Annals of Parasitology 2022, 68(3), 453–460
doi: 10.17420/ap6803.451

Original paper

Metazoan parasite community of *Hoplias malabaricus* (Characiformes, Erythrinidae) in a stream of Caatinga domain, Brazil

Maria Fernanda Barros Gouveia DINIZ, Wallas Benevides Barbosa de SOUSA, Maria Naiane Martins de CARVALHO, Fábio Hideki YAMADA

Laboratório de Ecologia Parasitária (LABEP), Universidade Regional do Cariri (URCA), Crato, CE, 63105-000, Brazil

Corresponding Author: Fábio Hideki Yamada; e-mail: fhyamda@hotmail.com

ABSTRACT. We purpose to describe and characterize the structure of the parasitic community of *H. malabaricus* in a stream from Caatinga domain, Ceará state, Brazil. A total of 42 specimens of *H. malabaricus* have been collected between December 2018 and August 2019, in which, 34 specimens were parasitized by at least one parasite. A total of 1,872 parasites were recovered, of which, 157 were *Urocleidoides cuiabai* (prevalence = 50%), 268 *Urocleidodes brasiliensis* (prevalence = 71.43%), 98 Dactylogyridae gen. sp. (prevalence = 14.29%), 401 Diplostomidae gen. sp. (prevalence = 4.76%), 183 *Spiroxys* sp. (prevalence = 42.86%) and 765 *Pindapixara tarira* (prevalence = 9.52%). The respective parasite species of *H. malabaricus* showed a pattern of overdispersion (or aggregation) typical of the parasite-host systems, corroborating with previous studies of parasitic communities of freshwater fish in Brazil. A positive and significant correlation between the host size and abundance of *U. brasiliensis* was verified. The ontogeny of fish can influence the parasitic load, some larger hosts tend to host larger quantities of parasites. The parasitic levels can vary with the host sex due to the differences in the ecological and physiological interactions between male and female. However, the host sex did not show influences in the prevalence and parasitic burden. All parasite taxa in this study have not yet been reported in the Carás stream, Caatinga domain. This finding extends the geographical distribution of this parasite species, furthermore, contributing to the knowledge of the biodiversity of fish parasites in the Neotropical region.

Keywords: Caatinga domain, freshwater fish, Neotropical region, parasitism

Introduction

The Brazilian freshwater ecosystems hold a high diversity of fishes with approximately 4,000 species [1,2]. The fish species *Hoplias malabaricus* (Bloch, 1794), (common names wolf fish, tiger fish), is widely distributed throughout South and Central Americas, being present since Costa Rica to Argentina, in most river basins [3]. This species tolerates low concentrations of dissolved oxygen and inhabits lentic ecosystems of shallow depth and with abundant aquatic vegetation [4]. This fish is carnivorous as an adult, feeding mainly on other fish [5], but also feed on insects, crustaceans and other invertebrates [6].

Parasitism is an ecological interaction between individuals of different species, being an intimate and a long-term relationship, in which there is a variable degree metabolic dependence [7]. According to Price [8], the host-parasite relationship is considered the most common ecological interaction on earth and all living organisms are parasitized by at least a parasite species. Furthermore, the parasitism can affect the hosts populations in their behavior, physiology, morphology or reproduction [9]. Parasite diversity is intrinsically linked to its function in the environment, stabilizing the abundance of populations and balancing the food chain [10]. Thus, knowledge about parasitic degree is extremely necessary for environmental conservation [11].

Figure 1. Geographical location of the Carás stream, municipality of Crato, Ceará state, Brazil

Several studies considering parasites community of freshwater fish have been conducted in the Neotropical region. For instance, Takemoto et al. [12], recorded between the years 2000 to 2007 around 337 parasitic associations of fish parasites in the Upper Paraná river floodplain, Brazil. According to Eiras et al. [13], 1,034 parasite species parasitizing aroud 451 host species were registered in Brazil. Among of several taxonomic groups of metazoan parasites we highlighted the class Monogenea, Cohen et al. [14] inventoried 651 monogeneans species in freshwater fish of South America, being that 67% of this total parasitized fish exclusively from the Brazilian freshwater ecosystem.

