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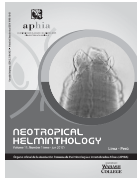

ORIGINAL ARTICLE / ARTÍCULO ORIGINAL

MONOGENEAN PARASITES SPECIES IN *SERRASALMUS ALTISPINIS* MERCKX, JÉGU & SANTOS (CHARACIFORMES: SERRASALMIDAE) FROM BRAZILIAN AMAZON FLOODPLAINS LAKES

ESPECIES DE MONOGENEOS PARÁSITOS EN *SERRASALMUS ALTISPINIS* MERCKX, JÉGU & SANTOS, 2000 (CHARACIFORMES: SERRASALMIDAE) DE LAGOS INUNDABLES DE LA AMAZONÍA BRASILEÑA

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ABSTRACT

Serrasalmus altispinis Merckx, Jégu & Santos, 2000 is an abundant fish species from floodplain lakes in the Brazilian Amazon. Information concerning to its parasitic fauna is lacking. The present study aimed to identify the Monogenean species that parasitize their gills. Fifty-nine specimens of *S. altispinis* were caught in six floodplain lakes in the Brazilian Amazon, between March and December 2013. Seven-hundred-thirty-nine (739) Monogenean specimens belonging to seven genera and 22 species were collected. All parasites species are recorded for the first time in *S. altispinis*. Within the Monogenean species, *Anacanthorus jegui* Van Every & Kritsky, 1992 showed to be the most prevalent species (50.85%) and *Notozothecium deleastoideum* Kritsky, Boeger & Jegú, 1998 the dominant one (20.08%) showing the greatest intensity of infection (149) and mean abundance (2.51), respectively. The large number of Monogenean species registered in *S. altispinis,* points out to the importance of this fish species in maintaining the diversity in Brazilian Amazon floodplain lakes.

Key words: Dactylogyridae – ectoparasites – fish – gills – piranha

RESUMEN

Serrasalmus altispinis Merckx, Jégu & Santos, 2000 es una especie de pez abundante en lagos inundables de la Amazonía brasileña y debido a su reciente descripción, carece de información acerca de su fauna parasitaria; así, el presente estudio tuvo como objetivo identificar las especies de Monogenea que parasitan sus branquias. Cincuenta y nueve especímenes de *S. altispinis* fueron capturadas en seis lagos inundables de la Amazonía brasileña entre marzo y diciembre del 2013. Fueron colectados setecientos treinta y nueve (739) especímenes de Monogenea, perteneciendo a siete géneros y 22 especies. Todas las especies fueron registradas por primera vez en *S. altispinis*. Dentro de las especies de Monogenea, *Anacanthorus jegui* Van Every & Kritsky, 1992 fue la especie con mayor prevalencia parasitaria (50,85%) y *Notozothecium deleastoidem* Kritsky, Boeger & Jegú, 1998 la especie dominante (20,08%), registrando también la mayor intensidad de infección (149) y abundancia media (2,51). El alto número de especies de Monogenea registradas en *S. altispinis,* resalta la importancia de esta especie de mantener la diversidad en lagos inundables de la Amazonía brasileña.

Palavras clave: Branquias – Dactylogyridae – ecotoparásitos – peces – piraña

INTRODUCTION

The class Monogenea is very diverse in number of species, morphology and ecology (Poulin, 2002). Monogenean species parasitize the, skin, outer and inner organs of several aquatic vertebrates, and they are well known by their high host and infestation site's specificity (Poulin, 1992).

In the Neotropical region there exist around 300 Monogenean species and Brazil has the largest number of parasites recorded in Serrasalmidae fish species (Cohen *et al.*, 2013). Dactylogyridae is the most diverse taxon on these hosts (Boeger *et al*., 2006).

Hosts, defined as home, mating point and resource for parasites, consist of replicated habitats in time and space. Host-parasite systems are undoubtedly interesting models for understanding patterns and processes in community ecology (Price, 1990).

