**Original Article**

# Structure of the parasites communities in two Erythrinidae fish from Amazon river system (Brazil)

Estrutura da comunidade de parasitos em dois peixes Erythrinidae do sistema do Rio Amazonas (Brasil)

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## Abstract

This study compared the parasite communities of *Hoplias malabaricus* and *Hoplerythrinus unitaeniatus* from Amazon river system. *Hoplias malabaricus* were infected by *Ichthyophthirius multifiliis*, *Piscinoodinium pillulare*, *Tetrahymena* sp., *Urocleidoides eremitus*, *Braga patagonica*, metacercariae of *Clinostomum marginatum*, *Procamallanus* (*Spirocamallanus*) *inopinatus*, larvae of *Contracaecum* sp. and larvae of *Nomimoscolex matogrossensis*. *Hoplerythrinus unitaeniatus* were also infected by these same species of protozoans, nematodes, digeneans and cestodes, except for *Tetrahymena* sp. and *B. patagonica*, which were replaced by *Argulus pestifer*, *Urocleidoides* sp., *Whittingtonocotyle caetei*, *Whittingtonocotyle jeju* and *Gorytocephalus spectabilis*. For both hosts, *I. multifiliis* and *P. pillulare* were the predominant parasites. Most of the parasites presented an overdispersion. Parasite species richness, Brillouin diversity, evenness and Berger-Parker dominance were similar for the two hosts. The length and weight of *H. malabaricus* showed a positive correlation with the abundance of *U. eremitus* and *Contracaecum* sp., while the weight of *H. unitaeniatus* showed a positive correlation with the abundance of *I. multifiliis*. The diversity of ectoparasites seemed to be influenced by the behavior of these two hosts. This was shown by the similar parasite communities and was characterized by low species diversity, low evenness and low richness, and by a high prevalence of ectoparasites.

**Keywords:** Amazon, diversity, Erythrinidae, overdispersion, parasites infracommunity.

## Resumo

Este estudo comparou a comunidade parasitária de *Hoplias malabaricus* e *Hoplerythrinus unitaeniatus* do sistema do Rio Amazonas. *Hoplias malabaricus* estavam infectados por *Ichthyophthirius multifiliis*, *Piscinoodinium pillulare*, *Tetrahymena* sp., *Urocleidoides eremitus*, *Braga patagonica*, metacercarias de *Clinostomum marginatum*, *Procamallanus* (*Spirocamallanus*) *inopinatus*, larvas de *Contracaecum* sp. e larvas de *Nomimoscolex matogrossensis*. *Hoplerythrinus unitaeniatus* estavam também infectados por essas mesmas espécies de protozoários, nematoides, digeneas e cestóide, exceto *Tetrahymena* sp. e *B. patagonica*, que foram substituídos por *Argulus pestifer*, *Urocleidoides* sp., *Whittingtonocotyle caetei*, *Whittingtonocotyle jeju* e *Gorytocephalus spectabilis*. Para ambos os hospedeiros, a dominância foi de *I. multifiliis* e *P. pillulare*. Houve dispersão agregada para a maioria dos parasitos e similar riqueza de espécies de parasitos, diversidade de Brillouin, uniformidade e dominância de Berger-Parker, para ambos os hospedeiros. O comprimento e peso de *H. malabaricus* mostrou correlação positiva com a abundância de *U. eremitus* e *Contracaecum* sp., enquanto o peso de *H. unitaeniatus* mostrou correlação positiva com abundância de *I. multifiliis*. A diversidade de ectoparasitos parece influenciada pelo comportamento desses dois hospedeiros. Isso é mostrado pela similar comunidade de parasitos e caracterizada por uma baixa diversidade de espécies, baixa uniformidade e baixa riqueza de espécies, e pela elevada prevalência de ectoparasitos.

**Palavras-chave:** Amazônia, diversidade, Erythrinidae, agregação, infracomunidades de parasitos.

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## Introduction

*Hoplias malabaricus* Bloch, 1794 (Thraira), and *Hoplerythrinus unitaeniatus* Spix & Agassiz, 1829 (Aimara), are benthopelagic species of Erythrinidae with wide distribution in South and Central America. Both of these fish are sedentary and occur in several types of fluvial and lacustrine environments, especially in shallow water environments and near submerged or marginal vegetation, where prey abundance tends to be high, thus increasing their success in catching their prey. These fish are piscivorous when adults, but juveniles also feed on plankton, crustaceans, insects and seeds. These species are habitually active at twilight and night and do not undertake migration (SANTOS et al., 2006; SOARES et al., 2011; BENIGNO et al., 2014). These fish are also commonly found in the Amazon river system, which is a complex ecosystem that includes tributary rivers and streams and floodplains and periodically flooded forest alongside them.

