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## Biodiversity and ecology of the parasitic infracommunities of *Loricaria prolixa* (Siluriformes: Loricariidae) from the Tietê-Batalha Basin, SP, Brazil

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**ABSTRACT.** The parasitic biodiversity of the *Loricaria prolixa*, an endemic fish from the Paraná and Prata basins was studied and analyzed the parasitic's communities dynamics and their ecological relations with this host. Samples were collected in the Batalha River and 39 specimens were analyzed from 2014 to 2016. All fishes were parasitized. The component community was composed by twelve species with 8694 metazoan found on the surface, gills, eyes, brain, intestine and blood of the hosts. *Demidospermus spirophallus*, Diplostomidae gen. sp., *Rhabdochona kidderi* and *Oligobdella* sp. showed higher values for the parasitism's ecological descriptors, and were centrals and dominants species. The infracommunities were characterized by specific richness smaller in relation to diversity, and both superior to equitability ( $H' = 0.94$ ;  $J = 0.6$ ;  $d = 0.83$ ). There was a significant positive correlation between the host standard length and the parasite abundance of *D. spirophallus*, Diplostomidae gen. sp. and *Oligobdella* sp., while *Procamallanus (Spirocamallanus) inopinatus* presented a significant negative correlation. This is the first contribution concerning the parasite biodiversity of *L. prolixa*. *Clinostomum detruncatum*, Diplostomidae gen. sp., *Austrodiplostomum compactum*, *R. kidderi*, *P. (S.) inopinatus*, *P. (S.) rebecca*, *Cucullanus pinnae pinnae*, *Oligobdella* sp. and *Trypanosoma* sp. were first recorded in this host.

**Keywords:** catfishes; fish parasites; freshwater; biological diversity.

## Biodiversidade e ecologia das infracomunidades parasitárias de *Loricaria prolixa* (Siluriformes: Loricariidae) provenientes da Bacia do Tietê-Batalha, SP, Brasil

**RESUMO.** Foi realizado o estudo da biodiversidade parasitária da *Loricaria prolixa*, um peixe endêmico das bacias do Paraná e Prata, e analisada a dinâmica das comunidades parasitárias e suas relações ecológicas com este hospedeiro. Os peixes foram coletados no rio Batalha e 39 indivíduos foram analisados de 2014 a 2016. Todos os peixes estavam parasitados. A comunidade componente foi composta por doze espécies com 8694 metazoários encontrados na superfície, brânquias, olhos, cérebro, intestino e sangue dos hospedeiros. *Demidospermus spirophallus*, Diplostomidae gen. sp., *Rhabdochona kidderi* e *Oligobdella* sp. apresentaram maiores valores para os descritores ecológicos e foram consideradas centrais e dominantes. As infracomunidades se caracterizaram com uma riqueza específica menor em relação à diversidade, e ambas superiores à equitatividade ( $H' = 0.94$ ;  $J = 0.6$ ;  $d = 0.83$ ). Houve correlação significativa positiva entre o comprimento padrão dos hospedeiros e a abundância de *D. spirophallus*, Diplostomidae gen. sp. e *Oligobdella* sp., enquanto que *Procamallanus (Spirocamallanus) inopinatus* apresentou correlação significativa negativa. Esta é a primeira análise ecológica sobre a biodiversidade parasitária de *L. prolixa*. *Clinostomum detruncatum*, Diplostomidae gen. sp., *Austrodiplostomum compactum*, *R. kidderi*, *P. (S.) inopinatus*, *P. (S.) rebecca*, *Cucullanus pinnae pinnae*, *Oligobdella* sp. e *Trypanosoma* sp. foram registrados pela primeira vez neste hospedeiro.

**Palavras-chaves:** cascudos; parasitos de peixes; água doce; diversidade biológica.

### Introduction

Regarding the Ostariophysi fishes, the Siluriformes are the most diverse and have the greatest distribution; they are found in the main drains of almost all continents, with only two

families essentially marines (Pinna, 1998). About 3,100 species belonging to this order have been already described, and more than half of these are located in the Neotropics (Covain & Fisch-Muller, 2007). The most specious family of Siluriformes, the Loricariidae 'armored-catfishes', with more than 700

valid species, is located in this region (Ferraris Jr., 2007).