Taxonomical studies contribute to the knowledge of the diversity, not only with the discovery of new species, but also by registering new occurrences in new hosts and in new geographical areas (Luque & Poulin, 2007). Studies in Serrasalmidae species have showed the major role of this fish species as hosts of many Monogenean parasites, thus, contributing directly with the local biodiversity (Boeger & Kritsky, 1988; Kritsky *et al.* 1988; Boeger & Thatcher, 1988; Kritsky *et al.,* 1997).

Within Serralsamidae, *Serrasalmus altispinis* Merckx, Jégu & Santos, 2000, commonly known as "piranha seca" inhabits lakes of white water Rivers, usually being capture together with *S. rhombeus* close to the aquatic vegetation and in the flooded forest (Claro-Jr., 2003). As *S. altispinis* is a recently described species (Merckx *et al.*, 2000). There is still scarce information about their parasitic fauna, thus, the present study aimed to identify the species of Monogenea that parasitize their gills in different Brazilian Amazon floodplain lakes.

MATERIAL AND METHODS

Between March and December 2013, 59 *S. altispinis* were captured in five floodplain lakes of the Solimões River: Lake Baixio (03°17'27, 2"S/ 60°04'29,6"W) in the township of Iranduba, Lake Preto (03°21'17, 1''S/ 60°37'28,6''W) in Manacapurú; Lake Ananá (03°53'54,8''S/ 61°40'18,4"W) in Anori; Lake Araçá (S03°45' 04,3" S/ 62°21' 25,9" W) in Codajás and Lake Maracá (03°50'32,8"S/ 62°34'32,4"W) in Coari and one lake in the Purus River: São Tomé (03°49' 39,0"S/ 61°25' 24,6" W).

Fish were caught using 100 mm between adjacent nodes-meshed, 20 m long x 2 m high gillnets. Posteriorly the fishes were quickly immersed in 75 mg clove oil·L^{-1} solution and euthanized (CONCEA, 2013). In the field, fishes were measured and weighed and posteriorly gills were removed and preserved in formalin 5% for posterior analyses at the laboratory of Fish Parasitology (LPP) in the National Institute of Amazonian Research (INPA).

At the laboratory, the Monogenean species found were preserved in formalin 5% (Amato *et al*., 1991). For morphological studies, the parasites were mounted in Grey and Wess medium (Amato *et al.,* 1991).

Taxonomical identification was according to Boeger & Kritsky (1988); Kritsky *et al.* (1988); Boeger & Thatcher (1988); Kritsky *et al.* (1997). Morphometric analyses were performed using a computerized system for analysis of images QWin Lite 2.5 (Leica). Voucher specimens were deposited in the zoological collection of the National Institute of Amazonian Research (INPA). Vocher numbers are showed in the results following the species name between brackets.

The ecological terms in parasitology follow Bush *et al.* (1997): prevalence (P) is the number of infected fish with one or more individuals of a particular parasite species (or taxonomic group) divided by the number of hosts examined (expressed as a percentage). Intensity (of infection, I) is the number of individuals of a particular parasite species in a single infected host (expressed as a numerical range); mean intensity (of infection, mI) is the average intensity, or the total number of parasites of a particular species found in a sample divided by the number of infected hosts; and mean abundance (of infection, mA) is the average abundance, or the total number of parasites of a particular species found in a sample divided by the number of total hosts.

On the prevalence basis and according to Bush & Holmes (1986), the parasite species were termed: Core (prevalence > 66%), secondary (prevalence between 33 and 66%) and satellite (prevalence < 33%).

The dominance index of each parasite species was calculated according to Rohde *et al.* (1995): $D_A = [(N_A / N_A + N_B + N_C + \ldots N_N) \times 100]$; where N_A is the dominance of species A; $N_A + N_B + N_C + \ldots N_N$ is the total number of individuals of species A, B, C …N.

The constancy of occurrence method (Dajoz, 1973) aided to identify the resident species, by the followed expression: $c = [(p / P) \times 100]$, where p is the number of collections containing the species in interest and P is the total number of collections performed. The species with $c \geq 50$ were considered constant, with $25 \leq c < 50$, accessory and with $c < 25$, accidental.