*Hoplias malabaricus* and *H. unitaeniatus* are important fishery resources in the feeding of human riverine populations from Amazon, and they are fish used in aquaculture and as ornamental fish (BENIGNO et al., 2014). In Brasil, the farmed production of *H. malabaricus* in 2001 was 926.5 tons and the fished production was approximately 10,000 tons, whereas the fished production of *H. unitaeniatus* was 316.3 tons (BRASIL, 2013). Thus, development of fishery programs requires information on the health of natural stocks. Knowledge of the parasites of natural populations of fish makes it possible to evaluate the impact of these parasites on their hosts, given that many parasites may influence the structure, size, feeding, growth rate and reproduction of natural populations (TAKEMOTO et al., 2009; MOREIRA et al., 2009; TAVARES-DIAS et al., 2014a), along with the quality and acceptance of infected fish in the consumer market (BENIGNO et al., 2014). Furthermore, studies on parasitic infections in fish populations provide an important increase in the information available on the parasite-host system.

In *H. malabaricus*, there have been reports of infections due to species of crustaceans, monogeneans, nematodes, digeneans, acanthocephalans, cestodes and hirudineans (CHAMBRIER et al., 1996; TAKEMOTO et al., 2009; ROCHA, 2011; ROSIM et al., 2011; BENIGNO et al., 2012; GRAÇA et al., 2013; BENIGNO et al., 2014). On the other hand, *H. unitaeniatus* has been parasitized by species of crustaceans (MALTA, 1984; LEAL et al., 2010), nematodes (MARTINS et al., 2005; BENIGNO et al., 2012) and acanthocephalans (TAKEMOTO et al., 2009). However, the structure of the parasite communities and infracommunities of these two hosts has not been studied. The present study compared the parasite communities and infracommunities of *H. malabaricus* and *H. unitaeniatus* from Amazon river system in Brazil.

## Materials and Methods

### Fish and study area

Between August and December 2011, 33 specimens of *Hoplias malabaricus* (20.9 ± 3.0 cm and 113.8 ± 43.7 g) and 30 specimens of *Hoplerythrinus unitaeniatus* (21.9 ± 2.6 cm and 148.1 ± 42.8 g) were collected in the Igarapé Fortaleza basin, in the municipality of Macapá (Amapá State), in the eastern Amazon region of Brazil, for parasitological analyses. The Igarapé Fortaleza is a tributary creek of the Amazon river system that has a relatively defined river bed and extensive adjacent lowland areas that are strongly influenced by the daily tides of the Amazon river and the seasonal levels governed by the rainfall of the Amazon region. The Igarapé Fortaleza basin has rich vegetation consisting of floodplain forest and a variety of species of macrophytes (TAVARES-DIAS et al., 2014a; BITTENCOURT et al., 2014).

All the fish were caught using nets of mesh size 20-30 mm between knots and were transported packed in ice to the Laboratory for Aquatic Organism Health, at Embrapa Amapá, in Macapá.

### Parasite analysis procedures

The mouth, opercula, gills, visceras and gastrointestinal tract of each fish were examined. The gills were removed, fixed in 5% formol and analyzed with the aid of a stereomicroscope and standard optical microscope. The gastrointestinal tract was removed in order to investigate the possible presence of endoparasites, which was done under a stereomicroscope. The methodology used for collecting, fixing, staining and counting the parasites followed the recommendations in the literature (EIRAS et al., 2006). The parasitological terms adopted were those recommended by Rohde et al. (1995) and Bush et al. (1997).

The Brillouin index (*HB*), evenness (*E*), Berger-Parker dominance index (*d*) and species richness (MAGURRAN, 2004) were calculated for the parasite component community, by using the Diversity software (Pisces Conservation Ltd., UK). The dispersion index (ID) and the discrepancy index (D) were calculated using the Quantitative Parasitology 3.0 software, in order to detect the distribution pattern of each parasite infracommunity (RÓZSA et al., 2000), in species with prevalence >10%. The significance of ID for each parasite species was tested using *d*-statistics (LUDWIG & REYNOLDS, 1988).

The species richness, *HB*, *E* and *d* of the two hosts were compared using the Mann-Whitney *U* test. Data on body weight (g) and total length (cm) were used to calculate the relative condition factor (Kn) of the fish (LE-CREN, 1951), which was compared with the standard value (Kn = 1.0) by means of the t test. The Pearson correlation coefficient (r) was used to determine correlations of the host length with the species richness, *HB*, *E*, *d* and parasite abundance (ZAR, 2010).

At each collection time, the hydrogen ion potential (pH) (mean of 6.6 ± 0.2), temperature (28.1 ± 0.3 °C) and dissolved oxygen level (3.0 ± 0.4) were determined using digital apparatus appropriate for each purpose.

