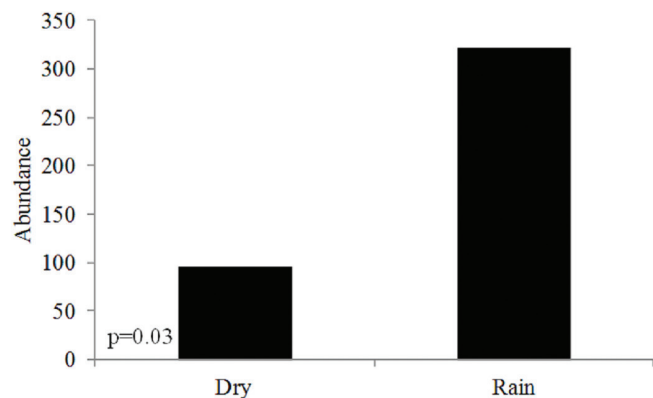


Figure 3. Comparison of the abundance of monogeneans parasitizing the gills of *S. hilarii* in the Taquari River, upper Paranapanema River, Brazil, between the dry period (April to July) and the rainy period (October to January). Significantly different values in Mann-Whitney U test ($p < 0.05$).

Discussion

The present study reports occurrences of five monogenean species parasitizing *S. hilarii* in the Taquari River, Brazil. Individual species of *Anacanthorus* show varying ability to infest closely related

host species. Furthermore, subgroups within *Anacanthorus*, based on the general morphology of the copulatory complex, appear to express high host specificity to familial groups within the Characidae. Because of these traits, species of *Anacanthorus* may provide valuable models for studying biogeography (KRITSKY et al., 1992). These characteristics may explain the higher abundance and mean intensity of infestations relating to *A. contortus*.

The genus *Anacanthorus* has large species diversity. To date, 70 species have been described, mostly from the Amazon region (Table 5). According to Van Every and Kritsky (1992), species diversity among Amazonian fish and their parasites may have resulted from lacustrine resource partitioning, similar to that proposed to explain cichlid diversity in some African lakes (LOWE-MCCONNELL, 1987) and Pliocene diversity in lake Idaho (SMITH, 1975).

So far, monogenean species of *Anacanthorus* have been recorded parasitizing twenty species of fish of the order Characiformes in the Neotropical region: *Brycon amazonicus*, *Brycon melanopterus*, *Brycon orthotaenia*, *Catoprion mento*, *Colossoma bidens*, *Colossoma macropomum*, *Myleus rubripinnis*, *Mylossoma duriventris*, *Oreochromis mossambicus* (= *Tilapia mossambica*), *Piaractus mesopotamicus*, *Pristobrycon eigenmanni* (= *Serrasalmus eigenmanni*), *Pristobrycon striolatus*, *Pristobrycon* sp., *Pygocentrus nattereri*, *Roeboides myersii*, *Salminus brasiliensis*, *Serrasalmus elongatus*, *Serrasalmus rhombeus*, *Serrasalmus spilopleura*, *Serrasalmus* sp., *Triporthesus albus*, *Triporthesus angulatus*, *Triporthesus elongatus*, *Triporthesus* sp. and *Salminus affinis* (KRITSKY et al., 1979; KRITSKY et al., 1992; KOHN; COHEN, 1998; FISCHER et al., 2003; ANDRADE; MALTA, 2006; MONTEIRO et al., 2010; COHEN et al., 2012).

The genus *Jainus* has been recorded in the following hosts in South America: *Brycon amazonicus*, *B. cephalus*, *B. melanopterus*, *Chalceus macrolepidotus*, *Cretochanes affinis*, *Leporinus copelandii*, *Moenkhausia sanctaefilomenae*, *Salminus brasiliensis* and *Schizodon borellii* (MIZELLE et al., 1969; KRITSKY et al., 1980; KOHN; COHEN, 1998; ANDRADE et al., 2001; ANDRADE; MALTA, 2006; TAKEMOTO et al., 2009; KARLING et al., 2011; COHEN et al., 2012). *Tereancistrum* has been recorded in *Brycon amazonicus*, *B. melanopterus*, *Leporinus fasciatus*, *Prochilodus reticulatus* and *Salminus brasiliensis* (KRITSKY et al., 1980; KOHN; COHEN, 1998; ANDRADE; MALTA, 2006; COHEN et al., 2012).