More than half of the freshwater fish species of the State of São Paulo, Brazil, belong to the order Siluriformes (Castro & Menezes, 2001). Among these species, the 'cascudo-chinelo', *Loricaria prolixa* (Isbrücker & Nijssen, 1978) is an endemic armored-catfish of the upper Paraná and Prata basins. This fish has brown spots all over its body dorsal region, with a white band above the eyes, another dark gray band in front of these through the nostrils, and few teeth in the maxillas (Isbrücker, 1981). Like other species of the genus, it has a benthic habit with a preference for lotic environments. It is considered as detritivores, but it can also use aquatic invertebrates as a food resource (Hahn, Agostinho, Gomes, & Bini, 1998).

Although it presents a great animal diversity, the Neotropical region still lacks specific ichthyoparasitological studies for the majority of resident species. The parasites have a role in the maintenance of biological and behavioural diversity of their hosts, and can regulate fish population sizes, sometimes with profound effects on trophic interactions, food webs, competitions and keystone species. These interactions suggest that parasites are integral components in shaping community and ecosystem structure (Combes, 1996; Barber, Hoare, & Krause, 2000).

Studies involving the biodiversity characterization of fish parasites in Brazilian river basins have been undertaken in the last few decades (Eiras, Takemoto, Pavanelli, & Adriano, 2011). However, not all geographic areas are equally considered in these analyzes, and even well-known sites, such as the State of São Paulo, still have sub-basins, as the Tietê-Batalha basin, with scarce ecological studies on the parasitic fauna of their resident fishes (Pedro, Pelegrini, Azevedo, & Abdallah, 2016).

Therefore, this study consisted in an analysis of the parasite biodiversity present in *L. prolixa* from the Batalha River, as well as an evaluation of the dynamics of the parasitic communities and their ecological relations with this host.

## Material and methods

A total of 39 specimens of *L. prolixa*, with standard length ranging from 11.0 to 36.5 cm ( $28.52 \pm 6.23$ ), was collected in the Batalha River, at a point located in the municipality of Reginópolis (21° 53' 17" S and 49° 13' 31" W), São Paulo, during February 2014 to February 2016. These collections followed the guidelines of the scientific fishing

license under approval by the *Instituto Chico Mendes de Biodiversidade* (ICMBio) through the *Sistema de Autorização e Informação em Biodiversidade* (Sisbio – authorization no. 40998-2). Nylon monofilament's gillnets with different mesh types (ranging from 2 to 10 cm with alternated internodes) were used for this procedure, being placed overnight and removed before dawn in the regions near the bottom or slopes, which are the preferred sites of this host species. The fish were stored individually in plastic bags and taken for laboratory analysis. The host identification was obtained according to Ferraris Jr. (2003) and Covain and Fisch-Muller (2007).

The fish were submitted to necropsy including all organs. Before this procedure, 10 specimens parasitized by Hirudinea had been selected for blood analysis, which was extracted through cardiac puncture and three slides were made and fixed in methanol for checking the presence of hemoparasites. The fixing and preparing methodologies for the metazoan parasites collected were those cited in Eiras, Takemoto, and Pavanelli (2006). A species accumulation curve was done to determine if the sample size was sufficient to obtain the highest proportion of parasite species that characterized the component community. The Bootstrap estimator was used to verify the expected parasite richness for the number of hosts analyzed (Poulin, 1998).

The quantitative descriptors of parasitic infrapopulations (prevalence, mean intensity and mean abundance) were obtained according to Bush, Lafferty, Lotz, and Shostak (1997). Based on their colonization strategies, parasite species were classified, according to Esch, Kennedy, Bush, and Aho (1988) in allogenic, when they complete the life cycle in birds or mammals, and autogenic, when they use the fish as definitive hosts. Parasite species were also classified according to their importance degree within the parasitic infracommunities, such as central, secondary, or satellite, according to their prevalence (Hanski, 1982).