The variance-to-mean-ratio (VMR) and the Green index (GI) were used to examine dispersion patterns of Monogenean species (Ludwig & Reynolds, 1988). Green's index was used to compare samples that vary in the total number of individuals, their sample means and the number of sample units in the sample. GI varies between 0 (for random) and 1 (for maximum clumping) (Ludwig & Reynolds, 1988). Statistical significance was set at $p < 0.05$. Data were analyzed using the software BioEstat 5.0.

RESULTS

Fifty-nine gills of *S. altispinis* with 11.89 cm ± 2.40 standard lengths were analyzed. Fifty-three fish (90%) were parasitized by at least one Monogenean species. Seven hundred and thirty nine (739) specimens of the class Monogenea, belonging to seven genera and 22 species were collected: *Amphithecium diclonophallum* Kritsky, Boeger & Jégu, 1997 (INPA 620); *A. falcatum* Boeger & Kritsky, 1988 (INPA 621); *Anacanthorus amazonicus* Kritsky & Boeger, 1995 (INPA 622); *A. cintus* Van Every & Kritsky, 1992 (INPA 623), *A. cladophallus* Van Every & Kritsky, 1992 (INPA 624); *A. crytocaulus* Van Every & Kritsky, 1992 (INPA 625); *A. gravihamulatus* Van Every & Kritsky, 1992 (INPA 626); *A. jegui* Van Every & Kritsky, 1992 (INPA 627); *A. lepyrophallus* Kritsky, Boeger & Van Every 1992 (INPA 628); *A. mesocondylus* Van Every & Kritsky, 1992 (INPA 629); *A. peryphallus* Kritsky, Boeger & Van Every 1992 (INPA 630); *A. prodigiosus* Van Every & Kritsky, 1992 (INPA 631); *A. sciponophallus* Van Every & Kritsky, 1992 (INPA 632); *A. serrasalmi* Van Every & Kritsky, 1992 (INPA 633), *Anacanthorus* sp. (INPA

Table 1. Parasitic indexes, dominance index (DI), community status (CM) and constancy of occurrence method (C%) of the Monogenean parasites species in *Serrasalmus altispinis* collected in Brazilian Amazon floodplain lakes.

Monogenean species	N	Ni	*P* (%)	I	Rx	mI ± *s*	mA	DI	CM	C%	C
Amphithecium diclonophallum	59	7	11.86	12	(1 - 5)	1.71 ± 1.49	0.2	1.63	Satellite	17	Accidental
Amphithecium facatum	59	22	37.29	71	(1 - 14)	3.22 ± 3	1.2	9.63	Secondary	42	Accesory
Anacanthorus amazonicus	59	8	13.56	21	(1 - 13)	2.62 ± 4.20	0.36	2.85	Satellite	25	Accesory
Anacanthorus cintus	59	2	3.39	4	(1 - 3)	2 ± 1.41	0.07	0.54	Satellite	4	Accidental
Anacanthorus cladophallus	59	1	1.69	1	1	1	0.02	0.14	Satellite	4	Accidental
Anacanthorus crytocalus	59	2	3.39	2	2	1	0.03	0.27	Satellite	8	Accidental
Anacanthorus gravihamulatus	59	2	3.39	2	2	1	0.03	0.27	Satellite	8	Accidental
Anacanthorus jegui	59	30	50.85	104	(1 - 13)	3.46 ± 2.99	1.76	14.11	Secondary	46	Accesory
Anacanthorus lepyrophallus	59	13	22.03	45	(1 - 16)	3.46 ± 4.99	0.76	6.11	Satellite	38	Accesory
Anacanthorus mesocondylus	59	18	30.51	34	(1 - 13)	1.88 ± 2.80	0.58	4.61	Satellite	33	Accesory
Anacanthorus peryphallus	59	13	22.03	21	(1 - 3)	1.61 ± 0.76	0.36	2.85	Satellite	33	Accesory
Anacanthorus prodigiosus	59	9	15.25	12	(1 - 3)	1.33 ± 0.70	0.2	1.63	Satellite	13	Accidental
Anacanthorus sciponophalus	59	20	33.9	44	(1 - 7)	2.2 ± 1.63	0.75	5.97	Secondary	46	Accesory
Anacanthorus serrasalmi	59	3	5.08	4	(1 - 2)	1.33 ± 0.57	0.07	0.54	Satellite	8	Accidental
Anacanthorus sp.	59	22	37.29	68	(1 - 5)	3.04 ± 1.60	1.14	9.09	Secondary	33	Accesory
Calpidothecium crescentis	59	1	1.69	1	1	1	0.02	0.14	Satellite	4	Accidental
Enallothecium aegidatum	59	16	27.12	54	(1 - 7)	3.31 ± 1.92	0.9	7.19	Satellite	38	Accesory
Myramothecium whittingtoni	59	2	3.39	2	2	1	0.03	0.27	Satellite	8	Accidental
Notothecium cyphophallum	59	17	28.81	71	(1 - 21)	4.17 ± 5.99	1.2	9.63	Satellite	33	Accesory
Notothecium deleastoideum	59	23	38.98	149	(1 - 25)	6.43 ± 6.05	2.51	20.08	Secondary	42	Accesory
Notozothecium euzeti	59	1	1.69	1	1	1	0.02	0.14	Satellite	4	Accidental
Notozothecium minor	59	12	20.34	16	(1 - 3)	1.33 ± 0.77	0.27	2.17	Satellite	29	Accesory

