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Original Article

Community and infracommunities of metazoan parasites in *Hemiodus unimaculatus* (Hemiodontidae) from Jari River basin, a tributary of Amazon River (Brazil)

Comunidade e infracomunidades de parasitos metazoários em *Hemiodus unimaculatus* (Hemiodontidae) da bacia do Rio Jari, um tributário do Rio Amazonas (Brasil)

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Abstract

Parasites are an important part of biodiversity, and knowledge of species and their relationship with their hosts helps in monitoring an ecosystem over time. The aim of this study was to investigate the fauna of metazoan parasites in *Hemiodus unimaculatus* from the Jari River, in the eastern Amazon region, northern Brazil. Of the fish examined, 96.7% were parasitized by one or more species, and a total of 336 parasites such as Dactylogyridae gen. sp.1, Dactylogyridae gen. sp.2, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.4, Gyrodactilydae gen. sp*., Urocleidoides* sp.1, *Urocleidoides* sp.2, *Urocleidoides* sp.3, metacercariae of Digenea gen. sp., *Procamallanus* (*Spirocamallanus*) *inopinatus*, *Contracaecum* sp., *Neoechinorhynchus* sp. and Acarina gen. sp. The parasite community showed low Brillouin diversity (0.58 ± 0.29), low evenness (0.44 ± 0.21) and low species richness (7.40 ± 3.83). There was a predominance of ectoparasites, mainly monogeneans and digeneans. The parasites showed an aggregate dispersion, except for *P*. (*S.*) *inopinatus*, which had a random dispersion. The size of the hosts had no effect on diversity, species richness and abundance of parasites, but other factors structured the parasite community. This is the first study on the parasite community and infracommunities in *H. unimaculatus*.

Keywords: Aggregation, Amazon, freshwater fish, parasites.

Resumo

O objetivo deste estudo foi investigar a fauna de parasitos metazoários em *Hemiodus unimaculatus* do Rio Jari, na Amazônia oriental brasileira. Dos peixes examinados, 96,7% estavam parasitados por uma ou mais espécies, e um total de 336 parasitos, como Dactylogyridae gen. sp.1, Dactylogyridae gen. sp.2, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.4, Gyrodactilydae gen. sp., *Urocleidoides* sp.1, *Urocleidoides* sp.2, *Urocleidoides* sp.3, metacercárias de Digenea gen. sp., *Procamallanus* (*Spirocamallanus*) *inopinatus*, *Contracaecum* sp., *Neoechinorhyncus* sp. e Acarina gen. sp. A comunidade de parasitos apresentou baixa diversidade de Brillouin (0,58 ± 0,29), baixa equitabilidade (0,44 ± 0,21) e baixa riqueza de espécies (7,40 ± 3,83). Houve predominância de ectoparasitos, principalmente monogeneas e digeneas. Os parasitos apresentaram dispersão agregada, exceto *P.* (*S.*) *inopinatus*, que teve uma dispersão aleatória. O tamanho dos hospedeiros não teve efeito sobre a diversidade, riqueza de espécies e abundância de parasitos, mas outros fatores estruturaram a comunidade de parasitos. Este é o primeiro estudo sobre a comunidade e infracomunidades de parasitos em *H. unimaculatus*.

Palavras-chave: Agregação, Amazônia, peixe de água doce, parasitos.

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Introduction

The Amazon River system is home to the greatest aquatic diversity on the planet, as this large Neotropical basin has a considerable volume of water and unique environmental characteristics, in addition to several tributaries of various sizes throughout several countries of South America (Soares et al., 2008; Val, 2019). This large hydrographic basin that forms rivers, lakes, streams and floodplains of different sizes and shapes, has different environments with different types of water (white, black and clear) with various properties and with different levels of oxygen and pH (Val, 2019), such as the Jari River (Abreu & Cunha, 2016).