Thus, we purpose to describe and characterize the structure of the parasitic community of *H. malabaricus* in a stream from Caatinga domain, Ceará state, Brazil. Intrinsic factors such as host size and sex can influence parasitism levels of hosts. In this context, prevalence, abundance and richness were used as the main ecological descriptors of parasitism in *H. malabaricus*, being correlated with size and sex of the hosts.

Materials and Methods

Forty-two specimens of *H. malabaricus* were caught through trawl and cast nets, from December 2018 to August 2019, in Carás stream (7°4'59"S, 39°28'59"W), municipality of Crato, Ceará state, Brazil (Fig. 1). Individuals were measured (standard length SL to the nearest 0.1 mm), weighed (to the nearest 0.1 g), and dissected for sex identification (i.e. macroscopic examination of gonad features). The hosts presented an average standard length of 10.61 cm (ranging from 6.3 to 20 cm) and an average weight of 28 g (5.88 to 135.21 g). The collections were authorized by the Biodiversity Authorization and Information System of the Brazilian government (SISBIO #61328-1) and all animal procedures were performed in full compliance with the Ethics Committee for Animal Experimentation (CEUA # 00165/2018.1). The collection, preservation and preparation of the parasites were conducted based on the methodology compiled by Eiras et al. [15]. The identification of the parasites was performed using Cohen et al. [14], Moravec [16] and Thatcher [17].

In order to assess the general patters of parasite composition and distribution and to examine

Table 1. Parasite component community in *Hoplias malabaricus* collected in the Carás stream, Caatinga domain, Brazil. Number of fish infected/infested (NI), total abundance (TA), prevalence (P%), mean intensity (MI), mean abundance (MA), range of variation (RA), site of infection/infestation (SI), classification of species (CL) according to Bush et al.[19]

Parasite species	NI	TA	P (%)	MI	MA	RA	SI	CL
Monogenea								
Urocleidoides cuiabai	21	157	50	7.48	3.74	1–98	Gills	Se
Urocleidodes brasiliensis	30	268	71.43	8.93	6.38	1–70	Gills	Ce
Dactylogyridae gen. sp.	6	98	14.29	16.33	2.33	3–83	Gills	Sa
Digenea								
Diplostomidae gen. sp.	2	401	4.76	200.5	9.55	20–381	Eyes	Sa
Nematoda								
Spiroxys sp.	18	183	42.86	10.17	4.36	2–53	Mesentry	Se
Copepoda								
Pindapixara tarira	4	765	9.52	191.25	18.21	15–492	Gills	Sa

* (Ce) Central species; (Se) Secondary species; and (Sa) Satellite species

species-specific interaction between parasites and hosts, statistical analyses were performed at community level (i.e., all helminths of all fish collected persite) and infracommunity (i.e., all the helminths of each individual host) component level. Ecological descriptors of prevalence, abundance, intensity and richness were calculated according to Bush et al. [18]. The classification of the species of the parasitic community followed Bush et al. [19]: species whose prevalence was higher than 66.66% were considered as central; between 33.33 and 66.66%, secondary; and less than 33.33%, satellite. The dispersion index (DI) ($DI=s^2/x$; where s^2 = sampling variance and x = sampling mean) and Green's index (GI) ($GI = s^2/m) - 1/\sum^{n}_{i=1}x_i - 1$; where s^2 = sampling variance; m = sampling mean; x_i = abundance) were calculated to verify the degree of parasite overdispersion (aggregation) of each parasite species [21]. The Log-likelihood G-test (paired contingency table 2 x 2) and Mann-Whitney´s U-test were performed to verify the influence of the host sex on the prevalence and abundance of each parasite species, respectively [21]. The Spearman's rank correlation (rs) was used to investigate the relationship of host SL with parasite abundance. The Pearson´s linear correlation (r) was applied to examine the relationship between host SL and parasite prevalence [21]. The statistical analyzes were performed using the Statistica software package version 7.1 [22]. The significance level adopted for statistical analysis was $P \leq 0.05$.

