

Diversity of monogenean parasites on gills of fishes from the Matapi River, in the Brazilian Amazon

Diversidade de parasitos monogeneas nas brânquias de peixes do Rio Matapi, na Amazônia brasileira

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Abstract

This study investigated the fauna of monogeneans on gills of 13 fish species from the Matapi River, Brazilian Amazon. A total 548 fish belonging to 13 species (1 Anostomidae, 3 Characidae, 1 Curimatidae, 1 Hemiodontidae, 2 Serrasalminae, 3 Scianidae, 1 Ageneiosidae and 1 Tetradontidae) were examined. From these fish, 6 species were infected and with a total prevalence of 22.4%. Monogeneans collected are represented by the following taxa: *Anacanthorus gravihamulatus*, *Notozothecium minor*, *Notozothecium penetrarum*, *Diplectanum piscinarius*, *Aetheolabes goeldiensis*, *Euryhaliotrema succedanus*, *Anacanthorus jegui*, *Urocleidoides astyanacis*, *Urocleidoides strombicirrus*, *Euryhaliotrema* sp. and *Urocleidoides* spp. There was a variation in the prevalence, mean intensity and mean abundance of monogeneans among the host populations examined. Monogeneans of *Metynnis lippincottianus*, *Plagioscion squamosissimus*, *Astyanax bimaculatus* and *Curimata incompta* presented a highly aggregated dispersion pattern. Body weight of *M. lippincottianus* and *C. incompta* presented a weak positive correlation with abundance of parasites. Lastly, this is first study for 12 fish species from the Matapi River and the first report of *E. succedanus* for *Plagioscion surinamensis* and *N. penetrarum* for *Serrasalmus rhombeus*.

Keywords: Brazil, ectoparasites, freshwater fish, infection, Monogenea.

Resumo

Este estudo investigou a fauna de monogeneas das brânquias de 13 espécies de peixes do Rio Matapi, na Amazônia brasileira. Foram examinados um total de 548 peixes pertencentes a 13 espécies (1 Anostomidae, 3 Characidae, 1 Curimatidae, 1 Hemiodontidae, 2 Serrasalminae, 3 Scianidae, 1 Ageneiosidae e 1 Tetradontidae). Entre esses peixes, 6 espécies estavam infectadas e houve uma prevalência total de 22,4%. As espécies de monogeneas coletadas foram distribuídas nos seguintes táxons: *Anacanthorus gravihamulatus*, *Notozothecium minor*, *Notozothecium penetrarum*, *Diplectanum piscinarius*, *Euryhaliotrema* sp., *Aetheolabes goeldiensis*, *Euryhaliotrema succedanus*, *Anacanthorus jegui*, *Urocleidoides astyanacis*, *Urocleidoides strombicirrus*, *Urocleidoides* spp. Houve variação na prevalência, intensidade média e abundância média de monogeneas entre as populações hospedeiras. Monogeneas em *Metynnis lippincottianus*, *Plagioscion squamosissimus*, *Astyanax bimaculatus* e *Curimata incompta* apresentaram um padrão de dispersão altamente agregado. O peso corporal de *M. lippincottianus* do Rio Matapi mostrou uma correlação positiva fraca com a abundância de *A. jegui*. O comprimento de *C. incompta* também mostrou uma correlação positiva fraca com abundância de *Urocleidoides* spp. Por fim, este é primeiro estudo para 12 espécies de peixes da bacia do Rio Matapi e registra pela primeira vez *E. succedanus* para *Plagioscion surinamensis* e *N. penetrarum* para *Serrasalmus rhombeus*.

Palavras-chave: Brasil, ectoparasitos, peixes de água doce, infecção, Monogenea.