The Jari River has clear waters with low amounts of suspended material, oligotrophic, predominantly acidic pH, and is influenced by daily tides from the Amazon River to the stretch near the city of Laranjal do Jari (Abreu & Cunha, 2016; EPE, 2011). It is estimated that the average flow of the Jari River in the period of greatest precipitation is around 3,500 m^3/s, while in the dry period it reaches only 30 m^3/s (Cunha et al., 2010; Abreu & Cunha, 2015). The most prominent floodplain forests in this basin are the igapó, and the marginal vegetation is important to maintain fauna, serving as shelter, and as a food source (EPE, 2011).

Hemiodus unimaculatus (Bloch, 1794), a Characiformes of the family Hemiodontidae, is distributed in hydrographic basins of Suriname, French Guiana, Peru, and in Brazil it occurs in the basins of the Amazon, Ucayali, Japurá, Negro, Solimões-Amazonas, Madeira, Trombetas, Tapajós, Xingu, Tocantins and Oiapoque (Martins et al., 2017; Queiroz et al., 2013; Soares et al., 2008; Vasconcelos & Tavares-Dias, 2016). This Hemiodontidae inhabits beaches, lagoons, lakes and rivers with white, clear and black waters, being able to be captured mainly in flooded forests. It is a benthopelagic and migratory fish, with omnivorous feeding habits, feeding on detritus, periphyton, silt, filamentous algae, aquatic macrophytes, seeds, flowers, fruits, microcrustaceans and, occasionally, small invertebrates and insect larvae of Diptera, Heteroptera and Ephemeroptera (Cintra et al., 2013; Queiroz et al., 2013; Santos et al., 2004; Silva et al., 2008; Soares et al., 2008, Marinho et al., 2021).

Several studies have shown the importance of knowing the diversity of parasites in several wild fish species in the Amazon region (Hoshino & Tavares-Dias, 2019; Neves et al., 2016; Neves & Tavares-Dias, 2019; Oliveira et al., 2017; Tavares-Dias et al., 2013; Vasconcelos & Tavares-Dias, 2016). Parasites are part of biodiversity and have been little studied (Scholz & Choudhury, 2014; Pérez-Ponce de León & Aguilar-Aguilar, 2019). These small organisms play an important role in the biota, as they are able to control the population growth of their hosts and thus, keep the ecosystem in balance (Cardoso et al., 2017; Luque & Poulin, 2007). Furthermore, knowing the species of parasites and understanding their relationships with their hosts aids in monitoring an ecosystem over time (Pérez-Ponce de León, 2014).

For *H. unimaculatus* only two parasite species were recorded: *Ergasilus turucuyus* (Malta & Varella, 1996) (Copepoda) and *Excorallana berbicensis* (Boone, 1918) (Isopoda) (Vasconcelos & Tavares-Dias, 2016). Furthermore, few studies have been carried out with other species of *Hemiodus* (Table 1). In Brazil, in *Hemiodus semitaeniatus* (Kner, 1858) two species of Monogenea were reported in *Hemiodus microlepis* (Kner, 1858), a species of Digenea was reported and in *Hemiodus orthonops* (Eigenmann & Kennedy 1903) and the occurrence of a Nematoda was reported (Table 1).

Table 1. List of species of metazoan parasites reported for *Hemiodus* spp.

Host species	Species of parasites	Groups	Localities	References
Hemiodus microlepis (Kner 1858)	*Rondotrema microvitellarium* (Thatcher, 1999)	Digenea	Guaporé River, RO (Brazil)	Thatcher (2006)
Hemiodus orthonops (Eigenmann & Kennedy 1903)	*Procamallanus Spirocamallanus*) *paraguayensis* (Petter, 1990)	Nematoda	Brazil	Thatcher (2006)
Hemiodus semitaeniatus (Kner 1858)	*Cleidodiscus microcirrus* (Price & Schlueter, 1967)	Monogenea	Brazil	Agarwal & Kritsky (1998), Thatcher (2006)
	Monocleithrium lavergneae (Price & McMahon, 1966)	Monogenea	Brazil	Agarwal & Kritsky (1998), Thatcher (2006)
Hemiodus sp.	*Procamallanus* (*Spirocamallanus*) sp.	Nematoda	Brazil	Luque et al. (2011)
Hemiodus unimaculatus (Bloch 1794)	*Ergasilus turucuyus* (Malta & Varella)	Copepoda	Araguari River (AP), Brazil	Vasconcelos & Tavares-Dias (2016)
	Excorallana berbicensis (Boone, 1918)	Isopoda	Araguari River (AP), Brazil	Vasconcelos & Tavares-Dias (2016)