Regarding the component community, the following parameters were considered: total number of parasite individuals, total number of parasite species, diversity measures obtained by the Shannon Diversity Index ( $H'$ ), Pielou Equitability Index ( $J$ ), and Margalef Richness Index ( $d$ ) (Magurran, 2011). The infracommunities were described according to the mean value of the parasite species and with the mean value of the individual's abundance.

The Dispersion Index (DI) was used for each infrapopulation to determine its distribution pattern in relation to the host population, and the  $d$  statistic

was also calculated to assess its significance. The Green Index (GI) was calculated to verify how much the infrapopulation's organisms are grouped (Ludwig & Reynolds, 1998). The dominance frequency and mean relative dominance (ratio between the individuals number of the same species by the total specimen's number of all species in the infracommunity) were calculated for each parasite species (Rohde, Hayward, & Heap, 1995). The Spearman Coefficient (rs) was used to verify the existence of a correlation between the hosts standard length and the parasite abundance.

All mentioned tests were applied only to parasite species with a prevalence higher than 10%. The blood protozoans were excluded from the ecological analysis because their occurrence record was obtained from only part of the hosts sampled. The results were considered significant when  $p < 0.05$ . Vouchers of identified specimens were deposited in the *Coleção Helmintológica do Instituto de Biociências de Botucatu* (CHIBB) of the *Universidade Estadual Paulista* (Unesp).

## Results and discussion

All analyzed hosts were parasitized by at least one parasite species. Blood samples from all the 10 fish examined were positive for hemoparasites. The accumulation curves of the observed parasitic metazoan and the Bootstrap richness estimator were very close, and almost stabilized at the same number of species observed and expected by Bootstrap (11 species) (Figure 1).

Only one host presented parasitism by a single species; all the others presented mixed infections, ranging from 2 to 7 different species in a single host. The component community was composed by twelve different species among ectoparasites, endoparasites and hemoparasites (kinetoplastid protozoans) with 8,694 collected metazoans. The species identified were: *Demidospermus spirophallus* Franceschini et al. (2017), *Clinostomum detrunctum* Braun, 1899 (metacercariae), Diplostomidae gen. sp. (metacercariae), *Austrodiplostomum compactum* (Lutz, 1928) (metacercariae), *Rhabdochona kidderi* Pearse (1936), *Rhabdochona* sp., *Contracaecum* sp. (L3 larval), *Procamallanus* (*Spirocamallanus*) *inopinatus* Travassos, Artigas, & Pereira (1928), *Procamallanus* (*Spirocamallanus*) *rebecae* (Andrade-Salas, Pineda-López & García-Magaña, 1994) (adult and larval), *Cucullanus pinnai pinnai* Travassos et al. (1928), *Oligobdella* sp. and *Trypanosoma* sp. Most species were considered as autogenic, and only *C. detrunctum*, Diplostomidae gen. sp. and *A. compactum* was considered as allogenic (Table 1).

The hosts analyzed for blood parasites ( $N = 10$ ) showed an 100% prevalence for *Trypanosoma* sp. These hosts were also parasitized by the vector of this protozoan, the leeches of the Glossiphonidae family identified as *Oligobdella* sp. (Table 1).

