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ZOOLOGY

Endoparasites of *Hypostomus commersoni* (Siluriformes, Loricariidae) from two shallow lagoons, Argentina

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ABSTRACT. *Hypostomus commersoni* is a freshwater fish, native to the Paraná River basin, which plays an important role in trophic networks of this system. This study aimed at analyzing the structure of the endohelminth community of *H. commersoni* from two shallow lagoons in the municipality of Santa Fe, Argentina. In the 51 hosts analyzed, 2103 helminths were found. Hosts from Belgrano Park lagoon were infested with *Genarchella genarchella*, *Saccocoelioides nanii*, *Raphidascaris* (*Sprentascaris*) sp., and *Gorytocephalus elongorchi*. Hosts from the Western Urban Nature Reserve lagoon were infested with *Thometrema magnifica, Procamallanus* (*Procamallanus*) *annipetterae*, *Raphidascaris* (*Sprentascaris*) sp., *Gorytocephalus elongorchi*, and Proteocephalidae spp. In both host populations, the prevalence of some parasites was high, and species richness and diversity of component communities were low. The distribution pattern of helminth was aggregated in all cases. No correlation was found between the length of the host and the richness and abundance of endoparasites. The total number of parasites and the specific richness per host in both lagoons did not differ significantly. The findings on *G. genarchella*, *P.* (*P.*) *annipetterae*, *G. elongorchi*, and Proteocephalidae spp. were the first records in his host.

Keywords: Digenea; Nematoda; Eucestoda; Acanthocephala; Siluriformes; Loricariidae.

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Introduction

The family Loricariidae has a neotropical distribution and stands out among Siluriformes for its high diversity (Bertora, Grosman, Sanzano, Cardoso, & Rosso, 2018). The significant variability in the morphological and pigmentation patterns of suckermouth armored catfish reflect their high degree of ecological specialization (Covain, & Fisch-Muller, 2007). The genus *Hypostomus* Lacépède, 1803 includes approximately 130 species of a wide geographical distribution extending from Colombia to the Salado River basin in the province of Buenos Aires, Argentina (Cardoso, Brancolini, Protogino, & Lizarralde, 2011). Fish of this genus inhabit the bottom of lotic and lentic aquatic environments (Sverlij et al., 2013) and play an important role in trophic webs of aquatic systems due to their periphytivorous-detritivorous habits (Abilhoa, Valduga, Frehse, & Vitule, 2016) as other suckermouth armored catfishes (Lujan, Winemiller, & Armbruster, 2012). They are considered important ecosystem engineers in the Neotropics, due to their influence on ecosystem processes such as nutrient cycling (Vitule et al., 2017). *Hypostomus commersoni* Valenciennes, 1836 is the species of this genus with the widest distribution range in Argentina, inhabiting all the main river networks of La Plata River basin and the Pampa Plains (Bertora et al., 2018; Cardoso et al., 2019), where its catch is very common (Sverlij et al., 2013; Scarabotti, Demonte, & Pouilly, 2017). Considering main life history traits, this species has recently been classified as equilibrium strategists (Borzone Mas, Alvarenga, & Scarabotti, 2019).

However, despite their frequency and abundance in the Paraná River floodplain and the importance of knowledge on ichthyoparasites for the management and conservation of aquatic environments, there are very few studies on helminth parasites of *H. commersoni* (Ostrowski de Nuñez, Arredondo, & Gil de Pertierra, 2017). The parasite communities of other species of the genus *Hypostomus* have been analyzed in different neotropical environments (Lopes, Fernandes, Bastos, Cohen, & Kohn, 2011; Borges, Oliveira, Santos & Tavares-Dias, 2018), as well as those of related taxa (Porto et al., 2012; Gonçalves, Oliveira, Santos, & Tavares-Dias, 2014; Cardoso, Oliveira, Neves, & Tavares-Dias, 2017).

The objective of this work was to analyze the structure of the endoparasite community of *H. commersoni* in two urban lagoons in the municipality of Santa Fe, Argentina.