## Results

All the specimens of *H. malabaricus* were parasitized by one or more parasites, such as *Ichthyophthirius multifiliis* Fouquet, 1876 (Ciliophora); *Piscinoodinium pillulare* Schäperclaus, 1954, Lom, 1981 (Dinoflagellida); *Tetrahymena* sp. (Ciliophora); *Braga patagonica* Schödte & Meinert, 1884 (Cymothoidae); *Urocleidoides eremitus*

Kritsky, Thatcher & Boeger, 1986 (Monogenoidea); metacercariae of *Clinostomum marginatum* Rudolphi, 1819 (Clinostomidae); larvae and adults of *Procamallanus (Spirocamallanus) inopinatus* Travassos, Artigas & Pereira, 1928 (Camallanidae); larvae of *Contracaecum* sp. (Anisakidae) and larvae of *Nomimoscolex matogrossensis* Rego & Pavanelli, 1990 (Monticelliidae). All the specimens of *H. unitaeniatus* were also parasitized by one or more parasite such as *I. multifiliis*; *P. pillulare*; *Argulus pestifer* Ringuelet, 1948 (Argulidae); *Urocleidoides* sp.; *Anacanthorus* sp.; *Whittingtonocotyle caetei* Santos-Neto, Rodrigues & Domingues, 2015; *Whittingtonocotyle jeju* Santos-Neto, Rodrigues & Domingues, 2015; (Monogenoidea), metacercariae of *C. marginatum*; larvae of *Contracaecum* sp.; larvae and adults of *P. (S.) inopinatus*; larvae and adults of *Gorytocephalus spectabilis* Machado Filho, 1959 (Neoechinorhynchidae) and larvae of *N. matogrossensis* (Table 1). However, for both hosts, *I. multifiliis* and *P. pillulare* predominated and the component community was dominated by ectoparasite species. There was an overdispersion of the parasites in *H. malabaricus* and *H. unitaeniatus*, except for *Tetrahymena* sp. in the gills of *H. malabaricus*, which showed random dispersion. In addition, *Urocleidoides* sp., *Whittingtonocotyle* spp. and *N. matogrossensis* presented random dispersion in *H. unitaeniatus* (Table 2).

The diversity of parasites was similar for *H. malabaricus* and *H. unitaeniatus* (Table 3). For *H. unitaeniatus*, hosts parasitized by three to five parasite species predominated and for *H. malabaricus*, hosts parasitized by four and five parasite species predominated (Figure 1). In *H. malabaricus*, the length of the hosts did not show any correlation with the species richness ($rs = 0.263$, $p = 0.139$), Brillouin index ($rs = 0.163$, $p = 0.363$) and evenness ($rs = 0.283$, $p = 0.110$). In *H. unitaeniatus*, the length of the hosts also did not show any correlation with the species richness ($rs = -0.044$, $p = 0.817$), Brillouin index ($rs = -0.261$, $p = 0.164$) or evenness ($rs = -0.261$, $p = 0.164$).

In *H. malabaricus*, the mean Kn ($1.01 \pm 0.03$; $t = -4.28$; $p = 0.006$) was greater than the standard, but in *H. unitaeniatus*, the Kn ($1.00 \pm 0.03$; $t = -5.04$; $p = 0.499$) did not differ from the standard (Kn = 1.00), according to the *t*-test. The length and weight of *H. malabaricus* showed a weak positive correlation with the abundance of *U. eremitus* and larvae of *Contracaecum* sp. For *H. unitaeniatus*, only the weight of the hosts showed a weak correlation with the abundance of *I. multifiliis* (Table 4). However, for both hosts, none of the parasite species showed any correlation ($p > 0.05$) with Kn.

## Discussion

The parasitic fauna of *H. malabaricus* was constituted by 10 taxons: three species of Protozoa, one of Isopoda, one of Monogenoidea, one of Cestoda, two of Nematoda and one of Digenea. The parasitic fauna of *H. unitaeniatus* comprised 12 taxons: two species of Protozoa, one of Argulidae, four of Monogenoidea, one of Cestoda, two of Nematoda, one of Acanthocephala and one of Digenea. However, the diversity was similar for the two Amazonian hosts. The parasite communities in *H. malabaricus* and *H. unitaeniatus* were dominated by the ectoparasites *I. multifiliis* and *P. pillulare*, in the same way as has been reported for other fish in the same area, i.e. the eastern Amazon region (BITTENCOURT et al., 2014; TAVARES-DIAS et al., 2014a). However, among the endohelminths of *H. malabaricus* and *H. unitaeniatus*, larvae predominated, especially those of *Contracaecum* sp. and *Clinostomum marginatum*, which are parasites with low host specificity. Thus, these two fish species are also hosts for different species of endohelminths that are transmitted via the trophic chain. These fish can be used as hosts by different endohelminth species, but the diversity of the community of