Results

Of the total of 42 examined fish, 34 (80.95%) were parasitized by at least one species. A total of 1,872 parasites specimens were recovered, presenting a mean intensity of 55.06 parasites by infected fish. Gill ectoparasites correspond to 68.80% of the total of metazoan parasites. The

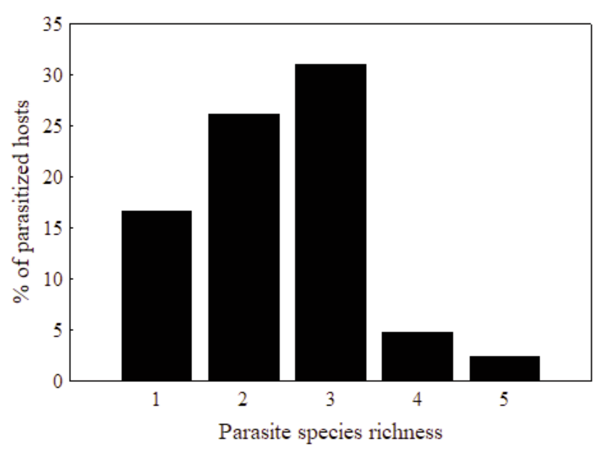

Figure 2. Richness of the parasitic infracommunity of *Hoplias malabaricus* collected from December 2018 to August 2019 in Carás stream, municipality of Crato, Ceará state, Brazil

Table 2. Dispersion index (DI) and Green´s index (GI) in *Hoplias malabaricus* collected in the Carás stream, Caatinga domain, Brazil

Parasite species	DI	GI	Dispersion type
Monogenea			
Urocleidoides cuiabai	62.325	0.393	Aggregated
Urocleidodes brasiliensis	20.594	0.073	Aggregated
Dactylogyridae gen. sp.	70.446	0.716	Aggregated
Digenea			
Diplostomidae gen. sp.	362.068	0.903	Aggregated
Nematoda			
Spiroxys sp.	21.247	0.111	Aggregated
Copepoda			
Pindapixara tarira	363.102	0.474	Aggregated

parasite component community was composed by following taxonomic groups: Monogenea (*Urocleidoides cuiabai* Rosim, Mendoza-Franco and Luque, 2011; *Urocleidodes brasiliensis* Rosim, Mendoza-Franco and Luque, 2011 and Dactylogyridae gen. sp.), Digenea (Diplostomidae gen. sp.), Nematoda (*Spiroxys* sp. Schneider, 1866) and Copepoda *Pindapixara tarira* (Malta, 1994). The monogenean species *U. brasiliensis* was the most prevalent with 71.43%, being considered as central species, while Diplostomidae gen. sp. showed highest mean intensity and *P. tarira* the highest parasitic burden, being considered satellite species (Tab. 1).

The richness of the parasite infracommunity ranged from 1–5, with 13 out of 42 examined hosts (30.95%) parasitized by three species and seven hosts (16.67%) parasitized by one species (Fig. 2). The parasitic fauna of *H. malabaricus* presented an aggregate dispersion pattern, the copepode *P. tarira* and the Diplostomidae gen. sp. presented the highest degree of aggregation (Tab. 2).