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Introduction

The Amazon River system has a high diversity and richness of fish species, representing the 7% of fish species from the planet. This richness and diversity are related to the various environmental characteristics of this basin, such as the seasonal variation in water level, pH, temperature, transparency, aquatic productivity, complexity of biotopes (lakes, rivers and streams), habitats (aquatic macrophytes and flooded forest), as well as other aspects directly related to its geology (Leal et al., 2018). In addition, this large hydrographic basin is formed by several tributaries of different size and importance for fishing activities that generates food and income for many riverine populations, as for example the Matapi River basin (Silva et al., 2016; Sousa et al., 2019).

The Matapi River is born in the central region of the state of Amapá (Brazil), flowing into the Amazon River, near the municipality of Santana. Its main tributaries are the Flexal and Pirativa rivers, and the Maruanum and Lago streams. This basin is influenced by daily floods from the tides of the Amazon River and is therefore influenced by the discharges from the Amazon River. These tides considerably affect the hydrodynamics of inundated forest and floodplain areas in the Matapi River basin (Santos et al., 2004; Silva et al., 2016; Sousa et al., 2019) and consequently, the life history of 104 species of fish known for this basin, among Characiformes, Cichliformes, Siluriformes, Clupeiformes, Tetraodontiformes, Gymnotiformes and Beloniformes. Among these families, Serrasalmidae, Characidae and Cichlidae are the most predominant (Silva et al., 2016). Despite this diversity of the ichthyofauna, there are only reports of monogeneans in the following cichlids: *Geophagus camopiensis* (Pellegrin, 1903), *Pterophyllum scalare* (Schultze, 1823), *Satanoperca jurupari* (Heckel, 1840) and *Satanoperca acuticeps* (Heckel, 1840) (Ferreira-Sobrinho & Tavares-Dias, 2016) and *Hemibrycon surinamensis* (Géry, 1962) (Sousa et al., 2019).

Monogenea (Van Beneden, 1858) are, in general, ectoparasites that mainly infect fish species, and have a simple and direct cycle and, consequently, may present a high reproduction rate in these hosts (Lapera et al., 2017). Some biotic factors influence the diversity and infection levels of monogeneans in fish, including the behavior, migratory habits, size, age, and sex of the hosts. Abiotic factors such as pollution, low dissolved oxygen, pH, water temperature and seasonality are also important for the levels of monogenean infection (Dogiel, 1961; Lizama et al., 2008; Vital et al., 2011, Takemoto et al., 2013; Tavares-Dias et al., 2014, 2017; Ferreira-Sobrinho & Tavares-Dias, 2016). Therefore, the diversity and infection levels by monogeneans can vary between the different species of fish (Whittington & Chisholm, 2008; Cohen et al., 2013), influenced by several factors. However, as the diversity of monogeneans in fish from the Matapi River is little known, the aim of this study was to investigate the fauna of these ectoparasites in the gills of 13 fish species of this basin.

Material and Methods

Fish collection procedures

Bimonthly, between March 2012 and August 2013, 13 species of fish were collected in the Matapi River (Table 1), in the municipality of Santana, state of Amapá, Brazil (Figure 1), for analysis of monogeneans in the gills. Fish were collected using gill nets of various mesh sizes (20, 25, 30, 35, 40 and 70 mm between knots), matapi traps, casting nets, hand lines and longlines, and the mean duration of fishing effort was 8 h. Gills were collected and fixed in formalin (5%) and transported to Laboratory of Aquaculture and Fishery of Embrapa Amapá, in Macapá (Brazil).

During fish collection, water temperature, electrical conductivity and pH were measured using a multiparameter analyzer (Horiba, model W23-XD). A Secchi disk was used to determine the transparency. The suspended solids analysis was performed using the gravimetric method and membrane filtration. Rainfall data were obtained from the Hydrometeorology and Renewable Energy Center (NHMET) of the Institute of Scientific and Technological Research of the State of Amapá (IEPA). The temperature was 27.5 ± 1.5 °C, pH 5.5 ± 0.7 , electrical conductivity 2.8 ± 1.9 μ S/cm, suspended solids 25.0 ± 29.5 , transparency 85.0 ± 57.3 cm and rainfall 219.4 ± 120.0 mm. Maximum temperature and precipitation occurred of June to December and minimum temperature and precipitation occurred of January to May.