**Table 1.** Site of infection (SI), prevalence (P), mean intensity (MI), mean abundance (MA) and total number of parasites (TNP) in two Erythrinidae fish from Amazonas river system (Brazil).

| Hosts | *Hoplias malabaricus* (n = 33) | | | | | *Hoplerythrinus unitaeniatus* (n = 30) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parasites | P (%) | MI | MA | TNP | SI | P (%) | IM | AM | NTP | SI |
| *Ichthyophthirius multifiliis* | 100 | 12,278.7 | 12,278.7 | 405,196 | Gills | 100 | 41,094.2 | 41,094.2 | 1,232,826.0 | Gills |
| *Piscinoodinium pillulare* | 51.5 | 1544.1 | 795.5 | 26,250 | Gills | 83.3 | 1152.8 | 960.7 | 28,820 | Gills |
| *Tetrahymena* sp. | 12.1 | 210.0 | 25.5 | 840 | Gills | - | - | - | - | - |
| *Braga patagonica* | 6.1 | 1.0 | 0.1 | 2.0 | Gills | - | - | - | - | - |
| *Argulus pestifer* | - | - | - | - | - | 6.7 | 1.0 | 0.1 | 2 | Gills |
| *Urocleidoides eremitus* | 97.0 | 29.1 | 28.2 | 931 | Gills | - | - | - | - | - |
| *Urocleidoides* sp. | - | - | - | - | - | 16.7 | 2.4 | 0.4 | 12 | Gills |
| *Anacanthorus* sp. | - | - | - | - | - | 10.0 | 3.0 | 0.3 | 9 | Gills |
| *Whittingtonocotyle caetei* and *Whittingtonocotyle jeju* | - | - | - | - | - | 53.3 | 2.2 | 1.2 | 35 | Gills |
| *Contracaecum* sp. | 51.5 | 8.1 | 4.2 | 138 | Intestine | 63.3 | 7.8 | 5 | 149 | Intestine |
| *Contracaecum* sp. | 33.3 | 20.4 | 6.8 | 224 | Caecum | 20.0 | 4.0 | 0.8 | 24 | Caecum |
| *Contracaecum* sp. | 6.1 | 3.0 | 0.2 | 6 | Liver | - | - | - | - | - |
| *Procamallanus (S.) inopinatus* | 9.1 | 1.3 | 0.1 | 4 | Stomach | 23.3 | 4.7 | 1.1 | 33 | Intestine |
| *Clinostomum marginatum* | 24.2 | 4.3 | 1.0 | 34 | Gills | 36.7 | 5.3 | 1.9 | 58 | Gills |
| *Clinostomum marginatum* | 9.1 | 3.0 | 0.3 | 9 | Intestine | 10.0 | 3.3 | 0.3 | 10 | Intestine |
| *Gorytocephalus spectabilis* | - | - | - | - | - | 36.7 | 3.3 | 1.2 | 36 | Intestine |
| *Nomimoscolex matogrossensis* | 21.2 | 3.1 | 0.7 | 22 | Intestine | 13.3 | 1.3 | 0.2 | 5 | Intestine |

**Table 2.** Index of dispersion (ID), *d*-statistics, discrepancy index (D) and frequency of dominance (FD) for infracommunities of parasites in two Erythrinidae fish from Amazonas river system (Brazil).

| Hosts | *Hoplias malabaricus* | | | | *Hoplerythrinus unitaeniatus* | | | |
|---|---|---|---|---|---|---|---|---|
| Parasites | ID | *d* | D | FD (%) | ID | *d* | D | FD (%) |
| *Ichthyophthirius multifiliis* | 3.87 | 7.79 | 0.37 | 0.934 | 1.80 | 2.67 | 0.27 | 0.977 |
| *Piscinoodinium pillulare* | 2.02 | 3.43 | 0.58 | 0.061 | 2.03 | 3.30 | 0.38 | 0.023 |
| *Tetrahymena* sp. | 1.53 | 1.95 | 0.87 | 0.002 | - | - | - | - |
| *Urocleidoides eremitus* | 2.34 | 4.29 | 0.31 | 0.002 | - | - | - | - |
| *Urocleidoides* sp. | - | - | - | - | 1.17 | 0.68 | 0.83 | - |
| *Whittingtonocotyle caetei* and *Whittingtonocotyle jeju* | - | - | - | - | 1.50 | 1.78 | 0.59 | - |
| *Clinostomum* sp. | 2.08 | 3.59 | 0.79 | - | 2.59 | 4.71 | 0.70 | - |
| *Contracaecum* sp. (intestine) | 2.57 | 4.88 | 0.60 | - | 2.52 | 4.54 | 0.55 | - |
| *Contracaecum* sp. (caecum) | 3.32 | 6.64 | 0.74 | - | 2.00 | 3.22 | 0.82 | - |
| *Procamallanus* (*S.*) *inopinatus* | - | - | - | - | 2.03 | 3.30 | 0.79 | - |
| *Gorytocephalus spectabilis* | - | - | - | - | 1.68 | 2.32 | 0.68 | - |
| *Nomimoscolex matogrossensis* | 1.89 | 3.06 | 0.81 | - | 1.28 | 1.07 | 0.86 | - |