Of the 42 fish analyzed 32 were males in which 25 (78.13%) were parasitized by at least one parasite species, comprising a mean intensity of 32.88. Of the 10 females examined nine (90%) were parasitized by at least one species, comprising a mean intensity of 116.67. There were no significant

Table 3. The Log-likelihood G-test and Mann-Whitney´s U-test to verify the influence of the host sex on the prevalence and abundance of each parasite species in *Hoplias malabaricuas* collected in the Carás stream, Caatinga domain, Brazil

Parasite species	G	*p*	Z(U)	*p*
Monogenea				
Urocleidoides cuiabai	0.1314	0.717	0.8269	0.4083
Urocleidodes brasiliensis	0.0836	0.7725	0.3691	0.712
Dactylogyridae gen. sp.	0.0054	0.9413	0.2215	0.8247
Digenea				
Diplostomidae gen. sp.	0.0016	0.9679	0.3396	0.7342
Nematoda				
Spiroxys sp.	0.0245	0.8755	0.6645	0.5064
Copepoda				
Pindapixara tarira	0.4165	0.5187	0.6792	0.497

**p*. Significance level (* Significant value)

Table 4. Spearman's rank correlation coeficient (rs) and Pearson´s correlation coefficient (r) to investigate the relationship of host length with parasite abundance and prevalence, respectively, of the parasitic community of *Hoplias malabaricus* collected in the Carás stream, Caatinga domain, Brazil

Parasite species	rs	*p*	r	*p*
Monogenea				
Urocleidoides cuiabai	0.2954	0.0574	0.4591	0.3597
Urocleidodes brasiliensis	0.4138	0.0064*	0.6372	0.1735
Dactylogyridae gen. sp.	0.179	0.2567	0.453	0.367
Digenea				
Diplostomidae gen. sp.	-0.1147	0.4697	-0.414	0.4144
Nematoda				
Spiroxys sp.	0.2665	0.088	0.8384	0.037
Copepoda				
Pindapixara tarira	0.138	0.3835	0.444	0.3777

**p*. significance level (* Significant value)

differences in the prevalence and parasitic burden between the sex of the hosts (Tab. 3). The abundance of monogeneans species *U. brasiliensis* showed a positive and significant correlation with the host standard length. The abundance and prevalence of others taxa did not present significant correlations with the host standard length (Tab. 4).

Discussion

According to Luque and Poulin [23], *H. malabaricus* presents the richest parasitic community of freshwater fish in neotropics. To date, *H. malabaricus* has around 118 parasitic associations in the Neotropical region with occurrences of several taxonomic groups of metazoan parasites: Myxozoa (n = 2), Monogenea (n = 25), Digenea (n = 25), Cestoda (n = 5), Nematoda (n = 28), Acanthocephala (n = 10), Copepoda (n = 12), Branchiura (n = 5), Isopoda (n = 2) and Hirudinea (n = 4). Our results have shown that the class Monogenea was the most dominat taxonomic group. Previous studies pointed out that biotics factors, such as behavior, migratory effect and natural fish biology can affect the prevalence and intensity of monogeneans [24–26]. In this study, *U. brasiliensis* was the most prevalent monogenean species found parasiting the gills. According to Eiras et al. [27], the genus *Urocleidoides* Mizelle and Price, 1964 has low host specificity and it can be found in orders: Characiformes, Siluriformes, Gymnotiformes and Cyprinodontiformes. However, Cohen et al. [14], Graça et al. [28] and Rosim et al. [29] have recorded *U. eremitus* Kristsky, Thatcher and Boeger, 1986, *U. malabaricusi* Rosim, Mendoza-Franco and Luque 2011, *U. cuiabai* and *U. brasiliensis* parasitizing only *H. malabaricus*.

The copepode *P. tarira* was the most abundant species parasitizing the gills of *H. malabaricus*. The copepods are most frequently and abundantly found in freshwater fish, being considered pathogenic parasites, which can lead the death of host by obtaining nutrients removed from the filaments, causing bleeding, obstruction and necrosis of filaments [23,30–32]. Until now, considering the diversity of records of crustaceans parasitizing freshwater fish in Brazil, *H. malabaricus* is the specific host reported for *P. tarira* [33,34].

Gião et al. [35] pointed out that feeding habits can influence the diversity and a low uniformity of the distribution pattern. However, the diet range and prey selectivity have shown to influence parasite infection levels, variations in levels of parasitism among conspecific individuals must be considered [36]. Interestingly, the parasite infracommunity of *H. malabaricus* showed a low endoparasitic richness and burden, on the other hand, ectoparasites showed dominant.