Material and Methods

Sampling was carried out in two lentic environments in the municipality of Santa Fe, Argentina: the lagoon located in General Manuel Belgrano Park – BL (31°39´ S, 60°42´ W) has a surface area of 12 hectares and an average depth of 2.7 meters, and a lagoon in the Western Urban Nature Reserve – WL (31°36´ S, 60°43´ W), with an average of 0.40 meters deep. Neither environment presents a surface connection with nearby channels of the alluvial plain of the Paraná River (Figure 1).

Figure 1. Urban lagoons in the municipality of Santa Fe, Argentina. Sampling sites: BL= Belgrano Lagoon, WL= West Lagoon.

Fish were sampled between May 2018 and April 2019, using trawls, hand nets and gillnets with different mesh sizes. The total number of specimens of *Hypostomus commersoni* obtained was 51. In BL, 25 fishes with a standard length between 18 and 37.5 cm (32.1 ± 4.8 cm) and a weight between 145.5 and 973.4 g (655.4 ± 231.5 g) were caught, while 26 specimens of sizes between 23 and 39.5 cm (30.1 ± 4.1 cm) and weights between 363.3 and 1,195 g (633.3 ± 194.7 g) were caught in WL. Regarding composition by sex, in BL 16 fishes were females and 9 males; and in WL, 17 females, 8 males and 1 individual, whose sex could not be determined, were obtained.

This study was approved by the Research Ethics and Safety Committee of the *Universidad Nacional del Litoral* (Santa Fe, Argentina), and fish collection was authorized by Resolutions 15/18 and 70/19 of the Santa Fe province, and 16/18 of the Municipality of Santa Fe. Fish were measured, weighed and frozen in the field. Sex determination and digestive tract dissection were performed in the Laboratory of Natural Sciences, of the Research Group in Ichtyoparasitology and Ichthyology, of the *Facultad de Humanidades y Ciencias, Universidad Nacional del Litoral*. Parasites found were preserved in 70% ethanol. Frequently used techniques for clearing and staining were applied to each group of helminths (Eiras, Takemoto, & Pavanelli, 2006) and their taxonomic identification as made using different keys.

To analyze parasite communities, the ecological terms used were those recommended by Bush, Lafferty, Lotz, and Shostak (1997) and Rózsa, Reiczigel, and Majaros (2000). The following descriptors for the parasite community were calculated: prevalence of parasitic infestation (P), mean intensity of infestation (MI), mean abundance (MA); species range per fish and alpha-diversity using Hill numbers. Hill numbers (effective number of species) are defined to the order of q (^{q}D), where parameter q indicates the weight given towards rare or common species. ^{0}D (species richness) is insensitive to relative frequencies and is therefore weighted towards rare species, and ^{1}D (exponential of Shannon) is weighted towards common species (Moreno, Barragán, Pineda, & Pavón, 2011). Simpson index (D) was calculated to determine dominance trends among species of parasites, dominance being accepted when $D > 0.25$ (Daly, Baetens & De Baets, 2018). Relative dominance (RD) was estimated by the Berger-Parker index (Amarante, Tassinari, Luque, & Pereira, 2016). In ecological analysis, only species with a prevalence greater than 10% were included (Bush et al., 1997). Fisher index (FI), Green dispersion (GI), Morisita index (MoI) and Discrepancy of Poulin index (DP) were estimated to detect the distribution pattern of parasitic infra-communities (Rózsa et al., 2000). A chi-square test (χ^2) was applied to determine the occurrence of associations between species of parasites and host fish and Spearman rank correlation (r_S) was used to check correlations between abundances of the species of parasites that formed associations. The Shapiro-Wilk test was used to determine whether the total length and weight of the hosts, parasite abundance and richness data followed a normal distribution pattern. Differences between lagoons for length and weight of the hosts were evaluated using the *t* test. The similarity between parasite communities of both lagoons was estimated by using the Sorensen index and the differences in parasite loads and specific richness between fish from both lagoons were evaluated using the Mann-Whitney U test. The association between the total length of the hosts and the number of parasites was investigated through Pearson correlation (*r*), and species richness was analyzed applying Spearman correlation. Past 4.0-2020 (Hammer, Harper, & Ryan, 2001) and Quantitative Parasitology 1.0.14 (Reiczigel, Marozzi, Fabian, & Rózsa, 2019) software was used for data processing. Results were considered significant when $p \leq 0.05$.