The present study was conducted in accordance with the recommendations of the Brazilian College for Animal Experimentation and with authorization from the Ethics Committee for Use of Animals of Embrapa Amapá (Protocol N° 014 - CEUA/CPAFAP).

Parasite collection and analysis procedures

Each fish was weighed (g), measured for total length (cm), and analyzed for the presence of monogeneans. The gills were removed and analyzed using a stereomicroscope. The monogeneans found were preserved in ethyl alcohol (70%). The techniques used to count and prepare the parasites for identification were those previously recommended by Eiras et al. (2006). The ecological terms used were those recommended by Bush et al. (1997).

In order to detect the distribution pattern of the parasite infracommunities (Rózsa et al., 2000), the index of dispersion (ID) and the Poulin discrepancy index (D) were calculated using the Quantitative Parasitology 3.0 software for species with prevalence >10%. The ID significance for each infracommunity was tested using the *d*-statistic (Ludwig & Reynolds, 1988).

Differences in parasite prevalence between host species were evaluated using the G test. The correlation between the parasite abundance with length and weight of hosts was estimated using the Spearman correlation coefficient (Zar, 2010).

Table 1. Body parameters of the host fish species collected in Matapi River, state of Amapá (Brazil).

Order, Family, and fish species	N	Weight (g)	Length (cm)
CHARACIFORMES			
Anostomidae			
<i>Leporinus friderici</i> (Bloch, 1794)	50	44.6 ± 31.2	14.0 ± 3.8
Characidae			
<i>Astyanax lacustris</i> (Lütken, 1875)	75	11.7 ± 4.8	8.2 ± 0.9
<i>Moenkhausia lepidura</i> (Kner, 1858)	8	9.6 ± 5.5	9.5 ± 1.5
<i>Tetragonopterus chalceus</i> (Spix & Agassiz, 1829)	40	19.6 ± 17.4	9.3 ± 2.1
Curimatidae			
<i>Curimata incompta</i> (Vari, 1984)	132	33.7 ± 17.9	12.5 ± 2.7
Hemiodontidae			
<i>Hemiodus unimaculatus</i> (Bloch, 1794)	48	30.8 ± 13.1	12.4 ± 3.2
Serrasalmidae			
<i>Metynnix lippincottianus</i> (Cope, 1870)	89	11.1 ± 6.8	7.4 ± 1.2
<i>Serrasalmus rhombeus</i> (Linnaeus, 1766)	9	17.7 ± 20.5	6.5 ± 2.5
PERCIFORMES			
Sciaenidae			
<i>Plagioscion auratus</i> (Castelnau, 1855)	14	101.6 ± 86.6	19.9 ± 5.5
<i>Plagioscion squamosissimus</i> (Heckel, 1840)	51	56.3 ± 54.4	15.7 ± 5.7
<i>Plagioscion surinamensis</i> (Bleeker, 1973)	5	13.6 ± 8.1	8.9 ± 3.1
SILURIFORMES			
Ageneiosidae			
<i>Ageneiosus ucayalensis</i> (Castelnau, 1855)	10	55.8 ± 19.6	19.8 ± 4.5
TETRAODONTIFORMES			
Tetraodontidae			
<i>Colomesus asellus</i> (Muller & Troschel, 1849)	17	17.7 ± 9.1	8.6 ± 1.2
Total	548	-	-