**Table 3.** Diversity parameters for communities of parasites in two Erythrinidae fish from Amazonas river system (Brazil). *U*: Mann-Whitney test, *p*: Probability.

| Indices | *H. malabaricus* | *H. unitaeniatus* | *U* | *p* |
|---|---|---|---|---|
| Species richness | 4.2 ± 1.2 | 4.7 ± 1.5 | 421.5 | 0.301 |
| Brillouin *(HB)* | 0.25 ± 0.26 | 0.13 ± 0.08 | 567.0 | 0.325 |
| Evenness *(E)* | 0.10 ± 0.11 | 0.05 ± 0.03 | 579.0 | 0.251 |
| Berger-Parker *(d)* | 0.91 ± 0.11 | 0.97 ± 0.02 | 427.5 | 0.356 |

**Table 4.** Spearman correlation coefficient (*rs*) of the abundance of parasites with the body length and body weight of two Erythrinidae fish from Amazonas river system (Brazil). *p*: Probability.

| Hosts | *Hoplias malabaricus* | | | | *Hoplerythrinus unitaeniatus* | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters | Total length | | Weight | | Total length | | Weight | |
| Parasites | rs | p | rs | p | rs | p | rs | p |
| *Ichthyophthirius multifiliis* | 0.228 | 0.220 | 0.253 | 0.156 | 0.155 | 0.414 | 0.423 | 0.019 |
| *Piscinoodinium pillulare* | 0.229 | 0.220 | 0.206 | 0.251 | −0.126 | 0.506 | 0.073 | 0.699 |
| *Urocleidoides eremitus* | 0.343 | 0.050 | 0.325 | 0.065 | - | - | - | - |
| *Whittingtonocotyle caetei* and *Whittingtonocotyle jeju* | - | - | - | - | 0.345 | 0.061 | 0.296 | 0.112 |
| *Contracaecum* sp. | 0.411 | 0.017 | 0.370 | 0.034 | −0.198 | 0.295 | −0.150 | 0.428 |
| *Clinostomum* sp. | 0.049 | 0.787 | 0.035 | 0.847 | 0.048 | 0.800 | 0.117 | 0.537 |
| *Nomimoscolex matogrossensis* | −0.011 | 0.950 | 0.075 | 0.679 | −0.035 | 0.855 | 0.209 | 0.268 |
| *Gorytocephalus spectabilis* | - | - | - | - | −0.007 | 0.971 | 0.013 | 0.946 |
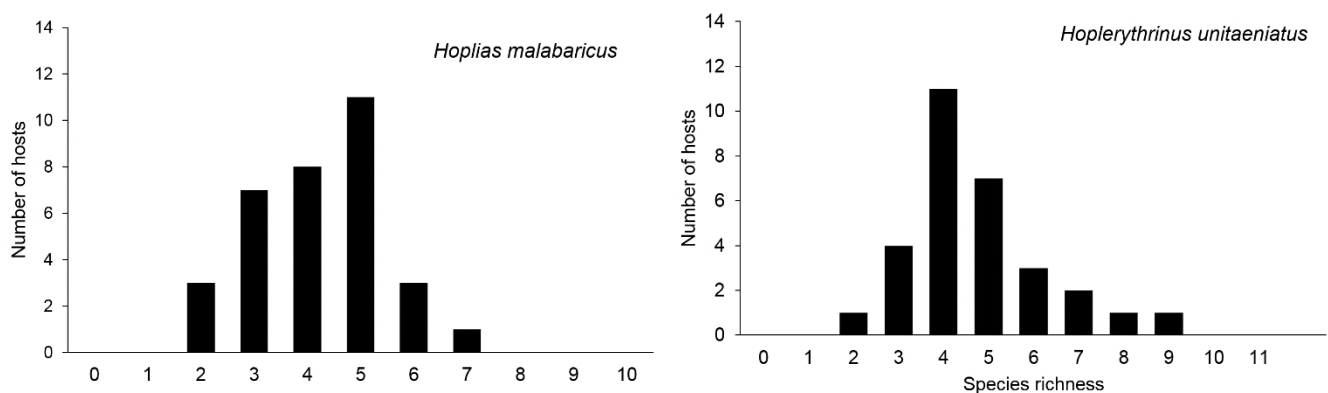


**Figure 1.** Species richness of parasites in two Erythrinidae fish from Amazonas river system (Brazil).

these endoparasites results from the interactions between the life histories and ecology of the hosts and parasites, among other factors (TAKEMOTO et al., 2009; MOREIRA et al., 2009; BITTENCOURT et al., 2014; TAVARES-DIAS et al., 2014a).