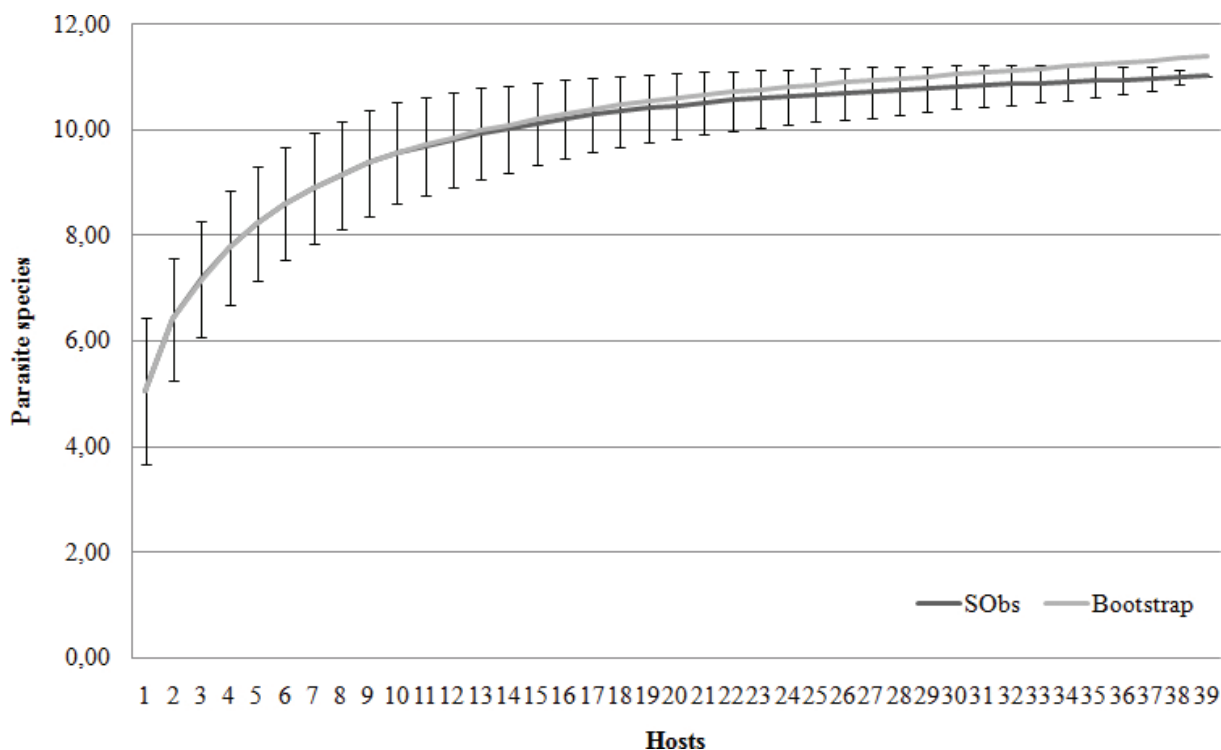
Among the metazoans, the ectoparasites of gills and surface showed higher values for the parasitism's ecological descriptors. *Oligobdella* sp. was the species with the highest prevalence (94.9%) while *D. spirophallus* presented higher mean intensity and abundance (141.3 and 123.3, respectively). These, along with *R. kidderi* and Diplostomidae gen. sp. were considered central species. However, the greatest species richness occurred among the endoparasites in the brain, eyes, and intestine. With the exception of *C. pinnai pinnai*, all parasites presented a prevalence higher than 10% (Table 1).

Two digenea species were found in the host eyes. Metacercariae of Diplostomidae gen. sp. was found parasitizing the crystalline lens, and *A. compactum* was observed only in the aqueous humor and brain, thus not overlapping niches between these larvae. Nevertheless, the greatest richness found among the metazoan parasites occurred in the Nematoda phylum, with more than 54% of the species parasitizing the intestine. In addition, *P. (S.) rebecae* was found in larval stage (L3) and adult in these hosts.

Metazoan diversity values estimated by the Shannon Diversity Index ( $H'$ ) with numerical abundance data ranged from 0.23 to 1.39 ( $0.94 \pm 0.33$ ), while the mean value of the Pielou ( $J$ ) equation was  $0.60 \pm 0.21$ , and the specific richness estimated by the Margalef index ( $d$ ) was  $0.83 \pm 0.30$ . Regarding the infracommunities, the mean value of parasite species per host analyzed was  $4.92 \pm 1.42$ , while the mean total parasite abundance collected per host was  $222.92 \pm 229.55$ .