In wild fish populations, the study and understanding of the community structure and infracommunity of parasites can provide support for the use of this knowledge in parasitic ecology (Neves et al., 2016; Oliveira et al., 2017; Neves & Tavares-Dias, 2019). Thus, the aim of this study was to investigate the community and infracommunities of metazoan parasites in *H. unimaculatus* from the Jari River basin, in the State of Amapá, in the Brazilian Amazon.

Materials and Methods

Collection of fish specimens

From May to November 2019, 30 specimens of *H. unimaculatus* (19.0 ± 1.2 cm and 137.0 ± 21.0 g) were collected for parasitological analysis in the lower Jari River, in the Jarilândia District in the municipality of Vitória do Jari, Amapá state (Figure 1). The fish were collected with gill nets with 25 mm and 30 mm mesh (ICMBio: 23276-1) and transported to the Aquaculture and Fisheries Laboratory of Embrapa Amapá (Macapá) for analysis.

This study was approved by the Ethics Committee for the Use of Animals at Embrapa Amapá (Protocol No. 014/2018 – CEUA/CPAFAP).

Collection and analysis procedures of the parasites

Each fish was euthanized using the medullary section method before obtaining the weight (g) and standard length (cm). Then, each fish was necropsied for parasitological analysis. The mouth, gills, operculum and fins were examined for the presence of ectoparasites, while the viscera and gastrointestinal tract for the presence of endoparasites. The parasites were collected, fixed, preserved and prepared for identification. Monogeneans