The parasitic infections presented an overdispersion in *H. unitaeniatus* and *H. malabaricus*. Overdispersion, which are common in freshwater fish, suggest that the parasite-host relationship is stable and is influenced by environmental factors relating mainly to spatial-temporal changes in physicochemical parameters and to differentiated host susceptibility to parasites due to differences in immunological, behavioral and genetic characteristics among the hosts (MOREIRA et al., 2009; LOPES et al., 2009; POULIN, 2013), along with differences in the dimensional proportions of sites in these hosts for parasitic infections. However, infection by *Tetrahymena* sp. in *H. malabaricus*, and by *Urocleidoides* sp., *Whittingtonocotyle* spp. and *N. matogrossensis* in *H. unitaeniatus* presented a random distribution, possibly due to the lower opportunity that these parasites had for colonizing such hosts. Therefore, the overdispersion pattern has some extremely important implications for the parasite population and its evolutive dynamics, and also for its hosts.

The gills of *H. malabaricus* and *H. unitaeniatus* were the main sites of parasitic infection, due to the presence of protozoans, monogenoideans, crustaceans and metacercarial ectoparasites. In both hosts, *I. multifiliis* and *P. pillulare* predominated, but *H. unitaeniatus* presented higher intensity and abundance levels for *I. multifiliis*, and these levels increased with increasing host weight. Infections due to these two protozoan species are highly influenced by the characteristics of the local environment and by the sedentary behavior of these two hosts, which generally live close to vegetation in order to ambush their prey (SANTOS et al., 2006; SOARES et al., 2011). These protozoa are known to proliferate in eutrophic environments like the Igarapé Fortaleza basin (BITTENCOURT et al., 2014), which was the habitat de *H. malabaricus* and *H. unitaeniatus* in the present study. This was the first report of *I. multifiliis* and *P. pillulare* in *H. unitaeniatus* and the first report of *P. pillulare* for *H. malabaricus*.

Protozoa of the genus *Tetrahymena* are commonly found in organic material at the bottom of water bodies and they parasitize fish, amphibians, crustaceans and turbellarians (HERBERT & GRAHAM, 2008; COLORNI, 2008). *Tetrahymena* sp. was only found in the gills of *H. malabaricus*, with greater prevalence (12.1%) than what has been described for *Carnegiella strigata* (0.89%) in the Negro river, central Amazon region (TAVARES-DIAS et al., 2010). The present study is the second report on these protozoa for fish in Brazil. Dickerson (2012) stated that fish parasitized by *Tetrahymena* sp. may present protection against infection by *I. multifiliis*. This may have been the reason for the lower intensity and abundance of *I. multifiliis* that was observed in *H. malabaricus*, in comparison with *H. unitaeniatus*. On the other hand, factors relating to the innate immunity of *H. malabaricus* also cannot be ruled out.

In the gills of *H. malabaricus*, there was low parasitism of *B. patagonica*, which is a cymothoid without specific parasitic activity that also parasitizes other fish in the Amazon region (TAVARES-DIAS et al., 2014b). The first report of *A. pestifer* for *H. unitaeniatus* comprised a low level of gill parasitism, similar

to what has been described for *Pseudoplatystoma trigrinum* in Manaus, state of Amazonas (LOPES et al., 2009). However, this parasitism of *A. pestifer* was lower than what was described for *Pseudoplatystoma fasciatum* and *P. trigrinum* from Janauacá Lake, (MALTA, 1984) and for *Pseudoplatystoma punctifer* from Manaus region, both in state of Amazonas (LOPES et al., 2009). Thus, *A. pestifer* is an argulid with low parasitic specificity and it depends on its hosts for geographic dispersion and distribution (MALTA, 1984).