Results

A total of 2,103 endoparasites were found, 1,370 in BL fish and 733 in WL fish. In BL fish, 4 metazoan taxa were found: *Genarchella genarchella* Travassos, Artigas & Pereira, 1928 (metacercariae); *Saccocoelioides nanii* Szidat, 1954; *Raphidascaris* (*Sprentascaris*) sp. Petter & Cassone, 1984 and *Gorytocephalus elongorchi* Thatcher, 1979. In WL specimens, 7 taxa were found: *Thometrema magnifica,* Szidat, 1954; three morphospecies of Proteocephalidae La Rue, 1911 (sp.1, sp.2, and sp.3); *Raphidascaris* (*Sprentascaris*) sp.; *Procamallanus* (*Procamallanus*) *annipetterae* Kohn & Fernandes, 1988 and *G. elongorchi*.

In WL, 100% fish were parasitized, while the prevalence in BL was 96%. The parasite descriptors and the attributes of the communities associated with the hosts of each lagoon are listed in Table 1.

The most frequent endohelminths found in BL fish were *G. genarchella* and *Raphidascaris* (*S.*) sp., while *S. nanii* was the species with the highest mean infestation intensity and a maximum abundance of 695 individuals in one host. In WL fish, *Raphidascaris* (*S.*) sp. presented the highest values of prevalence, mean intensity of infestation (MI) and mean abundance (MA) (Table 2).

The parasite fauna of the hosts from the two environments presented low similarity (Sørensen index = 36.37%). In both sites, an association between the presence of *G. elongorchi* with another parasite was found. In BL, it was found associated with *Raphidascaris* (*S.*) sp. ($\chi^2 = 4.573$, $p = 0.032$) and their correlated abundances ($r = 0.639$, $p = 0.000$), while in WL, it was found associated with *T. magnifica* ($\chi^2 = 5.418$, $p = 0.02$) and its inversely correlated abundances ($r = -0.491$, $p = 0.011$).

The dispersion pattern of all helminths was aggregated (Table 3).

Table 1. Parasitic descriptors and diversity of endohelminth communities of *Hypostomus commersoni* in two shallow lagoons, Santa Fe, Argentina.

Descriptors Mean ± SD (amplitude)	Belgrano Lagoon	West Lagoon
Intensity of Infestation	57.08 ± 143.76 (2-721)	28.19 ± 28.47 (1-122)
Infestation Abundance	54.8 ± 141.2 (0-721)	28.19 ± 28.47 (1-122)
Diversity of order 0	2.12 ± 1.01 (0-4)	2.35 ± 1.16 (1-6)
Diversity of order 1	1.68 ± 0.63 (1-3.23)	1.76 ± 0.57 (1-2.98)
Simpson index	0.83 ± 0.41 (0-1)	0.69 ± 0.2 (0.41-1)

SD = standard deviation.

Table 2. Endohelminth parasites of *Hypostomus commersoni* in two shallow lagoons, Santa Fe, Argentina.

Parasite species	Belgrano Lagoon (N = 25)				West Lagoon (N = 26)			
	P	MI	MA	RD	P	MI	MA	RD
Digenea								
Genarchella genarchella	60.0	4.08	3.92	7.15	-	-	-	-
Saccocoelioides nanii	36.0	36.5	35.04	63.9	-	-	-	-
Thometrema magnifica	-	-	-	-	57.7	3.5	3.5	12.4
Eucestoda								
Proteocephalidae sp.1	-	-	-	-	7.7	0.15	0.15	0.6
Proteocephalidae sp.2	-	-	-	-	7.7	0.12	0.12	0.4
Proteocephalidae sp.3	-	-	-	-	3.9	0.04	0.04	0.1
Nematoda								
Procamallanus (*P.*) *annipetterae*	-	-	-	-	19.2	0.23	0.23	0.8
Raphidascaris (*S.*) sp.	60.0	6.71	6.44	11.8	92.3	21.46	21.46	76.1
Acanthocephala								
Gorytocephalus elongorchi	56.0	9.79	9.4	17.2	46.2	2.69	2.69	9.6

P = Prevalence (%), MI = Mean Intensity, MA = Mean Abundance, RD = Relative Dominance (%).