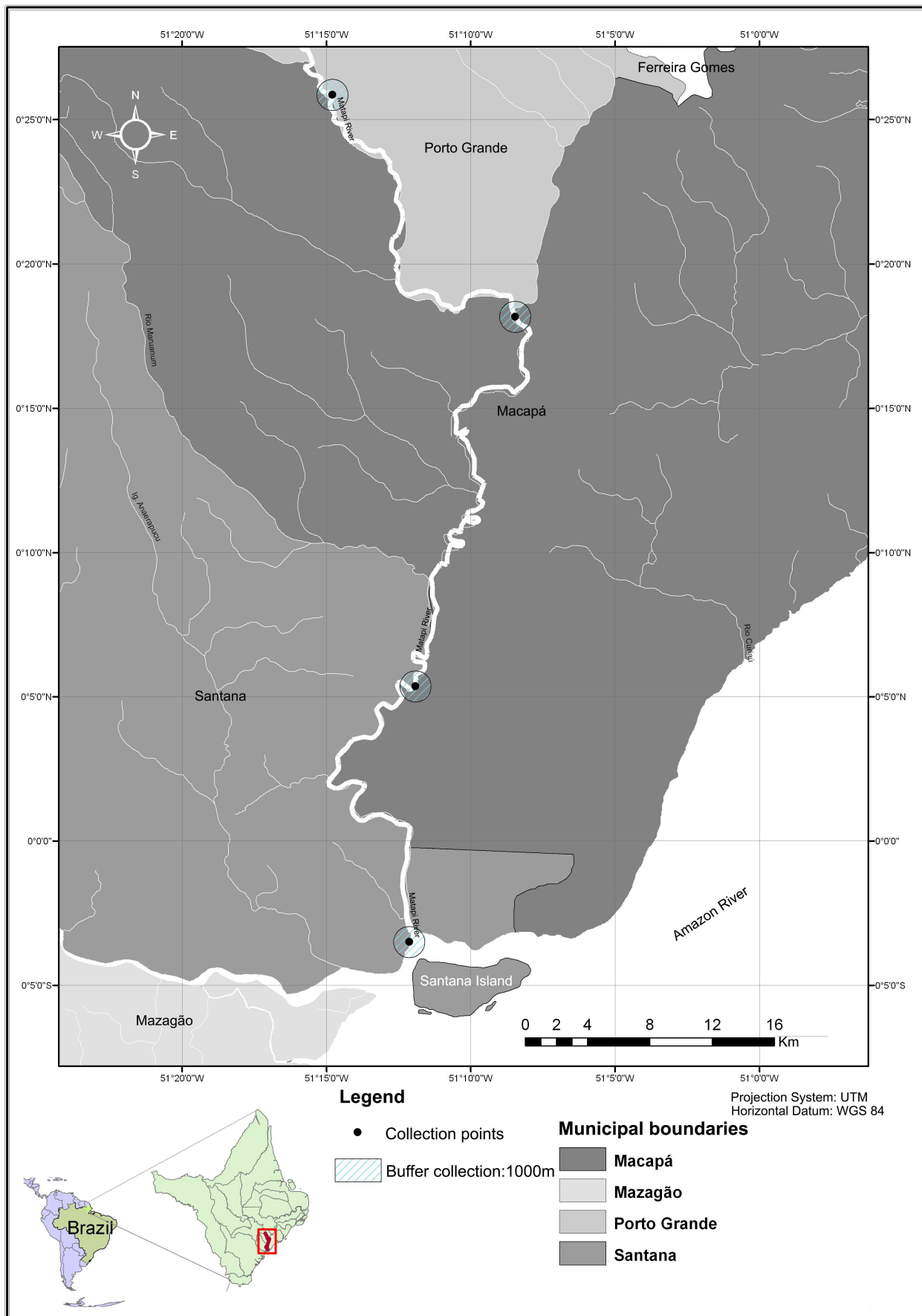


Figure 1. Collection sites of the fish species in Matapi River, state of Amapá, Brazil.

Results

Thirteen fish species were caught and a total of 548 specimens were examined. The total prevalence of monogeneans was 22.4%, and *Metynnis lippincottianus*, *Curimata incompta* and *Astyanax bimaculatus* were the more abundant fish species (Table 1).