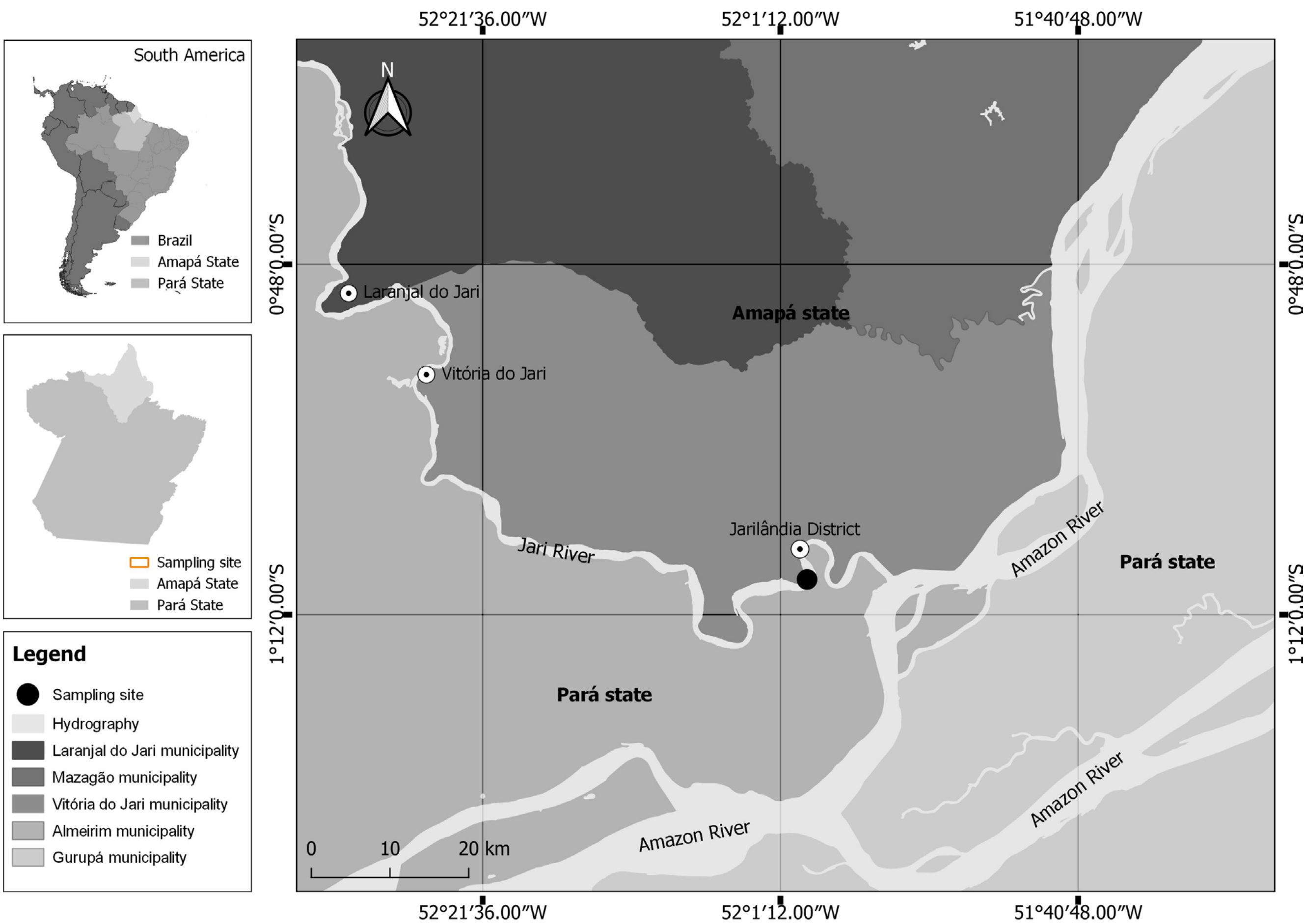

Figure 1. Location of the sampling of *Hemiodus unimaculatus* in the Jari River, a tributary of the Amazon River in the state of Amapá (Brazil).

were clarified in Hoyer medium to visualize the sclerotized structures. Nematodes were diaphanized in phenol to visualize the organs. Trematodes and acanthocephalans were stained with Langeron's alcoholic Carmin and diaphanized to visualize the internal structures (Eiras et al., 2006)

Analysis of the data

The ecological terms used here followed the recommendations of Bush et al. (1997). The Brillouin index (*HB*), evenness (*E*), Berger-Parker dominance index (*d*), species richness (Magurran, 2004) and dominance frequency, i.e., percentage of infracommunities in which a given parasite species is numerically dominant (Rohde et al., 1995) were calculated to assess the component community of parasites using the software Diversity (Pisces Conservation Ltd, UK). The Poulin dispersion index (ID) and discrepancy index (D) were calculated using the Quantitative Parasitology 3.0 software to detect the distribution pattern of parasite infracommunities (Rózsa et al., 2000) for species with a prevalence of >10%. The significance of the ID for each parasite infracommunity was tested using the d-statistic test (Ludwig & Reynolds, 1988).

Spearman's correlation coefficient (*rs*) was used to determine possible correlations of abundance, Brillouin diversity and species richness of parasites with host length and body weight (Zar, 2010).

Results

Communities and infracommunities of parasites

Of the examined *H. unimaculatus* (n = 30), 96.7% were parasitized by one or more species of monogenean parasites (Dactylogyridae gen. sp.1, Dactylogyridae gen. sp.2, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.4, *Urocleidoides* sp.1, *Urocleidoides* sp.2, *Urocleidoides* sp.3 and Gyrodactylidae gen. sp.), digeneans, nematodes, acanthocephalans and mites. There was a dominance of monogenean, digenea and acanthocephalan species (Table 2).

The component community was predominantly composed of ectoparasites. There was low diversity, low evenness and low species richness (Table 3). The parasites showed aggregated dispersion, except for *Procamallanus* (*Spirocamallanus*) *inopinatus* (Travassos, Artigas & Pereira, 1928) (Table 4).