The monogenean species *U. brasiliensis* presented high prevalence in the gills, being classified as a central species. This species is characterized by present widely distributed and higher dispersing capacity [37]. According to Zuben [38], the aggregation pattern in host parasite system is intended to balance to the maximum abundance and density of parasites in each host, minimizing the interspecific competition. Furthermore, environmental factors and alterations in the immune system which affects the susceptibility of hosts to infections, can probably affect the aggregate distribution. The parasite species of *H. malabaricus* showed a pattern of overdispersion (or aggregation) typical of the parasite-host systems, corroborating with previous studies of parasitic communities of freshwater fish in Brazil [29–33,38].

According to Esch et al. [39], the host sex can be related with their parasitic levels, as a consequence of their biological behaviors or due to a physiological incompatibility. However, in the present study, the prevalence and parasitic burden did not vary in relation to the host sex, probably due to the similarities behavior and size between males and females [39,40]. Luque and Cezar [41], analyzing ectoparasites of marine fish, detected no differences between parasitism levels and host sex. This result was also found by Graça and Machado [42] and Graça et al. [28] in parasitic fauna studies of *H. malabaricus* from the Upper Paraná River Floodplain, Brazil.

In the present study, a positive and significant correlation between the size of the fish and the abundance of *U. brasiliensis*, corroborates with the hypothesis covered by Rohde [43], pointed out that, the expansion of the superficial area of the gills and the maximum exposure time to the parasites, influence on the increase in parasitic burden in larger fish. According to Poulin and Leung [44] and Abdallah et al. [45], the host size is correlated with their age, being one of the intrinsic factors in the variance of parasitic infrapopulations [46]. Therefore, during the growth of the fish, several changes occurs in their habits, whether in their performance or in their biology, and with this, it can affect the parasitic fauna [47]. Graça et al. [28] verified the same positive correlation between the host size and abundance of species of the genus *Urocleidoides* in *H. malabaricus* from the Upper Paraná River floodplain. In contrast, Lizama et al. [48] argue that changes in parasitism levels are probably caused due to the unique properties of the sampling area of their hosts. Although the host is large, it does not mean that they make up extensive parasitic abundance, since they are subject to greater exposure to pathogenes [49].

In a general analysis, the parasitic fauna of *H. malabaricus* from the Carás stream, presented a predominance of ectoparasites, mainly by the class Monogenea. It was noted, a typically aggregate distribution pattern and a significant correlation between the host size and abundance for some parasitic *taxa*. The parasite species *U. brasiliensis*, *U. cuiabai*, Dactylogyridae gen. sp., Diplostomidae gen. sp. and *P. tarira* have been reported for the first time in the Carás stream. This finding extends the geographical distribution of this parasite species, furthermore, contributing to the knowledge of the biodiversity of fish parasites in the Neotropical region.

References

[1] Reis R.E., Kullander S.O., Ferraris Jr C. 2003. Check list of the freshwater fishes of South and Central America. Edipucrs, Porto Alegre.

[2] Buckup P.A., Menezes N.A., Ghazzi M. S. 2007. Catálogo das espécies de peixes de água doce do Brasil. Museu Nacional, Rio de Janeiro (in Portuguese). https://www.researchgate.net/publication/234128916_Catalogo_das_Especies_de_Peixes_de_Agua_ Doce_do_Brasil

[3] Oyakawa O. 2003. Family Erythrinidae (Trahiras). In: Check list of the freshwater fishes of South and Central America. (Eds. R.E Reis, S.O. Kullander, C.J. Ferrari Jr.). Edipucrs: 238–240.

[4] Shibatta O.A., Orsi M.L., Bennemann S.T., Silvasouza A.T. 2002. Diversidade e distribuição de peixes na bacia do rio Tibagi. In: A bacia do rio Tibagi. (Eds. M.E. Medri, E. Bianchini, O.A. Shibatta, J.A. Pimenta). Eduem: 403–423 (in Portuguese with summary in English).