All the parasites had an aggregate distribution pattern, with a high degree of aggregation for *D. spirophallus* ( $DI = 302.72$ ;  $GI = 7.94$ ). Towards the dominance indexes, the four central species *D. spirophallus*, Diplostomidae gen. sp., *R. kidderi*, and *Oligobdella* sp. presented significant values of dominance frequency and relative dominance (Table 2).

According to the Spearman Correlation Coefficient (rs), there was a significant positive correlation between the standard host length and the parasite abundance of *D. spirophallus*, Diplostomidae gen. sp. and *Oligobdella* sp., while *P. (S.) inopinatus* presented a significant negative correlation for this coefficient (Table 3).



**Figure 1.** Accumulation curve of species richness observed (SObs) and Bootstrap richness estimator (Bootstrap) of the metazoan parasites of *Loricaria prolixa* (Isbrücker & Nijssen, 1978) collected in the Batalha River, municipality of Reginópolis, São Paulo State, Brazil.

**Table 1.** Quantitative descriptors, colonization strategy and the importance level of parasites of *Loricaria prolixa* (Isbrücker & Nijssen, 1978) captured in the Batalha River, municipality of Reginópolis, São Paulo State (P = Prevalence; VA = Variation Amplitude; MI = Mean Intensity; S = Standard Deviation; MA = Mean Abundance, IL = Importance Level; CS = Colonization Strategy; SI = Site of infection/infestation).

Parasite species	P %	VA	MI $\pm$ S	MA $\pm$ S	IL	CS	SI
Monogenea							
<i>Demidospemus spirocephallus</i> (CHIBB 220L)	89.7	1 – 1070	141.3 $\pm$ 200.7	123.3 $\pm$ 193.2	Central	Autogenic	Gills and surface
Digenea (Metacercarial)							
<i>Clinostomum detrunctum</i> (CHIBB 223L)	23.1	1 – 3	1.4 $\pm$ 0.7	0.3 $\pm$ 0.7	Satellite	Allogenic	Gills
Diplostomidae gen. sp. (CHIBB 224L)	84.6	1 – 44	8.9 $\pm$ 9.2	7.5 $\pm$ 9	Central	Allogenic	Eyes (lens)
<i>Austrodiplostomum compactum</i> (CHIBB 222L)	17.9	1 – 4	2 $\pm$ 1.3	0.4 $\pm$ 0.9	Satellite	Allogenic	Eyes (humor) and brain
Nematoda							
<i>Rhabdochona kidderi</i> (CHIBB 7947)	82.1	1 – 384	41.2 $\pm$ 69.8	33.8 $\pm$ 65	Central	Autogenic	Intestine
<i>Rhabdochona</i> sp. (CHIBB 7949)	51.3	2 – 91	11.9 $\pm$ 19.6	6.1 $\pm$ 15.1	Secondary	Autogenic	Intestine
<i>Contracaecum</i> sp. (L3) (CHIBB 7951)	25.6	1 – 3	1.3 $\pm$ 0.7	0.3 $\pm$ 0.7	Satellite	Autogenic	Intestine
<i>Procamallanus</i> (S.) <i>inopinatus</i> (CHIBB 7954)	10.3	1 – 2	1.25 $\pm$ 0.5	0.1 $\pm$ 0.4	Satellite	Autogenic	Intestine
<i>Procamallanus</i> (S.) <i>rebecae</i> (adult/L3) (CHIBB 7952)	10.3	1 – 3	1.5 $\pm$ 1	0.1 $\pm$ 0.5	Satellite	Autogenic	Intestine
<i>Cucullanus pinnae pinnae</i> (CHIBB 7950)	2.6	3	3	0.1 $\pm$ 0.5	Satellite	Autogenic	Intestine
Hirudinea							
<i>Oligobdella</i> sp. (CHIBB 225L)	94.9	1 – 215	53.5 $\pm$ 50.8	50.7 $\pm$ 50.8	Central	Autogenic	Gills and Surface
Kinetoplastida							
<i>Trypanosoma</i> sp.	100*	-	-	-	-	Autogenic	Blood

\*Blood samples were analyzed from only 10 hosts.