During this study, we observed differences in correlations between the abundance of monogeneans and pH, which possibly influenced the presence or absence of these organisms. However,

Table 5. Checklist of *Anacanthorus* species and their hosts and geographical distribution in the Neotropical region.

Species	Host	Family host	Locality	Reference
<i>A. acuminatus</i>	<i>Tripottheus albus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Tripottheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Tripottheus elongatus</i>	Characidae	Amazon and Solimões Rivers, Brazil	Kritsky et al. (1992)
<i>A. alatus</i>	<i>Tripottheus albus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Tripottheus elongatus</i>	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. amazonicus</i>	<i>Pristobrycon striolatus</i>	Serrasalmidae	Samaumã Pond and Uatumã River, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumã and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	San Martín, Beni and Ichilo Rivers, Bolivia	Córdova and Pariselle (2007)
	<i>Serrasalmus</i> sp.	Serrasalmidae	Agua Branca Igarape, and Pitinga and Uatumã Rivers, Brazil	Van Every and Kritsky (1992)
<i>A. anacanthorus</i>	<i>Pygocentrus nattereri</i>	Serrasalmidae	Amazon River, Brazil	Mizelle and Price (1965)
<i>A. andersoni</i>	<i>Tripottheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. beleophallus</i>	<i>Pristobrycon eigenmanni</i>	Serrasalmidae	Negro River, Brazil	Kritsky et al. (1992)
<i>A. bellus</i>	<i>Tripottheus albus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Tripottheus elongatus</i>	Characidae	Amazon and Solimões Rivers, Brazil	Kritsky et al. (1992)
	<i>Tripottheus</i> sp.	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. bicuspidatus</i>	<i>Salminus brasiliensis</i>	Characidae	Paraná River, Brazil	Cohen et al. (2012)
<i>A. brasiliensis</i>	<i>Pygocentrus nattereri</i>	Serrasalmidae	Amazon River, Brazil	Mizelle and Price (1965)
<i>A. brevis</i>	<i>Brycon melanopterus</i>	Characidae	Xeruiy River, Brazil	Mizelle and Kritsky (1969)
<i>A. brevicirrus</i>	<i>Brycon orthotaenia</i>	Characidae	São Francisco River, Brazil	Monteiro et al. (2010)
<i>A. calophallus</i>	<i>Tripottheus elongatus</i>	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. carinatus</i>	<i>Tripottheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. catoprioni</i>	<i>Catoprion mento</i>	Serrasalmidae	Uatumã and Amazon Rivers, Brazil	Kritsky et al. (1992)
<i>A. chaunophallus</i>	<i>Tripottheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. chelophorus</i>	<i>Tripottheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Tripottheus</i> sp.	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. cinctus</i>	<i>Pristobrycon striolatus</i>	Serrasalmidae	Samaumã Pond and Uatumã River, Brazil	Van Every and Kritsky (1992)
<i>A. cladophallus</i>	<i>Serrasalmus spilopleura</i>	Serrasalmidae	Solimões River, Brazil	Van Every and Kritsky (1992)
<i>A. colombianus</i>	<i>Oreochromis mossambicus</i>	Cichlidae	Ruedasuelta Pond, Colombia	Kritsky and Thatcher (1974)
	<i>Salminus affinis</i>	Characidae	Jamundi River, Colombia	Kritsky and Thatcher (1974)
<i>A. contortus</i>	<i>Salminus brasiliensis</i>	Characidae	Paraná River, Brazil	Cohen et al. (2012)
<i>A. cornutus</i>	<i>Tripottheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. crytocaulus</i>	<i>Pristobrycon striolatus</i>	Serrasalmidae	Agua Branca Igarape, Samaumã Pond and Pitinga and Uatumã Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Salminus affinis</i>	Characidae	Jamundi River, Colombia	Kritsky and Thatcher (1974)
<i>A. cuticulovaginus</i>	<i>Salminus brasiliensis</i>	Characidae	Paraná River, Brazil	Cohen et al. (2012)
<i>A. dipelecinus</i>	<i>Roeboides myersi</i>	Characidae	Solimões and Negro Rivers, Brazil	Kritsky et al. (1992)
<i>A. douradensis</i>	<i>Salminus brasiliensis</i>	Characidae	Paraná River, Brazil	Cohen et al. (2012)
<i>A. elegans</i>	<i>Brycon melanopterus</i>	Characidae	Janauacá Lake, Brazil	Kritsky et al. (1979)
<i>A. euryphallus</i>	<i>Tripottheus albus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Tripottheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Tripottheus elongatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. formosus</i>	<i>Tripottheus elongatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Tripottheus</i> sp.	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. franciscanus</i>	<i>Brycon orthotaenia</i>	Characidae	São Francisco River, Brazil	Monteiro et al. (2010)
<i>A. furculus</i>	<i>Tripottheus elongatus</i>	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. glyptophallus</i>	<i>Tripottheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. gravihamulatus</i>	<i>Pristobrycon eigenmanni</i>	Serrasalmidae	Uatumã River, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Agua Branca Igarape, and Pitinga and Uatumã Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Madre Dios River, Bolivia	Córdova and Pariselle (2007)
	<i>Serrasalmus</i> sp.	Serrasalmidae	Agua Branca Igarape, and Pitinga and Uatumã Rivers, Brazil	Van Every and Kritsky (1992)