From the 13 species of fish examined, six species were infected by one or more species of monogeneans, such as: *Anacanthorus gravihamulatus* Van Every & Kristsky, 1992; *Notozothecium minor* Boerger & Kristsky, 1988; *Notozothecium penetrarum* Boerger & Kristsky, 1988; *Diplectanum piscinarius* Kristsky & Thatcher, 1984; *Aetheolabes goeldiensis* Boerger & Kristsky, 2009; *Euryhaliotrema succedanus* Kristsky & Boerger, 2002; *Anacanthorus jegui* Kristsky & Boerge, 2002; *Urocleidoides astyanacis* Gioia, Cordeiro & Artigas, 1988; *Urocleidoides strombicirrus* (Price & Bussing, 1967) Kristsky & Thatcher, 1974; *Euryhaliotrema* sp.; *Urocleidoides* sp.1 and *Urocleidoides* sp.2. There was a variation in the prevalence, mean intensity and mean abundance of monogeneans among the host populations examined (Table 2). The prevalence of monogeneans in *Serrasalmus rhombeus* was similar to *Plagioscion squamosissimus* ($G = 0.951$, $p = 0.548$), *Plagioscion surinamensis* ($G = 0.498$, $p = 0.929$), *Metynnis lippincottianus* ($G = 0.098$, $p = 0.890$), *Astyanax bimaculatus* ($G = 5.019$, $p = 0.059$) and *Curimata incompta* ($G = 0.057$, $p = 0.874$). The prevalence of monogeneans in *P. squamosissimus* was similar to *P. surinamensis* ($G = 0.001$, $p = 0.651$) and *C. incompta* ($G = 3.107$, $p = 0.113$), and lower than in *M. lippincottianus* ($G = 7.456$, $p = 0.011$) and *A. bimaculatus* ($G = 5.992$, $p = 0.024$). The prevalence of monogeneans in *P. surinamensis* was similar to *M. lippincottianus* ($G = 1.237$, $p = 0.549$) and *A. bimaculatus* ($G = 0.867$, $p = 0.640$) and *C. incompta* ($G = 0.463$, $p = 0.849$). The prevalence of monogeneans in *M. lippincottianus* was similar to *C. incompta* ($G = 1.876$, $p = 0.229$), and lower than in *A. bimaculatus* ($G = 33.565$, $p < 0.001$). The prevalence of monogeneans in *A. bimaculatus* was higher than in *C. incompta* ($G = 25.499$, $p < 0.001$).

The infection by monogeneans in *M. lippincottianus* ($ID = 2.290$, $d = 6.8$, $D = 0.859$), *Plagioscion squamosissimus* ($ID = 5.930$, $d = 14.3$, $D = 0.763$), *A. bimaculatus* ($ID = 3.450$, $d = 10.4$, $D = 0.843$) and *C. incompta* ($ID = 4.550$, $d = 18.3$, $D = 0.855$) had a highly aggregated dispersion pattern.

There was no correlation between the abundance of monogeneans and the length ($r_s = -0.203$, $p = 0.152$) and weight ($r_s = -0.187$, $p = 0.188$) of *P. squamosissimus*. A weak positive correlation between the abundance of monogeneans and the length ($r_s = 0.293$, $p = 0.0006$) was found, but there was no correlation with the weight ($r_s = 0.099$, $p = 0.257$) of *C. incompta*. There was a correlation between the abundance of monogeneans and the length ($r_s = 0.187$, $p = 0.078$) of *M. lippincottianus*, but a weak positive correlation between the abundance of monogeneans and the weight ($r_s = 0.204$, $p = 0.05$) was observed. For *A. bimaculatus*, there was a correlation between the abundance of monogeneans and the length ($r_s = -0.033$, $p = 0.781$) and weight ($r_s = 0.041$, $p = 0.439$) of hosts.