[5] Hahn N.S., Agostinho A.A., Gomes L.C., Bini M. 1998. Estrutura trófica da ictiofauna do reservatório de Itaipu (Paraná-Brasil) nos primeiros anos. *Interciência* 23(5): 299–305 (in Portuguese).

[6] Hahn N.S., Andrian I.F., Fugi R., Almeida V.L. 1997. Ecologia trófica. In: A planície de inundação do alto rio Paraná: aspectos físicos, biológicos e socioeconômicos. (Eds. A.E.A.M. Vazzoler, A.A. Agostinho, N.S. Hahn). Eduem: 209–228 (in Portuguese).

[7] Rey L. 2010. Bases da parasitologia médica Guanabara Koogan, Rio Janeiro (in Portuguese).

[8] Price W.P. 1987. Evolution in parasites communities. *International Journal for Parasitology* 17(1): 209–2014. doi:10.1016/0020-7519(87)90043-9

[9] Marcogliese D.J. 2004. Parasites: small players with crucial roles in the ecological theatre. *EcoHealth* 1(2): 151–164. doi:10.1007/s10393-004-0028-3

[10] Poulin R., Morand S. 2004. Parasite biodiversity. Smithsonian Books, Washington.

[11] Poulin R. 2004. Macroecological patterns of species richness in parasite assemblages. *Basic and Applied*

Ecology 5(5): 423–434.
doi:10.1016/j.baae.2004.08.003

[12] Takemoto R.M., Pavanelli G.C., Lizama M.A.P., Lacerda A.C.F., Yamada F.H., Moreira L.H. A., Ceschini T.L., Bellay S. 2009. Diversity of parasites of fish from the Upper Parana River floodplain, Brazil. *Brazilian Journal of Biology* 69(2): 691–705. doi:10.1590/S1519-69842009000300023

[13] Eiras J.C., Takemoto R.M., Pavanelli G.C., Adriano E.A. 2011. About the biodiversity of parasites of freshwater fish from Brazil. *European Association of Fish Pathology* 31(4): 161–168.

[14] Cohen S.C., Justo M.C.N., Kohn A. 2013. South American Monogenoidea parasites of fishes, amphibians and reptiles. Conselho Nacional de Desenvolvimento Cientifico e Tecnológico (CNPq), Sao Paulo.

[15] Eiras J.C., Takemoto R.M., Pavanelli G.C. 2006. Métodos de estudo e técnicas laboratoriais em parasitologia de peixes. Eduem, Maringá (in Portuguese)

[16] Moravec F. 1998. Nematodes of freshwater fishes of the Neotropical region. Academia, Publishing House of the Academy of Sciences of the Czech Republic, Czech Republic.

[17] Thatcher V.E. 2006. Amazon Fish Parasites. *Pensoft Publishers*, Bulgaria.

[18] Bush A.O., Lafferty K.D., Lotz J.M., Shostak A.W. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. *The Journal of Parasitology* 83(4): 575–583. doi:10.2307/3284227

[19] Bush A.O., Aho J.M., Kennedy C.R. 1990. Ecological versus phylogenetic determinants of helminth parasite community richness. *Evolutionary Ecology* 4: 1–20. doi:10.1007/BF02270711

[20] Ludwig J.A., Reynolds J.F. 1988. Statistical ecology: a primer on methods and computing. Wiley-Interscience Publications, New York.

[21] Zar J.H. 1996. Biostatisical analysis. Prentice-Hall, New Jersey.

[22] Statsoft Inc. 2005. Statistica (data analysis software system), version 7.1.

[23] Luque J.L., Poulin R. 2007. Metazoan parasite species richness in Neotropical fishes: hotspots and the geography of biodiversity. *Parasitology* 134(6): 865–878. doi:10.1017/S0031182007002272

[24] Eiras J.C. 1994. Elementos da Ictioparasitologia Fundação Eng. Antônio de Almeida, Porto, Portugal (in Portuguese).