Table 5. Continued...

Species	Host	Family host	Locality	Reference
<i>A. hoplophallus</i>	<i>Myleus rubripinnis</i>	Serrasalmidae	Uatumá River, Brazil	Kritsky et al. (1992)
<i>A. jegui</i>	<i>Pristobrycon eigenmanni</i>	Serrasalmidae	Uatumá River, Brazil	Kritsky et al. (1992)
	<i>Pristobrycon</i> sp.	Serrasalmidae	Uatumá River, Brazil	Kritsky et al. (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	San Martín, Beni, Madre Dios and Ichilo Rivers, Bolivia	Córdova and Pariselle (2007)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Agua Branca Igarape, and Pitinga and Uatumá Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus spilopleura</i>	Serrasalmidae	Solimões River, Brazil	Kritsky et al. (1992)
	<i>Serrasalmus</i> sp.	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumá and Amazon Rivers, Brazil	Kritsky et al. (1992)
<i>A. kruidenieri</i>	<i>Brycon melanopterus</i>	Characidae	Janauacá Lake Amazon, Brazil	Kritsky et al. (1979)
<i>A. lasiophallus</i>	<i>Pristobrycon striolatus</i>	Serrasalmidae	Agua Branca Igarape, Samaumá Pond and Pitinga and Uatumá Rivers, Brazil	Van Every and Kritsky (1992)
<i>A. lepyrophallus</i>	<i>Serrasalmus elongatus</i>	Serrasalmidae	Negro River, Brazil	Kritsky et al. (1992)
	<i>Serrasalmus</i> sp.	Serrasalmidae	Amazon and Solimões Rivers, Brazil	Kritsky et al. (1992)
<i>A. lygophallus</i>	<i>Triportheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. maltai</i>	<i>Pygocentrus nattereri</i>	Serrasalmidae	Mamoré River, Brazil	Boeger and Kritsky (1988)
<i>A. mastigophallus</i>	<i>Pristobrycon eigenmanni</i>	Serrasalmidae	Uatumá River, Brazil	Kritsky et al. (1992)
<i>A. mesocondylus</i>	<i>Pristobrycon eigenmanni</i>	Serrasalmidae	Uatumá and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Pristobrycon</i> sp.	Serrasalmidae	Uatumá River, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus elongatus</i>	Serrasalmidae	Solimões and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumá and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus spilopleura</i>	Serrasalmidae	Solimões River, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus</i> sp.	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumá and Solimões Rivers, Brazil	Van Every and Kritsky (1992)
<i>A. nanus</i>	<i>Triportheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. neotropicalis</i>	<i>Pygocentrus nattereri</i>	Serrasalmidae	Amazon River, Brazil	Mizelle and Price (1965)
<i>A. palamophallus</i>	<i>Pristobrycon eigenmanni</i>	Serrasalmidae	Uatumá River, Brazil	Kritsky et al. (1992)
<i>A. parakruidenieri</i>	<i>Salminus brasiliensis</i>	Characidae	Paraná River, Brazil	Cohen et al. (2012)
<i>A. paraspathulatus</i>	<i>Mylossoma aureum</i>	Serrasalmidae	Guandu River, Brazil	Azevedo et al. (2010)
	<i>Mylossoma duriventris</i>	Serrasalmidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. pedanophallus</i>	<i>Myleus rubripinnis</i>	Serrasalmidae	Uatumá River, Brazil	Kritsky et al. (1992)
<i>A. pelorophallus</i>	<i>Triportheus elongatus</i>	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. penilabiatus</i>	<i>Colossoma macropomum</i>	Serrasalmidae	National Department of Public Works against Drought, Brazil	Pamplona-Basilio et al. (2001)
	<i>Piaractus brachypomus</i>	Serrasalmidae	National Department of Public Works against Drought, Brazil	Pamplona-Basilio et al. (2001)
	<i>Piaractus mesopotamicus</i>	Serrasalmidae	Aquaculture Center (CAUNESP), Brazil	Boeger et al. (1995)
	<i>Piaractus mesopotamicus</i>	Serrasalmidae	National Department of Public Works against Drought, Brazil	Pamplona-Basilio et al. (2001)
<i>A. periphallus</i>	<i>Serrasalmus</i> sp.	Serrasalmidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. pithophallus</i>	<i>Triportheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
<i>A. prodigiosus</i>	<i>Serrasalmus elongatus</i>	Serrasalmidae	Negro River, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumá and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus</i> sp.	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumá and Solimões Rivers, Brazil	Van Every and Kritsky (1992)
<i>A. quinqueramus</i>	<i>Triportheus albus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Triportheus elongatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Triportheus</i> sp.	Characidae	Solimões Rives, Brazil	Kritsky et al. (1992)
<i>A. ramosissimus</i>	<i>Serrasalmus elongatus</i>	Serrasalmidae	Solimões River, Brazil	Van Every and Kritsky (1992)
<i>A. ramulosus</i>	<i>Triportheus albus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Triportheus elongatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)