Discussion

Monogeneans are parasites that are part of the biodiversity of ecosystems and serve as indicators of environmental quality, since they are generally present in greater abundance in environments with poor quality (Dogiel, 1961; Lizama et al., 2008; Takemoto et al., 2013; Ferreira-Sobrinho & Tavares-Dias, 2016; Lopera et al., 2017; Oliveira et al., 2017; Tavares-Dias et al., 2017). In *M. lippincottianus*, *P. squamosissimus*, *C. incompta* and *A. bimaculatus*, there was an aggregated dispersion for monogeneans, a pattern also reported for these parasites in other wild fish populations (Lizama et al., 2008; Hoshino & Tavares-Dias, 2014; Oliveira et al., 2017; Gallegos-Navarro et al., 2018), due to genetic heterogeneity, exposure and susceptibility of the host population and local environmental factors (Oliveira & Tavares-Dias, 2016; Tavares-Dias et al., 2017; Oliveira et al., 2017; Gallegos-Navarro et al., 2018).

In fish populations, sometimes the parasite abundance is correlated with body size of the host population, but this correlation may also be weak or non-existent due to several factors, for example, small variation in host size, small sampling, etc. (Lizama et al., 2008; Hoshino & Tavares-Dias, 2014; Tavares-Dias et al., 2014, 2017; Neves et al., 2016; Oliveira & Tavares-Dias, 2016; Lopera et al., 2017; Gallegos-Navarro et al., 2018). In *M. lippincottianus* from the Matapi River, the abundance of *A. jegui* had a weak positive correlation with body weight of this host. The abundance of *Urocleidoides* spp. also showed a weak positive correlation with the length of *C. incompta*. Similar finding was reported by Neves et al. (2016) for this same host from the Igarapé Fortaleza basin, in State of Amapá. Therefore, weight or length had little influence on the monogenean community of these two hosts.

In this study, *Plagioscion auratus* was not infected by any monogenean species, but *P. squamosissimus* was infected by *D. piscinarius*, *E. succedanus* and *A. goeldiensis*, and *P. surinamensis* was infected only by *E. succedanus*. However, Cohen et al. (2013) listed other species of monogeneans also infecting *P. squamosissimus* in Brazil:

Table 2. Species of Monogenea from the gills of fish species from the Matapi River, Amapá, Brazil.

Host species	Plagioscion squamosissimus			Plagioscion surinamensis			Serrasalmus rhombeus			Metynnix lippincottianus			Astyanax bimaculatus			Curimata incompta		
	P (%)	MI	MA	P (%)	MI	MA	P (%)	MI	MA	P (%)	MI	MA	P (%)	MI	MA	P (%)	MI	MA
<i>Anacanthorus gravihamulatus</i>	0	0	0	0	0	0	11.1	1	0.1 ± 0.3	0	0	0	0	0	0	0	0	0
<i>Notozothecium minor</i>	0	0	0	0	0	0	22.2	1.5	0.3 ± 0.7	0	0	0	0	0	0	0	0	0
<i>Notozothecium penetrarum</i>	0	0	0	0	0	0	33.3	1.7	0.6 ± 0.9	0	0	0	0	0	0	0	0	0
<i>Diplectanum piscinarium</i> and <i>Euryhaliootrema succedanus</i>	35.3	8.3	2.9 ± 6.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Aetheolabes goeldiensis</i>	29.4	4.3	1.3 ± 2.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Euryhaliootrema succedanus</i>	0	0	0	40.0	1.0	0.4 ± 0.5	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anacanthorus jegui</i>	0	0	0	0	0	0	0	0	0	19.1	1.9	0.4 ± 0.9	0	0	0	0	0	0
<i>Urocleidoides astyanacis</i>	0	0	0	0	0	0	0	0	0	0	0	0	58.7	6	3.5 ± 6.1	0	0	0
<i>Urocleidoides strombicirrus</i>	0	0	0	0	0	0	0	0	0	0	0	0	22.7	4.6	1.0 ± 3.3	0	0	0
<i>Urocleidoides</i> sp.1 and <i>Urocleidoides</i> sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.0	4.1	1.0 ± 4.6

P: Prevalence; MI: Mean intensity; MA: Mean abundance.