Table 3. Spatial dispersion indices of *Hypostomus commersoni* endoparasites in two shallow lagoons, Santa Fe, Argentina.

Endoparasite species	Dispersion Indices				Dispersion pattern
	FI	GI	MoI	PD	
Genarchella genarchella	21.29	0.21	11.68	0.879	Aggregate
Saccocoelioides nanii	529.91	0.6	31.84	0.939	Aggregate
Thometrema magnifica	6.59	0.06	4.19	0.787	Aggregate
Procamallanus (*P.*) *annipetterae*	1.24	0.05	3.47	0.897	Aggregate
Raphidascaris (*S.*) sp.	30.82	0.04	3.14	0.646	Aggregate
Gorytocephalus elongorchi	29.93	0.1	5.87	0.763	Aggregate

FI = Fisher index, GI = Green index, MoI = Morisita index, PD = Poulin Discrepancy index.

The total length of fish in both lagoons was significantly different (t = 2.689; p = 0.01), while their weight was not (t = 0.165; p = 0.869). The total number of parasites and the species richness per host between lagoons did not differ significantly (U = 299.5; p = 0.63, and U = 298.5; p = 0.6 respectively).

No correlation was detected between host length and parasite abundance (r = 0.447, p = 0.116), nor between host length and endoparasite richness (r_S = -0.477, p = 0.109).

Discussion

Endohelminth diversity may change according to the characteristics of aquatic systems and may be related to some biological traits of hosts, such as size, longevity and especially diet (Yamada, & Takemoto, 2017).

Hypostomus commersoni is a frequent species in moderately oxygenated waters with sandy bottom (Cardoso et al., 2019). This fish is very resistant and can remain alive out of the water for long periods because they have a high vascularity in the stomach that allows greater oxygenation (Almiron, Casciotta, Ciotek, & Giorgis, 2015). Both populations analyzed inhabit eutrophic lentic environments, characterized by nutrient enrichment and low levels of dissolved oxygen (Frau, Mayora, & Devercelli, 2018; Frau et al., 2019). Urban wetlands tend to accumulate pollutants due to their proximity to human activities and because they are used to filter the generated waste (Hassall, 2014). These systems make an important contribution to biodiversity and it is necessary to gain deeper knowledge of their services throughout the region (Ramirez & Gutierrez-Fonseca, 2020).

In a review of the composition and structure of the parasite community in Loricariidae fish in Brazil, Borges et al. (2018) observed a high prevalence and a low abundance of larval endoparasites, as well as infra-communities characterized by inter-specific associations and high dispersion.

In both populations analyzed herein, endohelminth richness was 4 species in fish from BL and 7 species in fish from WL.

In their biological cycle, digeneans have mollusks as primary intermediate hosts and fish as intermediate or definitive hosts (Merlo, Parietti, & Etchegoin, 2014; Borges et al., 2018). In this study, the species of Digenea found in both sites were different. *Saccocoelioides nanii*, a species already registered in *H. commersoni* (Ostrowski de Nuñez et al., 2017) and in other fish that consume algae and detritus (Lehun et al., 2020) was found only in hosts of Belgrano Lagoon (BL). The infestation of this species was characterized by low prevalence and high intensity. *Genarchella genarchella*, a digenean without a specific host, was also found in fish from this site. This species was also recently reported for *Hypostomus ventromaculatus* Boeseman, 1968

(Borges et al., 2018) and other Loricariidae in Brazil, which have been considered possible definitive hosts (Cardoso et al., 2017). The finding of *G. genarchella* metacercariae in the gas bladder of *H. commersoni* represents the first record of this organ for this host species. This infestation could be caused by the consumption of *Heleobia parchappii* (d'Orbigny, 1835), a mollusk in which this digenean develops its life cycle (Martorelli, 1989) and which was frequently found in the intestinal content of *H. commersoni* from this lagoon. In his study of the biological cycle of *G. genarchella,* Martorelli (1989) considered parasite transmission from snails to fish by trophic route to be possible. *Thometrema magnifica*, a digenean which has been previously cited for *H. commersoni* (Ostrowski de Núñez et al., 2017), was only found in fish from the Western Lagoon (WL) with twice the prevalence found in fish from lotic environments of the middle and lower Paraná River.