Table 5. Continued...

Species	Host	Family host	Locality	Reference
<i>A. reginae</i>	<i>Pygocentrus nattereri</i>	Serrasalmidae	Solimões River, Brazil, and Amazon River, Loreto, Peru	Boeger and Kritsky (1988), Iannacone and Luque (1993)
<i>A. rondonensis</i>	<i>Pygocentrus nattereri</i>	Serrasalmidae	Mamoré River, Brazil	Boeger and Kritsky (1988)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Madre Dios River, Bolivia	Córdova and Pariselle (2007)
<i>A. scapanus</i>	<i>Serrasalmus spilopleura</i>	Serrasalmidae	Solimões River, Brazil	Van Every and Kritsky (1992)
<i>A. sciponophallus</i>	<i>Serrasalmus elongatus</i>	Serrasalmidae	Solimões and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumã and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	San Martin, Beni, Madre Dios and Ichilo Rivers, Bolivia	Córdova and Pariselle (2007)
	<i>Serrasalmus spilopleura</i>	Serrasalmidae	Solimões River, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus</i> sp.	Serrasalmidae	Solimões, Uatumã and Negro Rivers, Brazil	Van Every and Kritsky (1992)
<i>A. serrasalmi</i>	<i>Pristobrycon</i> sp.	Serrasalmidae	Uatumã River, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus elongatus</i>	Serrasalmidae	Solimões and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus rhombeus</i>	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumã and Negro Rivers, Brazil	Van Every and Kritsky (1992)
	<i>Serrasalmus</i> sp.	Serrasalmidae	Agua Branca Igarape, and Pitinga, Uatumã and Negro Rivers, Brazil	Van Every and Kritsky (1992)
<i>A. spatulatus</i>	<i>Colossoma bidens</i>	Serrasalmidae	Janauacá Lake Amazon, Brazil	Kritsky et al. (1979)
	<i>Colossoma macropomum</i>	Serrasalmidae	Janauacá Lake Amazon, Brazil	Kritsky et al. (1979)
	<i>Colossoma macropomum</i>	Serrasalmidae	Delta Amacuro and Portuguesa, Venezuela	Aragort et al. (2002), Centeno et al. (2004)
<i>A. spinatus</i>	<i>Myleus rubripinnis</i>	Serrasalmidae	Uatumã River, Brazil	Kritsky et al. (1992)
<i>A. spiralocirrus</i>	<i>Brycon amazonicus</i>	Characidae	Amazon River, Brazil	Andrade and Malta (2006)
	<i>Brycon melanopterus</i>	Characidae	Janauacá Lake Amazon, Brazil	Kritsky et al. (1979)
<i>A. stachophallus</i>	<i>Pygocentrus nattereri</i>	Serrasalmidae	Amazon and Solimões Rivers, Brazil	Kritsky et al. (1992)
	<i>Pygocentrus nattereri</i>	Serrasalmidae	Solimões River, Brazil	Boeger and Kritsky (1988)
	<i>Pygocentrus nattereri</i>	Serrasalmidae	Amazon River, Loreto, Peru	Iannacone and Luque (1993)
<i>A. stagmophallus</i>	<i>Myleus rubripinnis</i>	Serrasalmidae	Uatumã River, Brazil	Kritsky et al. (1992)
<i>A. strongylophallus</i>	<i>Triportheus elongatus</i>	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. thatcheri</i>	<i>Pygocentrus nattereri</i>	Serrasalmidae	Solimões River, Brazil	Boeger and Kritsky (1988)
<i>A. tricornis</i>	<i>Triportheus angulatus</i>	Characidae	Amazon River, Brazil	Kritsky et al. (1992)