N = Number of examined fish; Ni = number of infected fish; *P* % = prevalence; I = intensity of infection; Rx = intensity of infection range variation; mI = mean intensity of infection; mA = mean abundance; ± *s* = shunting line standard.

Table 2. Morphometric characters measuring matrix of Monogenean species parasitizing *Serrasalmus altispinis* (measures in µm).

Monogenean Species	**Body lenght**	**Body wider width**	**Haptorial lenght**	**Haptorial width**	**Ventral anchor lenght**	**Dorsal anchor lenght**	**Ventral bar**	**Dorsal bar**	**Cirrus lenght**	**Accesory piece**
Amphithecium diclonophallum	230 (222-237)	100 (94-106)	51 (49-62)	75 (69-80)	30 (31-34)	33 (32-36)	31 (30-33)	28 (27-30)	30 (26-33)	18 (16-20)
Amphithecium facatum	250 (218-290)	80 (65-86)	54 (50-60)	76 (70-80)	27 (24-29)	31 (29-36)	28 (26-33)	26 (24-27)	40 (37-42)	33 (31-36)
Anacanthorus amazonicus	365 (300 – 403)	90 (80-99)	40 (36-42)	75 (70-79)	-	-	-	-	62 (59-73)	50 (47-55)
Anacanthorus cintus	460 (312-583)	85 (76-91)	30 (28-38)	73 (65-88)	-	-	-	-	52 (46-54)	50 (39-53)
Anacanthorus cladophallus	360	80	40	65	-	-	-	-	54	50
Anacanthorus crytocalus	400	68	40	81	-	-	-	-	43	45
Anacanthorus gravihamulatus	538	110	88	73	-	-	-	-	60	58
Anacanthorus jegui	483 (463-506)	80 (73-94)	34 (33-38)	73 (54-88)	-	-	-	-	48 (44-54)	39 (34-40)
Anacanthorus lepyrophallus	410 (280-529)	88 (72-100)	43 (34-49)	74 (61-79)	-	-	-	-	58 (50-66)	48 (43-55)
Anacanthorus mesocondylus	418 (362-490)	99 (96-110)	42 (38-44)	79 (70-89)	-	-	--	-	76 (69-83)	78 (70-79)