This study is the first involving ecological aspects of the parasite diversity of *L. prolixa*. *Clinostomum detrunctum*, *Diplostomidae* gen. sp., *A. compactum*, *R. kidderi*, *P. (S.) inopinatus*, *P. (S.) rebecae*, *C. pinnae pinnae*, *Oligobdella* sp. and *Trypanosoma* sp. were recorded for the first time for this host, and many of them were also recorded for the first time for this region. *Austrodiplostomum compactum*, *Contracaecum* sp. and *P. (S.) inopinatus* had been already cited by Pedro et al. (2016) and Leite et al. (2017) in other fish species in this basin.

The ectoparasites presented high values for the ecological descriptors of parasitism in this study, beyond being the dominant species within the infracommunities. Regarding the monogenetic species, the small size of these helminths in relation to the other metazoan parasites is important to understand how much parasitic biomass can be sustained by the hosts and how this can determine the structure of the parasitic community. *Demidospemus spirophallus* showed much higher abundance and mean intensity compared to the

other parasites, probably due to the small size, high levels of reproduction and infection rates of these ectoparasites (Neves, Pereira, Tavares-Dias, & Luque, 2013). The occurrence of *Oligobdella* sp., the most prevalent metazoan parasite in the analyzed hosts, is related to the bentonic habit of *L. prolixa*. The leeches of the Glossiphoniidae family lay their eggs on the substrate or bury them at the bottom of the water bodies, facilitating infestation. The hirudins presence in gills or body surface results in spoliative damage greater than simple local hemorrhage. In large abundances, they can cause severe anemias to the host. In addition, they may be the gateway to secondary bacterial and fungal infections (Thatcher, 2006; Woo, 2006).

**Table 2.** Dispersion Index (DI), Statistical Test *d*, Green's Index (GI), Dominance Frequency (DF%) and Relative Dominance (RD) with standard deviation (SD) of *Loricaria prolixa* (Isbrücker & Nijssen, 1978) parasites from the Batalha River, Reginópolis, São Paulo State, Brazil.

	DI	<i>d</i>	GI	DF (%)	RD ± SD
<i>Demidospermus spirophallus</i>	302.72	143.02	7.94	52.28	0.55 ± 4.95
<i>Clinostomum detrunctum</i>	1.48	1.95	0.01	0	0.0015 ± 0.02
Diplostomidae gen. sp.	10.77	19.95	0.26	2.56	0.03 ± 0.23
<i>Austrodiplostomum compactum</i>	2.42	4.90	0.04	0	0.0016 ± 0.02
<i>Rhabdochona kidderi</i>	125.08	88.84	3.26	12.82	0.15 ± 1.67
<i>Rhabdochona</i> sp.	37.45	44.69	0.96	0	0.03 ± 0.39
<i>Contracaecum</i> sp.	1.33	1.93	0.01	0	0.0015 ± 0.02
<i>Procamallanus</i> (S.) <i>inopinatus</i>	1.31	1.92	0.01	0	0.0006 ± 0.01
<i>Procamallanus</i> (S.) <i>rebecae</i>	1.89	3.32	0.02	0	0.0007 ± 0.01
<i>Oligobdella</i> sp.	50.95	53.57	1.31	30.77	0.23 ± 1.30

**Table 3.** Value of Spearman's Rank Correlation Coefficients (rs) to evaluate the relationship between parasites abundance and the standard length of *Loricaria prolixa* (Isbrücker & Nijssen, 1978) collected in the Batalha River, São Paulo State, Brazil.

	rs	p
<i>Demidospermus spirophallus</i>	0.39*	0.01
<i>Clinostomum detrunctum</i>	0.23	0.15
Diplostomidae gen. sp.	0.63*	< 0.0001
<i>Austrodiplostomum compactum</i>	0.23	0.16
<i>Rhabdochona kidderi</i>	-0.15	0.35
<i>Rhabdochona</i> sp.	0.25	0.12
<i>Contracaecum</i> sp.	0.16	0.34
<i>Procamallanus</i> (S.) <i>inopinatus</i>	-0.33*	0.04
<i>Procamallanus</i> (S.) <i>rebecae</i>	-0.18	0.27
<i>Oligobdella</i> sp.	0.52*	0.001

\*Value with significance levels of  $p < 0.05$ .