Table 2. Metazoan parasites in *Hemiodus unimaculatus* of the Jari River, a tributary of the Amazon River in the state of Amapá (Brazil).

Species of parasites	P (%)	MI ± SD	MA ± SD	TNP	FD (%)	SI
Dactylogyridae gen. sp.1, Dactylogyridae gen. sp.2, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.4, *Urocleidoides* sp.1, *Urocleidoides* sp.2, *Urocleidoides* sp.3 and Gyrodactylidae gen. sp.	66.7	4.5 ± 4.5	3.0 ± 4.4	91	27.1	Gills
Digenea gen. sp. (metacercariae)	60.0	4.1 ± 3.1	2.4 ± 3.0	73	21.7	Gills
Neoechinorhynchus n. sp.	46.7	5.9 ± 5.3	2.7 ± 5.1	82	24.4	Pyloric cecum
Neoechinorhynchus n. sp.	3.3	2.0 ± 0	0.06 ± 0.4	2	0.6	Abdominal cavity
Neoechinorhynchus n. sp.	53.3	2.3 ± 1.9	1.2 ± 1.8	37	11.0	Intestine
Procamallanus (*Spirocamallanus*) *inopinatus*	50.0	2.40 ± 1.6	1.2 ± 1.6	36	10.7	Pyloric cecum
Procamallanus (*Spirocamallanus*) *inopinatus*	26.7	1.63 ± 1.0	0.4 ± 0.9	13	3.9	Intestine
Contracaecum sp. (larvae)	3.3	1.00 ± 0	0.03± 0.2	1	0.3	Intestine
Acarina gen. sp.	3.3	1.00 ± 0	0.03 ± 0.2	1	0.3	Gills

P: Prevalence, MI: Mean intensity, MA: Mean abundance, TNP: Total number of parasites, FD: Frequency of dominance, SI: Site of infection, SD: Standard deviation.

Table 3. Component community of the metazoan parasites in *Hemiodus unimaculatus* of the Jari River, a tributary of the Amazon River in the state of Amapá (Brazil).

Parameters	Values
All parasite species	
Number of hosts examined	30
Total prevalence (%) of parasites	96.7
Total number of parasites	336
Number of species of parasites	13
Brillouin diversity index	0.58 ± 0.29
Equitability	0.44 ± 0.21
Species richness of parasites	7.40 ± 3.83
Berger-Parker dominance	0.62 ± 0.19
Endoparasite species	
Number of species of endoparasites	3
Percent of endoparasites (%)	23.1
Species of endoparasites (larvae)	1
Species of endoparasites (adults)	2
Species of ectoparasites	
Number of species of ectoparasites	10
Percent of ectoparasites (%)	76.9
Species of ectoparasites (larvae)	1

Table 4. Dispersion index (ID), *d*-statistic (*d*) and discrepancy index (D) for the infracommunity of parasites in *Hemiodus unimaculatus* of the Jari River, a tributary of the Amazon River in the state of Amapá (Brazil).

Parasite species	ID	*d*	D	Type of dispersion
Dactylogyridae gen. sp.1, Dactylogyridae gen. sp.2, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.4, *Urocleidoides* sp.1, *Urocleidoides* sp.2, *Urocleidoides* sp.3 and Gyrodactylidae gen. sp.	1.87	2.86	0.503	Aggregate
Digenea gen. sp.	2.77	5.12	0.583	Aggregate
Neoechinorhyncus n. sp.	1.82	2.72	0.454	Aggregate
Procamallanus (*S.*) *inopinatus*	1.09	0.40	0.484	Random

Brillouin diversity (*rs* = -0.337, p = 0.194) and species richness of the parasites did not correlate with host length (*rs* = -0.424, p = 0.099). The abundance of monogeneans showed no correlation with the length (*rs* = -0.192, p = 0.469) and weight (*rs* = 0.037, p = 0.905) of the hosts. The abundance of Digenea gen. sp. showed no correlation with the length (*rs* = 0.0679, p = 0.797) and weight (*rs* = -0.273, p = 0.491) of the hosts. The abundance of *Neoechinorhynchus* n. sp. there was no correlation with the length (*rs* = -0.072, p = 0.780) and weight (*rs* = 0.259, p = 0.545) of the hosts. The abundance of *P*. (*S*.) *inopinatus* did not correlate with the length (*rs* = -0.336, 0.198) and weight (*rs* = 0.198, 0.198) of the hosts.