[25] Graça W.J., Pavanelli C.S. 2007. Peixes da planície de inundação do alto rio Paraná e áreas adjacentes. Eduem, Maringá (in Portuguese).

[26] Pavanelli G.C., Eiras J.C., Takemoto R.M. 2008. Doenças de peixes: profilaxia, diagnóstico e tratamento. Eduem, Maringá (in Portuguese).

[27] Eiras J.C., Takemoto R.M., Pavanelli G.C. 2010. Diversidade dos parasitas de peixes de água doce do Brasil. Clichetec, Maringá (in Portuguese).

[28] Graça R.J., Hueda B.H., Oda F.H., Takemoto R.M. 2013. Monogenea (Platyhelminthes) parasites from the gills of *Hoplias* aff. *malabaricus* (Bloch, 1794) (Pisces: Erythrinidae) in the Upper Paraná River Floodplain, States of Paraná and Mato Grosso do Sul, Brazil. *Check List* 9(6): 1484–1487.
doi:10.15560/9.6.1484

[29] Rosim D.F., Mendonza-Franco E.F., Luque J.L. 2011. New and previously described species of *Urocleidoides* (Monogenoidea: Dactylogyridae) infecting the gills and nasal cavities of *Hoplias malabaricus* (Characiformes: Erythrinidae) from Brazil. *Journal of Parasitology* 97(3): 406–417. doi:10.1645/GE-2593.1

[30] Kabata Z. 1970. Crustacea as enemics of fishes. In: Diseases of fishes. (Eds. S.F. Snieszko, H.R. Axelrod). T.F.H. Publications: 1–71.

[31] Kabata Z. 1979. Parasitic copepoda of British fishes. The Ray Society 152.
doi:10.5962/bhl.title.58672

[32] Kabata Z. 1982. Copepoda (Crustacea) parasitic on fishes: problems and perspectives. In: *Advances in Parasitology.* (Eds. W.H.R. Lumsden, R. Muller, J.R. Baker) 19: 1–71.
doi:10.1016/S0065-308X(08)60265-1

[33] Rosim D.F. 2010. Biodiversidade das comunidades parasitárias em populações de *Hoplias malabaricus* (Bloch, 1794) (Characiformes, Erythrinidae) provenientes de quatro regiões hidrográficas do Brasil. PhD thesis, Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro (in Portuguese).
https://tede.ufrrj.br/jspui/bitstream/jspui/2748/2/2010%20-%20Daniele%20Fernanda% 20Rosim.pdf

[34] Luque J.L., Lacerda A.C., Lizama M.A.P., Takemoto R.M., Bellay S. 2013. Aspectos ecológicos. In: Parasitologia de peixes de água doce do Brasil. (Eds. J.C. Eiras, R.M. Takemoto, G.C. Pavanelli). Eduem: 67–84 (in Portuguese).

[35] Gião T., Pelegrini L.S., Azevedo R.K., Abdallah V.D. 2020. Biodiversity of parasites found in the trahira, *Hoplias malabaricus* (Bloch, 1794), collected in the Batalha River, Tietê-Batalha drainage basin, SP, Brazil. *Anais da Academia Brasileira de Ciências* 92(2): 1–23. doi:10.1590/0001-3765202020180610

[36] Cirtwill A.R., Stouffer D.B., Poulin R., Lagrue C. 2016. Are parasite richness and abundance linked to prey species richness and individual feeding preferences in fish hosts? *Parasitology* 143(1): 75–86. doi:10.1017/S003118201500150X

[37] Kennedy C.R. 2001. Metapopulation and community dynamics of helminth parasites of eels *Anguilla anguilla* in the River Exe system. *Parasitology* 122(6): 689–698.
doi:10.1017/S0031182001007879

[38] Zuben C.J.V. 1997. Implicações da agregação espacial de parasitas para a dinâmica populacional na

interação hospedeiro-parasita [Implications of spatial aggregation of parasites for the population dynamics in host-parasite interaction]. *Revista de Saúde Pública* 31(5): 523–530 (in Portuguese with summary in English). doi:10.1590/S0034-89101997000600014