Nematode species account for 21% of the parasite-host associations registered in the continental and marine fish fauna of South Latin America (Luque, Pereira, Alves, Oliva, & Timi, 2016). Fish can be intermediate, definitive or paratenic hosts in the life cycle of nematodes (Alves et al., 2019). *Raphidascaris* (*Sprentascaris*) species are nematodes that require fish and aquatic crustaceans as intermediate hosts (Zago et al., 2013). The finding of this genus has been frequent among Loricariidae (Borges et al., 2018). *Raphidascaris* (*S.*) *hypostomi* (Petter & Cassone, 1984) has been found in *H. commersoni* from Brazil and Paraguay (Petter & Cassone, 1984; Moravec, Kohn, & Fernandes, 1990; Petter, 1995). In both host populations, *Raphidascaris* (*S.*) sp., presented high prevalence and intensity, with infra-populations composed of adult and juvenile forms. In Argentina, Ramallo (2009) described the infestation with *R.* (*S.*) *marano* in specimens of *Hypostomus cordovae* Günther, 1880 from lotic environments, with a lower parasite load than that found for *Raphidascaris* (*S.*) sp. in *H. commersoni*. The finding of *Procamallanus* (*Procamallanus*) *annipetterae* constitutes the first report for *H. commersoni*. This nematode has been reported in *Hypostomus regani* (Ihering, 1905), *Hypostomus albopunctatus* (Regan, 1908) and *Hypostomus cochliodon* Kner, 1854 from Brazil (Kohn et al., 2011; Luque, Aguiar, Vieira, Gibson, & Santos, 2011).

Acanthocephala is a group of obligate parasites that use arthropods as intermediate hosts and vertebrates as definitive hosts; and occasionally vertebrates serve as paratenic hosts (Nuñez & Drago, 2017). *Gorytocephalus elongorchi* described by Thatcher (1971) in *Hypostomus carinatus* (Steindachner, 1881), has also been recorded in other species of this genus, such as *H. cochliodon* and *H. regani* (Lopes et al., 2011) and other species of Loricariidae (Porto et al., 2012; Cardoso et al., 2017). The intensity and abundance values of *G. elongorchi* in hosts from the two urban lentic environments widely exceed those obtained by other authors. This high parasite load could be partially attributed to the confinement and high density of *H. commersoni* in these isolated environments, given that the changes in abundance of parasites of the same host species from different locations can be influenced by different biotic and abiotic factors (Silva Pinheiro, Tavares-Dias, & Guerreiro Giese, 2019).

The life cycle of tapeworms includes one or more intermediate hosts (mainly arthropods) that enable their transmission along trophic chains (Alves, Chambrier, Scholz, & Luque, 2017). The Proteocephalidae found in *H. commersoni* correspond to immature forms and although they could not be determined at a specific level, three morphospecies with different characteristics were observed. Other authors have found immature Proteocephalidae in *Hypostomus* sp. (de Chambrier, & Vaucher, 1999) and *Proteocephalus* sp. in *H. ventromaculatus* (Borges et al., 2018). The genus *Proteocephalus* Weinland, 1858 uses planktonic crustaceans (Copepoda) as primary intermediate hosts and many Siluriformes fish are among its definitive hosts (Cardoso et al., 2017).

A low similarity was verified between parasite communities in hosts collected from both lagoons. According to Poulin, Krasnov, Mouillot, and Thieltges (2011), in most ichthyoparasite communities, the similarity in species composition decreased exponentially with increasing geographical distance between locations. In this study, despite the proximity between lagoons, their origins linked to different rivers and their state of isolation, could contribute to the difference in the parasite fauna of *H. commersoni* from the two lagoons.

The aggregate distribution of *H. commersoni* parasites corresponds to the typical distribution pattern found for fish parasites (Wilber, Johnson, & Briggs, 2017). Both endohelminth communities analyzed were characterized by high dominance and low species diversity.

Conclusion

This represents the first study on the diversity of *H. commersoni* helminths in urban lentic environments. Findings on *G. genarchella*, *P.* (*P.*) *annipetterae*, *G. elongorchi*, and Proteocephalidae spp. were the first records for this host. In both host populations, the prevalence of some parasites was high, and species richness and diversity of component communities were low.

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