There was a predominance of hosts parasitized by 9 to 11 species of parasites (Figure 2).

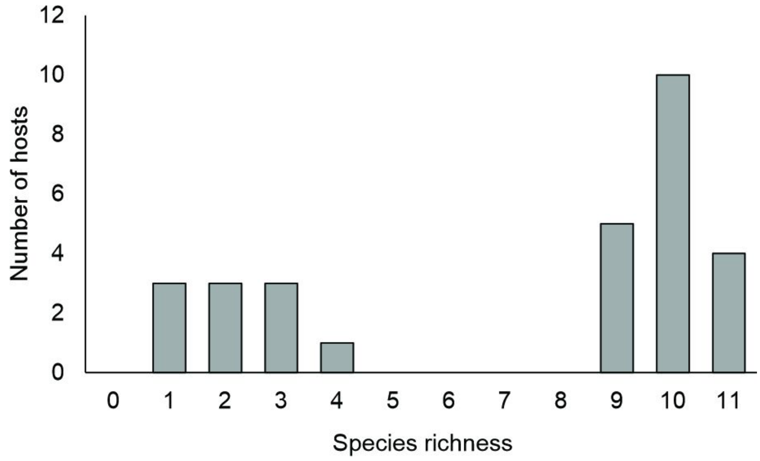

Figure 2. Species richness of the metazoan parasites in *Hemiodus unimaculatus* of the Jari River, a tributary of the Amazon River in the state of Amapá (Brazil).

Discussion

In host fish, the diversity and community of parasites is constituted by a set of species present in the environment. Feeding habits are important in the acquisition of endoparasites, while the host habitat, behavior and swimming ability of the parasites are important in the infestation by ectoparasites (Guidelli et al., 2003; Oliveira et al., 2017; Gonçalves et al., 2018). The community of metazoan parasites of *H. unimaculatus* from the Jari River was composed of eight species of monogeneans, one digenean, two nematodes, one acanthocephalan and one Acarina. There was low diversity, low evenness and low species richness and predominance of ectoparasites. Other species of monogeneans, digeneans and nematodes have been reported for *Hemiodus* spp. (Table 1). However, this is the first study of the parasite community in *H. unimaculatus*, so all parasite species found here are new records for this hemiodontid.

Fish can be parasitized by different species, which may be dispersed differently in hosts (Guidelli et al., 2003; Moller, 2006; Gonçalves et al., 2018). Aggregate dispersion pattern of parasites is mainly related to its strategy and direct reproduction, heterogeneity of hosts regarding susceptibility to parasites and the differentiated immune system, so that this aggregation pattern stabilizes the dynamics of the parasite-host relationship, controlling the parasitized fish population (Moller, 2006). In *H. unimaculatus* from the Jari River, the parasites showed an aggregated dispersion, a typical pattern in different parasitic species in fish (Rohde et al., 1995; Guidelli et al., 2003; Tavares-Dias et al., 2013; Gonçalves et al., 2018). However, infection by *P*. (*S*.) *inopinatus* showed random dispersion, a pattern that is reported for nematode species of fish parasites due to its pathogenicity (Gonçalves et al., 2018; Neves et al., 2020). Gaines et al. (2012) reported that *P*. (*S*.) *inopinatus* is pathogenic, causing severe histopathological changes in the intestine of *Arapaima gigas* (Schinz, 1822).