[39] Esch G.W., Kennedy C.R., Bush A.O., Aho J.M. 1988. Patterns in helminth communities in freshwater fish in Great Britain: alternative strategies for colonization. *Parasitology* 96(3): 519–532. doi:10.1017/s003118200008015x

[40] Azevedo R.K., Abdallah V.D., Luque J.L. 2007. Ecologia da comunidade de metazoários parasitos do apaiarí *Astronotus ocellatus* (Cope, 1872) (Perciformes: Cichlidae) do rio Guandu, estado do Rio de Janeiro, Brasil. *Revista Brasileira de Parasitologia Veterinária* 16(1): 15–20 (in Portuguese). https://www.redalyc.org/pdf/3978/397841461004.pdf

[41] Luque J.L., Cezar A.D. 2004. Metazoários ectoparasitos do pampo-galhudo, *Trachinotus goodei* Jordan and Evermann, 1896 (Osteichthyes: Carangidae), do litoral do Estado do Rio de Janeiro, Brasil. *Acta Scientiarum. Biological Sciences* 26(1): 19–24 (in Portuguese). doi:10.4025/actascibiolsci.v26i1.1654

[42] Graça R.J., Machado M.H. 2007. Ocorrência e aspectos ecológicos de metazoários parasitos de peixes do Lago do Parque do Ingá, Maringá, Estado do Paraná. *Acta Scientiarum Biological Sciences* 29(3): 321–326 (in Portuguese). doi:10.4025/actascibiolsci.v29i3.507

[43] Rohde K. 1993. Ecology of marine parasites: An introduction to marine parasitology. CAB International, Wallingford.

[44] Poulin R., Leung T.L.F. 2008. Body size, trophic level, and the use of fish as transmission routes by parasites. *Oecologia* 166(3): 731–738. doi:10.1007/s00442-011-1906-3

[45] Abdallah V.D., Azevedo R.K., Luque J.L. 2006. Ecologia da comunidade de metazoários parasitos do tamboatá *Hoplosternum littorale* (Hancock, 1828) (Siluriformes: Callichthyidae) do Rio Guandu, Estado do Rio de Janeiro, Brasil. *Acta Scientiarum. Biological* Sciences 28(4): 413–419 (in Portuguese). doi:10.4025/actascibiolsci.v28i4.407

[46] Dogiel V.A. 1961. Ecology of the parasites of freshwater fishes. In: Parasitology of fishes (Eds. V.A Dogiel, G.K Petrushevski, Yu.I. Polyanski). Oliver and Boyd, London: 1–47. https://www.cabdirect.org/cabdirect/abstract/19620800730

[47] Takemoto R.M., Amato J.F., Luque J.L. 1996. Comparative analysis of the metazoan parasite communities of leatherjackets, *Oligoplites palometa*, *O. saurus*, and *O. saliens* (Osteichthyes: Carangidae) from Sepetiba Bay, Rio de Janeiro, Brazil. *Revista Brasileira de Biologia* 56(4): 639–650.

[48] Lizama M.A.P., Takemoto R.M., Ranzani-Paiva M.J.T., Ayroza L.M.S., Pavanelli G.C. 2007. Relação parasito hospedeiro em peixes de pisciculturas da região de Assis, Estado de São Paulo, Brasil. *Piaractus mesopotamicus* (Holmberg, 1887). *Acta Scientiarum. Biological Sciences* 29(4): 437–445 (in Portuguese). doi:10.4025/actascibiolsci.v29i4.888

[49] Luque J.L., Amato J.F.R., Takemoto R.M. 1996. Comparative analysis of the communities of metazoan parasites of *Orthopristis ruber* and *Haemulon steindachneri* (Osteichthyes: Haemulidae) from the southeastern Brazilian littoral: I. structure and influence of the size and sex of hosts. *Revista Brasileira de Biologia* 56(2): 279–292.

Received 02 April 2022
Accepted 30 June 2022