Diplectanum decorrum Kritsky & Thatcher, 1984; *Diplectanum gymnopus*, Kritsky & Thatcher, 1984; *Diplectanum pescadae*, Kritsky & Thatcher, 1984; *Euryhaliotrema chaoi*, Kritsky and Boeger, 2002; *Euryhaliotrema potamocetes*, Kritsky & Boeger, 2002 and *Euryhaliotrema thatcheri*, Kritsky & Boeger, 2002. The infection levels of monogeneans in *P. squamosissimus* and *P. surinamensis* were similar, since they are congeneric species of hosts inhabiting the same environment. However, in *P. squamosissimus* from the Tietê River, where it was introduced, there was infection only by *D. piscinarius* (Lopera et al., 2017) and the parasitism levels were higher than in *P. squamosissimus* and *P. surinamensis* of the current study. Lopera et al. (2017) showed that infections by *D. piscinarius* cause lesions in the gills of *P. squamosissimus*, because this monogenean species can be potentially harmful to hosts.

In *M. lippincottianus*, we found only *A. jegui*, and infection levels were lower than the reported by Hoshino & Tavares-Dias (2014), for this same host in the Igarapé Fortaleza basin. *Serrasalmus rhombeus* was infected by *A. gravihamulatus*, *N. minor* and *N. penetrarum*. Cohen et al. (2013) listed other 22 species of monogeneans infecting *S. rhombeus* in Brazil, of which 4 are species of *Amphithecium*, 7 *Anacanthorus*, 3 *Enallothecium*, 3 *Mymarothecium*, 4 *Notothecium* and 1 *Notozothecium*. However, this is the first record of *N. penetrarum* for *S. rhombeus*, because this parasite was originally described in *Pygocentrus nattereri* Kner, 1960 from the Guaporé River, State of Rondônia, northern Brazil (Boeger & Kritsky, 1988). In addition, the infection levels of monogeneans in *S. rhombeus* were lower than reported for *P. nattereri* from the Solimões River, State of Amazonas (Vital et al., 2011).

Astyanax bimaculatus from the Matapi River was infected by *U. astyanacis* and *U. trombicirrus*, but *U. astyanacis* presented higher infection levels. However, infection levels by these monogeneans were higher than those observed for *Urocleidoides* sp., *Amphitecium* sp. and *Notozothecium* spp. in *Astyanax altiparanae* Garutti & Britski, 2000 from the Upper Paraná River, State of Paraná, Brazil (Lizama et al., 2008). In the present study, *Curimata incompta* was infected by *Urocleidoides* spp., a similar finding reported also for *C. incompta* (Neves et al., 2016) and for *Curimata cyprinoides* Linnaeus, 1766 (Tavares-Dias et al., 2013) both hosts from the Igarapé Fortaleza basin. Despite these results, species of monogeneans that parasitize fish of the genus *Curimata* are still unknown (Cohen et al., 2013). In addition, infection levels by *Urocleidoides* spp. in *C. incompta* were lower than the reported for *C. cyprinoides* (Tavares-Dias et al., 2013) and for *C. incompta* from the Igarapé Fortaleza basin, an environment eutrophicated due to the urbanization of two municipalities (Tavares-Dias et al., 2013; Neves et al., 2016).

Conclusions

We found a diversity of monogenean species with distinct infection patterns in the studied fish species that may have been influenced by the host species and sampling. This is the first study for these fish species from the Matapi River, recording for the first time *E. succedanus* for *P. surinamensis* and *Notozothecium penetrarum* for *S. rhombeus*. The present study established fauna and infection data for monogeneans in different fish species from Matapi River basin, an ecosystem that is subject to an increase in environmental changes due to agriculture, extensive breeding of buffalo in the várzea forests, urbanization and industrialization. Thus, these data will be used for comparisons in future studies regarding environmental impacts from anthropogenic actions in this basin.

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