In the Neotropical region, dactylogyrid monogeneans are a group of ectoparasites that make up the parasitic fauna of host fish (Thatcher, 2006). Of the eight species of monogeneans found in this study, seven were Dactylogyridae. However, in *H. unimaculatus* no species has been described (Table 1). *H. semitaeniatus* showed *Cleidodiscus microcirrus* (Price & Schlueter, 1967) and *Monocleithrium lavergneae* (Price & McMahon, 1966) have been reported. In the gills of *H. unimaculatus* from Jari River there was a high prevalence of monogeneans (Dactylogyridae gen. sp.1, Dactylogyridae gen. sp.2, Dactylogyridae gen. sp.3, Dactylogyridae gen. sp.4, *Urocleidoides* sp.1, *Urocleidoides* sp.1, *Urocleidoides* sp.2, *Urocleidoides* sp.3 and Gyrodactilydae gen. sp.), however, there was low mean intensity and mean abundance.

In fish from Brazil, *P*. (*S*.) *inopinatus* are found in the adult stage, with prevalence ranging from low to moderate, low intensity and low abundance (Neves et al., 2020), similar to that shown in the present study with *H. unimaculatus*. This level of parasitism can be attributed to the fact that this nematode has a complex life cycle, with transmission through prey-predator interactions (Thatcher, 2006; Neves et al., 2020). Thus, the presence of copepods (intermediate hosts), containing infective stages of *P*. (*S*.) *inopinatus* in the environment, determines the levels of its infection in fish populations, which are definitive hosts (Thatcher, 2006; Oliveira et al., 2017). To date, no nematode has been known to parasitize *H. unimaculatus* (Table 1). In addition, in *H. unimaculatus* from the Jari River there was also low infection of *Contracaecum* sp. larvae, a common nematode in fish from Brazil, which are second intermediate hosts, or paratenic, microcrustaceans are the first intermediate hosts and piscivorous birds are the definitive hosts (Pinheiro et al., 2019).

Digenean metacercariae were found with high prevalence in the gills of *H. unimaculatus* of Jari River, but with low average intensity and low average abundance. This indicates that this fish plays the role of an intermediate host for this ectoparasite. With a complex life cycle, many digeneans have piscivorous birds as definitive hosts (Thatcher, 2006; Morley, 2012). No species of digenea are known to infect *H. unimaculatus*. However, *Rondotrema microvitellarium* (Thatcher, 1999) has been reported to parasitize *H. microlepis* from Amazon (Thatcher, 2006).

Acanthocephalans of the *Neoechinorhynchus* genus are obligate endoparasites with a complex life cycle and use microcrustaceans, usually an ostracod, as a primary intermediate host, while fish can be paratenic, secondary intermediate or definitive hosts (Kennedy, 2006; Thatcher, 2006; Melo et al., 2015). To date, no acanthocephalan species has been reported for *Hemiodus* species (Table 1). In *H. unimaculatus*, there was moderate prevalence and low abundance of *Neoechinorhynchus* sp. These low levels of *Neoechinorhynchus* n. sp. in *H. unimaculatus* may be due to its omnivorous habit, which includes the intermediate host in its diet (Silva et al., 2008; Marinho et al., 2021).

Few studies have observed fish as hosts for mites, and few species have been described. These Acarina can generally be found in the gills, integument and digestive tract (Lizama et al., 2013), and high infections can cause severe damage to these hosts (Heckmann, 2003). In the gills of *H. unimaculatus* from the Jari River, infection by mites was low, which may have been accidental. Gonçalves et al. (2018) also reported low mite infestation in the gills of *Colossoma macropomum* (Cuvier, 1818) from the Jari River. More studies need to be carried out to understand the diversity of these parasites in neotropical fish.

In conclusion, the metazoan parasite community of *H. unimaculatus* from the Jari River presented low diversity, low richness, low intensity and low abundance. *Hemiodus unimaculatus* in the Jari River is an intermediate and definitive host. This first study on the community and infracommunity of metazoan parasites in *H. unimaculatus* showed that host size had no effect on the diversity, species richness and abundance of parasites, since their diet was a factor that influenced their parasite community.

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