Trypomastigote forms of *Trypanosoma* sp. were observed in the blood smear blades analyzed in the present study. The presence of these hemoparasites in fishes is well known in the literature, and they can occur in more than 200 species of teleosts and elasmobranchs of marine and freshwater environments around the world (Eiras, Segner, Wahli & Kapoor, 2008; Gupta & Gupta, 2012). Leeches are vectors of the *Trypanosoma* species that infect fishes, and a link between the loricarid fishes and Glossiphoniidae is observed in relation to these protozoans' transmission. More than 35 species of

*Trypanosoma* were already described only in fishes of the family Loricariidae, and three have been cited for the genus *Loricaria*: *Trypanosoma britskii* (Lopes et al., 1991) in *Loricaria lentiginosa* (Isbrücker, 1979); *Trypanosoma piracicabae* (Fonseca & Vaz, 1929) in *Loricaria piracicabae* (Ihering, 1907) and *Trypanosoma loricariae* (Fonseca & Vaz, 1928) in *Loricaria* sp. (Eiras, Takemoto, Pavanelli & Luque, 2012).

Almost all component species of the parasite community of *L. prolixa* do not present host-parasite specificity (generalists), even in relation to the genus *Loricaria*. Except *D. spirophallus*, described for this host, all other species have already been registered in several other fishes of different orders. *Demidospermus* species were recorded in Siluriformes from South America, denoting the high specific relationship between catfishes and these monogenetics (Mendoza-Palmero, Scholz, Mendoza-Franco & Kuchta, 2012).

The digenetic parasites of freshwater fish eyes are not-encysted metacercariae, belonging to the Diplostomatidae, and infect a considerable diversity of hosts being not specific parasites. They are worldwide distributed, and can infect different ocular structures of their hosts, causing visual impairment, cataracts, blindness; making the fish susceptible to predators and ending the transmission cycle for definitive hosts (Chappell, 1995; Seppälä, Karvonen & Valtonen, 2004). In this work, there was an evident separation of two species of diplostomatids in two distinct sites inside the host's ocular globe: *A. compactum* in the aqueous humor, and Diplostomidae gen. sp. just on the lens. The occurrence of *A. compactum* is common in Brazilian fishes, mainly in Siluriformes (Ramos et al., 2013). The Diplostomatidae gen. sp. metacercariae are quite different from the other species already described. They have smaller dimensions in relation to *A. compactum*, and show higher values for their ecological descriptors. Their taxonomic and molecular description are currently being studied by the authors of the present work.

*Clinostomum* spp. metacercariae can be found encysted in muscles, gills, skin or body cavity of parasitized fish. They are potentially zoonotic, when there is consumption of raw or undercooked contaminated fish, and may cause local inflammatory reactions in the oropharyngeal region (Hara, Miyauchi, Tahara, & Yamashita, 2014). In Brazil, there are few records of *C. detrunctum* parasitism in fish such as muscles and body surface of *Hemiancistrus punctulatus* Cardoso & Malabarba, 1999, on the body surface of *Rhamdia quelen* (Quoy & Gaimard, 1824), in muscles of *Trachelyopterus striatulus* (Steindachner, 1877) and in the coelomic

cavity of *Synbranchus marmoratus* Bloch, 1795 (Acosta et al., 2016).