Monogenean Species	Body lenght	Body wider width	Haptorial lenght	Haptorial width	Ventral anchor lenght	Dorsal anchor lenght	Ventral bar	Dorsal bar	Cirrus lenght	Accesory piece
Anacanthorus periphallus	320 (240-379)	109 (88-139)	47 (40-58)	90 (67-102)	-	-	-	-	53 (49-59)	50 (44-53)
Anacanthorus prodigiosus	470 (440-530)	106 (89-128)	48 (44-53)	88 (82-93)	-	-	-	-	68 (67-71)	55 (52-60)
Anacanthorus sciponophallus	384 (332-487)	83 (60-95)	34 (30-43)	72 (66-80)	-	-	-	-	80 (73-88)	75 (68-83)
Anacanthorus serrasalmi	530 (528-532)	102 (98-105)	46 (40-48)	78 (72-80)	-	-	-	-	62 (59-65)	59 (55-59)
Anacanthorus sp.	532 (433-597)	129 (109-162)	59 (41-62)	122 (84-148)	-	-	-	-	89 (79-100)	61 (47-69)
Calpidothecium crescentis	280	75	78	88	47	39	40	33	30	36
Enallothecium aegidatum	218 (180-238)	89 (86-97)	60 (55-66)	94 (88-97)	40 (38-43)	34 (29-34)	35 (33-41)	31 (33-37)	25 (22-27)	20 (18-25)
Myramothecium whittingtoni	358	99	75	76	33	30	40	30	47	17
Notothecium cyphophallum	230 (225-232)	110 (98-114)	69 (55-70)	104 (98-109)	51 (47-53)	44 (43-48)	40 (38-41)	36 (29-37)	44 (39-48)	30 (26-31)
Notothecium deleastoideum	262 (225-300)	99 (89-104)	56 (53-60)	99 (74-111)	45 (43-48)	44 (41-46)	33 (32-37)	46 (41-46)	37 (33-40)	31 (29-34)
Notozothecium euzeti	274	80	62	76	36	30	32	29	70	65
Notozothecium minor	249 (239-250)	88 (84-90)	76 (68-76)	81 (76-83)	44 (40-46)	33 (29-34)	43 (40-44)	28 (28-32)	55 (52-59)	30 (29-34)

634), *Calpidothecium crescentis* (Mizelle & Price, 1965)(INPA 635); *Enallothecium aegidatum* (Boeger & Kritsky, 1988) (INPA 636), *Mymarothecium whittingtoni* Kritsky, Boeger & Jegú, 1996 (INPA 637); *Notothecium cyphophallum* Kritsky, Boeger & Jegú, 1998 (INPA 638); *N. deleastoideum* Kritsky, Boeger & Jegú, 1998 (INPA 639); *Notozothecium euzeti* Kritsky, Boeger & Jegú, 1996 (INPA 640); *N. minor* Boeger & Kritsky, 1988 (INPA 641) (Table 1).

Amphitecium falcatum, *Anacanthorus jegui*, *A. sciponophalus*, *Ancanthorus* sp. and *Notothecium deleastoideum*, were considered secondary species (prevalence between 33-66%), the other species were considered satellite (prevalence < 33%). *Anacanthorus jegui* presented the highest prevalence (50.85%). *Notothecium deleastoideum* presented the highest intensity of infection (149) and was the dominant species (20.08%) (Table 1).

The constant fish species, according to the occurrence constancy method, varied among Monogenean species, being 55% of the species were accessory and 45% accidental (Table 1).

Values of the variance-to-mean-ratio and Green's index for each Monogenean species showed an aggregate distribution of the parasites in the host with a low degree of aggregation.

The Monogenean species morphometric measures and morphological characters are presented in table 2.

DISCUSSION

Twenty-five (25) Monogenean species (Cohen *et al*., 2013) are named for *Serrasalmus* spp. Out of the 25 species mentioned for *Serrasalmus* spp. 16 of them were found on *S. altispinis*: *A. diclonophallum, A. falcatum, A. amazonicus, A. gravihamulatus, A. jegui, A. lepyrophallus, A. mesocondylus, A. periphallus, A. prodigiosus, A. sciponophallus, A. serrasalmi, E. aegidatum, M. whittingtoni*, *N. cyphophallum, N. deleastoideum* and *Notozothecium minor.* Five species found in *S. altispinis* are registered for the first time in *Serrasalmus* spp.: *A. cintus, A. cladophallus, A. crytocalus, C. crescentis* and *N. euzeti*.

Of the parasite species that occur on hosts of the Family Serrasalmidae, 35 species of eight genera interact with more than one host species. Their majority is restricted to species of *Serrasalmus* (Braga *et al.*, 2014). The ability of using a lot of hosts may be related to the biological and ecological characteristics of both linage of hosts and species of parasites (Agosta *et al.*, 2010).