	<i>Triportheus elongatus</i>	Characidae	Solimões River, Brazil	Kritsky et al. (1992)
<i>A. xaniophallus</i>	<i>Pristobrycon eigenmanni</i>	Serrasalmidae	Uatumã River, Brazil	Kritsky et al. (1992)
	<i>Pristobrycon</i> sp.	Serrasalmidae	Uatumã and Negro Rivers, Brazil	Kritsky et al. (1992)

studies on the physiology of the host are needed in order to confirm the degree of influence of the pH of these organisms.

Regarding parasite dispersion, in most cases, the parasites are almost universally aggregated between their hosts (KRASNOV; POULIN, 2010). That is to say, most of the hosts have few if any parasites, while a small number of hosts are infected with many parasites (POULIN, 1993). This pattern is expected in most animals in nature, as observed regarding monogeneans parasitizing the gills of *S. hilarii* in the present study, except for *A. parisellei* in the lentic gradient. This type of distribution is possibly related to variations in the characteristics of the environment or the behavior of living beings that try to group (NERING; ZUBEN, 2010).

According Thomas et al. (2005), considerable progress has been made in understanding the functional value of parasites in ecosystems. Numerous theoretical and empirical studies have shown that parasites, in spite of their small size, are biologically and ecologically important in ecosystems. The influence of

monogeneans on fish behavior in nature is difficult to measure, but we considered them within the life history of the host in order to gain better understanding of both organisms within their ecological niches.

Knowledge of the geographical and systematic distribution of monogenean species is also of considerable importance, since these organisms can be used as tools to aid in understanding, conserving and preserving aquatic ecosystems.

The present study provides the first record of occurrences of the monogeneans *A. contortus*, *A. bicuspidatus*, *A. parisellei*, *J. iocensis* and *T. arcuatus* parasitizing the gills of the host *S. hilarii* in the Taquari River in the state of São Paulo, Brazil. This study contributes towards the knowledge of occurrences of these species of parasites in fish of the family Characidae and their geographical distribution, as well as listing the host species and geographical distribution of the genus *Anacanthorus* in South America.

Acknowledgements

The authors thank Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP process: 2011/22603-3) for the scholarship granted to the first author and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES process: AUX-PE-PNPD 3005/2010). They are grateful to the staff of the Fish Biology and Ecology Laboratory of the Institute of Biosciences, Botucatu, and Universidade Estadual Paulista (UNESP) for the structure provided for developing this work.

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