The nematode richness in the *L. prolixa* intestine, together with the high abundance of some species, is closely related to the host's eating habits, that, although classified as detritivore (Hahn et al., 1998), showed invertebrate remains within the intestinal contents, such as shells of molluscs, microcrustaceans, and aquatic insects, which would act as intermediate hosts of the species that complete the life cycle in this fish. However, the presence of larval nematodes in these hosts also evidences their importance as intermediate host, especially of the L3 larvae of *Contracaecum* sp. The Anisakidae species are known worldwide for their low specificity to the intermediate host, infecting several hosts of marine and freshwater environments, and also for their proven zoonotic potential of some of their larvae (Mattiucci & Nascetti, 2008). Furthermore, Leite et al. (2017) used *Contracaecum* sp. larvae collected in other host species in this same river and proved that these helminths can be used as pollution indicators, since they accumulate heavy metals. *Cucullanus pinnae pinnae* has already been cited for *Loricaria* sp. (Luque, Aguiar, Vieira, Gibson, & Santos, 2011); however, the records of *R. kidderi* and the camalanids *P. (S.) inopinatus* and *P. (S.) rebecca* are the first for the *Loricaria* genus.

All parasite populations in the present study presented an aggregate distribution pattern, which is a characteristic frequently observed in parasitic ecology (Shaw & Dobson, 1995; Poulin, 2007). Due to the breadth of its trophic spectrum, diversified and less specialized than fish, with more restricted diets (such as carnivores and planktivores), it is expected that omnivores and detritivores fishes, such as *L. prolixa*, have access to a greater number and diversity of parasites, which would also influence this aggregation degree. But this observation only applies specifically to endoparasites that are usually transmitted through the food chain. In addition, this host has a benthic habit, and this behavior causes it to explore a more generalist diet in relation to pelagic species. According to studies by Amarante, Tassinari, Luque, and Pereira (2015), benthic fishes present a higher level of aggregation in most of their parasite taxa.

Although the community component of *L. prolixa* has been characterized with relatively low values of its diversity indexes, the species richness found (12 species identified) is much superior compared to other loricarid species (Thatcher, 2006; Kohn, Fernandes, & Cohen, 2007; Luque et al., 2011; Eiras et al., 2012). This pattern coincides with that observed in many freshwater species, with

parasite communities highly dominated by one or two species (in this case, two species of ectoparasites were the dominants), and low diversity (Kennedy, Bush, & Aho, 1986). In the same river, Pedro et al. (2016) obtained slightly higher values of diversity indexes for *Acestrorhynchus lacustris* Lütken, 1875 ( $H' = 1.42$ ;  $J = 0.75$ ,  $d = 1.28$ ), besides other studies that characterize the parasitic faunas of other host species in the Tietê-Batalha basin.

The positive correlations observed in this study between parasite abundance and standard host length were significant with ectoparasites (*D. spirophallus* and *Oligobdella* sp.) and Diplostomidae gen. sp. This fact is commonly observed in ectoparasites whose transmission is direct. Larger fishes will have larger contact surfaces; therefore, they will be capable of supporting a greater parasitic abundance (Gonzalez-Lanza, Alvarez-Pellitero, & Sitja-Bobadilla, 1991). Another matter to consider is that larger hosts are also older, that is, they have been exposed to potential parasites for longer periods of time than the young fishes (Poulin & Morand, 2000). However, there was a negative correlation between the abundance of the nematode *P. (S.) inopinatus* and the host standard length. This may occur due to changes in the host's food habit, throughout its ontogenetic development, for instance, the host ceases to feed on a certain item, which would act as an intermediate host when the fish becomes adult or due to the more pronounced immune resistance found in older fishes (Adams, 1985).

## Conclusion

The present study contributes to the knowledge of the parasitic fauna of *L. prolixa* by increasing the geographic distribution of some species and registering new occurrences in this host (*C. detruncatum*, Diplostomidae gen. sp., *A. compactum*, *R. kidderi*, *P. (S.) inopinatus*, *P. (S.) rebecca*, *C. pinnae pinnae*, *Oligobdella* sp. and *Trypanosoma* sp.), which, in turn, is so little known regarding its ecological and biological aspects, besides the increase in the knowledge of diversity fish parasites in inland waters of the State of São Paulo.

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