In the gills of *H. malabaricus*, the levels of infection due to *U. eremitus* were high in comparison with the levels of *Urocleidoides* sp., *Anacanthorus* sp., *W. caetei* and *W. jeju* in *H. unitaeniatus*. In the gills of *H. unitaeniatus*, the coexistence of four species of monogenoideans was due to the low levels of infection and random dispersion of *Urocleidoides* sp. and *W. caetei* and *W. jeju*. *Urocleidoides eremitus* has been found to be present in *H. malabaricus* in several hydrographic basins in Brazil, along with *Urocleidoides naris, Urocleidoides cuiabai, Urocleioides brasiliensis* and Dactylogyridae gen. sp. (ROSIM et al., 2011). However, *U. naris, U. cuiabai* and *U. brasiliensis* seem not to have any distribution in the Amazon basin. Recently, in addition to these species of monogeneans, Graça et al. (2013) found *Cosmetocleithrum bulbocirrus, Vancleaveus janauacaensis* and *Anacanthorus* sp., along with another Dactylogyridae gen. sp. in *H. malabaricus* in the Paraná river (states of Paraná and Mato Grosso). In the present study, *Urocleidoides* sp. and *Anacanthorus* sp. in *H. unitaeniatus* are new species, and *W. caetei* and *W. jeju* are monogenoideans described recently by Santos-Neto et al. (2015). The present study not only expands the distribution of *U. eremitus* to the eastern Amazon region, but also provides the second report of species of monogeneans for *H. unitaeniatus*.

In fish, heterogeneity of the composition of the endohelminth fauna and the presence of different parasitic stages can mainly be correlated with the hosts' geographic distribution; habitat and way of life; age and longevity; position in the trophic chain; volume of food ingested; ontogenetic changes to immunocompetence and diet; and likelihood of contact with infective intermediate hosts in the environment (TAKEMOTO et al., 2009; MOREIRA et al., 2009; BITTENCOURT et al., 2014; TAVARES-DIAS et al., 2014a).

*Hoplias malabaricus* and *H. unitaeniatus* are piscivorous hosts when adults, but they feed on plankton, crustaceans, insects and seeds when they are juveniles (SANTOS et al., 2006; SOARES et al., 2011). Among the endohelminths of these hosts, larval stages predominated, particularly those of *Contracaecum* sp., along with metacercariae of *C. marginatum*. These parasites have zoonotic potential (BENIGNO et al., 2014). Other fish species that are intermediate or paratenic hosts in the same region as that of the present study have commonly shown predominance of the larvae of digeneans and nematodes (TAVARES-DIAS et al., 2014a; BITTENCOURT et al., 2014), as has *H. malabaricus* in other regions (TAKEMOTO et al., 2009; ROCHA, 2011). *Contracaecum* sp. uses species of microcrustaceans as intermediate hosts and fish as secondary or paratenic intermediate hosts, while piscivorous birds are the definitive hosts (MOREIRA et al., 2009; MORAVEC, 2009).

In Brazil, *C. marginatum* uses the gastropod *Biomphalaria* spp. as the primary intermediate host and fish as the secondary

intermediate host, and the cycle is completed in piscivorous birds, which form the definitive hosts (PINTO & MELO, 2013). Thus, in wild fish populations, the parasite transmission is through ingestion of prey (intermediate hosts) and variability of the feeding behavior of predatory fish like *H. malabaricus* and *H. unitaeniatus* may have a strong influence on the distribution of parasite species.

In wild populations of *H. malabaricus* (TAKEMOTO et al., 2009; ROCHA, 2011) and *H. unitaeniatus* (BENIGNO et al., 2012) in Brazil, the nematode fauna has been characterized by the presence of larvae of *Contracaecum* sp. and *Eustrongylides* sp., which are both important parasites from a public health point of view because of their zoonotic potential (TAKEMOTO et al., 2009; BENIGNO et al., 2012). Takemoto et al. (2009) also recorded this nematode in *H. malabaricus* in the Paraná river basin. In the present study, *H. malabaricus* and *H. unitaeniatus* were infected with larvae of *Contracaecum* sp. and larvae and adults of *P. (S.) inopinatus*. Both of these are nematodes with low parasitic specificity. There were similar levels of infection with larvae of *Contracaecum* sp. in *H. malabaricus* and *H. unitaeniatus*, but this parasitism was much less than what was described by Benigno et al. (2012), for both of these hosts on Marajó island, state of Pará (Brazil). *Procamallanus (S.) inopinatus*, a nematode that parasitizes fish in both their larval and adult stages (TAKEMOTO et al., 2009), was found in *H. unitaeniatus* and *H. malabaricus* in the present study, but the infection levels in *H. unitaeniatus* were higher than in *H. malabaricus*. The present study has provided the first report of *P. (S.) inopinatus* for *H. unitaeniatus*.