In this study *S. altispinis* was parasitized by 22 Monogenean species of seven genera. Species of five of these genera are specific of Serrasalmidae species: *Amphithecium; Calpidothecium; Enallothecium; Myramothecium* and *Notothecium.* Only two genera showed not to be specific to Serrasalmidae: *Anacanthorus,* which also parasitizes fish species of Characidae and Curimatidae, and *Notozothecium* that is also found in Cynodontidae (Braga *et al.*, 2014).

In this study, the thirteen species of the genus *Anacanthorus*: *A. amazonicus*; *A. cintus*; *A. cladophallus; A. crytocaulus; A. gravihamulatus; A. jegu; A. lepyrophallus; A. mesocondylus; A. peryphallus; A. prodigiosus; A. sciponophalus; A. serrasalmi; Ancanthorus* sp. and the two of *Notozothecium*: *N. euzeti* and *N. minor S. altispinis* are specific of Serrasalmidae, supporting Braga *et al.* (2014).

The opportunity to colonize new host species is related to the availability of suitable hosts for a successful colonization. Only hosts phylogenetically or ecologically related to their parasites will provide them with the necessary conditions for their survival and transmission (Noble & Noble, 1961).

Serrasalmidae species bear high parasite richness per host. They have shown to be parasitized by many species of many genera and also tend to share their parasites with closely related species. Thus, Serrasalmidae is considered the family with the largest number of hosts and Monogenean species within neotropical fishes (Braga *et al.,* 2014). The number of species found in this study is a clear example of how Serrasalmidae species can be parasitized by large number of Monogenean species.

The presence of core species indicates the existence of stable and balanced populations, indicating higher colonization and growth rates (Bush & Holmes, 1986). The presence of secondary species suggests moderate colonization rates and the establishment of their populations in unsaturated sites by the core species, interacting to occupy the same habitat (Bush & Holmes, 1986). Satellite species with a low rate of colonization usually settle in an infracommunity with a basic structure already determined by core and secondary species, being able to establish themselves only in small numbers or in existing random gaps (Bush & Holmes, 1986).

In this study, the absence of core species and the presence of several secondary and satellite species in the gills of *S. altispinis* can be explained with the high number of species registered for this host. The absence of core species increases the availability of the colonization area, where small groups of secondary and satellite species can be established. Possibly this is a strategy used by these parasite species to cohabit in the gills of *S. altispinis*. In this way the secondary species registered in this study, are established first in the gills of *S. altispinis* and later in unoccupied spaces, the satellite species are established in smaller groups.

According to the occurrence constancy method (Dajoz, 1973), the constant species are considered resident of the parasite assemblages, while the accessory and accidental species are considered transient or immigrant species. In the present study, there were registered only accessory and accidental species. In this way, the Monogenean species of *S. altispinis* can immigrate from host to host species, due to the low specificity of these parasites, which use more than one Serrasalmidae species as host.

The influence of a fish species' ability to form schools on the degree of parasite aggregation is presented as a determining factor in parasite diversity (Morand *et al.*, 2000). The formation of schools might be expected to allow greater access of parasitic groups to their hosts because schools increase the size of the resource to be explored from a macroecological perspective, and schooling can influence the abundance of certain parasites, susceptibility of hosts to infection and parasite aggregation values, which was observed in the present study for all Monogenean species.

The co-existence of species can be favored by reducing the overall intensity of competition via aggregated utilization of hosts (Jaenike & James, 1991). The co-existence of species is facilitated if species are distributed in a way that interspecific aggregation is reduced relative to intraspecific aggregation (Jaenike & James, 1991). In this study, 22 Monogenean species co-exist in the gills of *S. altispinis*. The success of this co-existence could be explained by the low degree of aggregation of all species that allow small groups to settle in the same habitat.

Serrasalmus altispinis is a host of 22 Monogenean gill parasite species. All these species are recorded for the first time in this fish. The high species richness found in *S. altispinis* increases the knowledge of the distribution of Monogenean parasites in a new host species. This fact reveals the determining role of this fish species in contributing to increase and maintain the biodiversity in Brazilian Amazonian floodplain lakes.

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