For *H. unitaeniatus* and *H. malabaricus*, there were similar levels of infection by metacercariae of *C. marginatum* in the gills and intestine. The parasitism levels were also similar to those of metacercariae of *Ithyoclinostomum dimorphum* and metacercariae of *Clinostomatopsis sorbens* in the mesentery and/or musculature of *H. unitaeniatus* and *H. malabaricus* on Marajó Island, state of Pará, which is also in the eastern Amazon region (BENIGNO et al., 2014). However, in other regions of Brazil, *H. malabaricus* has been infected with metacercariae of *I. dimorphum*, *Clinostomum complanatum*, *Austrodiplostomum compactum* and *Sphincterodiplostomum musculosum*, along with adults of *Pseudosellacotyla lutzi* (ROCHA, 2011). These results indicate the role that these two hosts play in the life cycles of these digeneans.

The life cycle of the acanthocephalans require a species of aquatic vertebrate as the definitive host and a microcrustacean (amphipods, copepods, isopods or ostracods) as an intermediate host (ROCHA, 2011; TAVARES-DIAS et al., 2014a). *Hoplias malabaricus* has been found to be parasitized mainly by *Quadrigyrus machadoi*, *Q. brasiliensis* and *Q. torquatus* (TAKEMOTO et al., 2009; ROCHA, 2011) and *H. unitaeniatus* only by *Q. brasiliensis* (TAKEMOTO et al., 2009). These are acanthocephalans with low parasitic specificity. The present study has provided the first report of *G. spectabilis* for *H. unitaeniatus*, with the presence of cystacanths and adults. The levels of infection were similar to those of cichlids in the same region as the present study that were parasitized by *G. spectabilis* (BITTENCOURT et al., 2014; TAVARES-DIAS et al., 2014a). These results indicate that *H. unitaeniatus* is preying on microcrustaceans that contain infective forms of *G. spectabilis*, a parasite that has an unknown life cycle. On the other hand, *H. malabaricus* was not being infected with acanthocephalans, since

the transmission and transportation of these parasites depends on the efficiency of the intermediate hosts, which acquire parasites through transferring them to other hosts. In addition, the size, development stage and species of the microcrustaceans ingested also significantly influence the likelihood that a fish might acquire infection due to acanthocephalans, which are endohelminths with a complex life cycle.

Planktonic microcrustaceans and cyclopoid copepods serve as intermediate hosts for larvae of species of Proteocephalidae. Fish become infected through ingesting these crustaceans, and the fish thus infected are especially the small ones that serve as food for larger predatory fish, which are hosts that carry higher levels of infection due to cestodes (SCHOLZ, 1999). The levels of infection due to *N. matogrossensis* were similar between *H. malabaricus* and *H. unitaeniatus*, but were higher than those reported by Chambrier et al. (1996) for *H. malabaricus* in Paraguay. In *H. malabaricus* and *H. unitaeniatus*, the presence of larvae of *N. matogrossensis* indicates that these fish are intermediate hosts for this proteocephalid. This is the first report of *N. matogrossensis* for *H. unitaeniatus*.

The Kn of *H. malabaricus* and *H. unitaeniatus* was not negatively influenced by the presence of ecto and endoparasites, thus reflecting the low pathogenicity of the parasite community encountered. Hosts that acquire resistance to parasites through adaptation may also not be affected with regard to their body conditions (GUIDELLI et al., 2011; TAVARES-DIAS et al., 2014a), depending on the organ infected and the parasite species, abundance and pathogenicity. However, the high Kn of *H. malabaricus* suggests that these fish were consuming greater quantities of food when they ingested the infective forms, which were transmitted via the trophic route, and thus had greater weight than expected.

In summary, the differences in parasitic fauna composition in this study were caused by occurrence of *Tetrahymena* sp. and *B. patagonica* in *H. malabaricus*, and absence of these parasites in *H. unitaeniatus*, along with absence of *G. spectabilis* and *A. pestifer* in *H. malabaricus*. All of these species lack parasitic specificity. Moreover, the parasite community was dominated by ectoparasites, which were favored by the way of life of *H. unitaeniatus* and *H. malabaricus*, which are hosts occupying a high position in the trophic chain, thereby contributing towards the presence of endohelminths. Thus, the results from this first investigation on the parasitic communities of these two piscivorous fish indicate that both of these hosts play an important role in the life cycles of these nematodes, digeneans, acanthocephalan and cestode, which were found at moderate infection levels. Parasite abundance and species richness were not affected by host body size, because the correlations were weak, as shown by the extremely low correlation coefficient values (body size explained less than 40% of the variance relating to parasite abundance). Thus, this indicates that factors other than host body size are more important determinants of variation of parasite abundance and species richness for the populations of both of these hosts. This was the first report on parasite diversity in wild *H. unitaeniatus* and *H. malabaricus* and it showed that these species had similar parasite communities, characterized by low species diversity, low evenness and species richness, and by high prevalence and diversity of ectoparasite species.

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