

CONDITION FACTOR AND ECOLOGY OF ENDOHELMINTHS IN *Metynnis lippincottianus* FROM THE CURIAÚ RIVER, IN EASTERN AMAZON (BRAZIL)

Abthyllane CARVALHO¹ 

Roger Leomar FERREIRA² 

Priscila ARAÚJO² 

Marcos TAVARES-DIAS³ 

Edilson MATOS^{1,4} 

Marcela VIDEIRA^{5*} 

¹Universidade Federal do Pará - UFPA, Programa de Pós Graduação em Biologia de Agentes Infecciosos e Parasitários, Rua Augusto Corrêa, nº 01, Guamá, CEP: 66.075-110, Belém, PA, Brazil.

²Universidade Federal do Amapá - UNIFAP, Programa de Pós Graduação em Ciências Ambientais da Amazônia, Rod. Juscelino Kubitschek, km 02, Jardim Marco Zero, CEP: 68.903-419, Macapá, AP, Brazil.

³Embrapa Amapá, Departamento de Aquicultura, Laboratório de Sanidade, Rod. Juscelino Kubitschek, KM 5, Jardim Marco Zero, CEP: 68.903-197, Macapá, AP, Brazil.

⁴Universidade Federal Rural da Amazônia - UFRA, Laboratório de Pesquisa Carlos Azevedo, Av. Presidente Tancredo Neves, nº 2501, Terra Firme, CEP: 66.077-830, Belém, PA, Brazil.

⁵Universidade do Estado do Amapá - UEAP, Colegiado de Engenharia de Pesca, Laboratório de Morfologia e Sanidade Animal, Av. Presidente Vargas, nº 650, Centro, CEP: 68.900-070, Macapá, AP, Brazil. marcela.videira@ueap.edu.br (corresponding author).

ABSTRACT

Fish are among the vertebrate groups most susceptible to parasitic infections due to environmental characteristics that can favor the development of parasites; also, position of the host in food web has been associated with the parasitism. The aim of this study was to investigate the ecology of parasites endohelminth in *Metynnis lippincottianus* from the Curiaú River, in eastern Amazon (Brazil), as well as to evaluate the parasite-host interactions. From 110 specimens of *M. lippincottianus* examined, 76.3% were infected by one or more parasite species, and a total of 146 parasites such as *Procamallanus (Spirocamallanus) inopinatus* (Nematoda), larvae of *Contraecum* sp. (Nematoda) and *Neoechinorhynchus pterodoridis* (Acanthocephala) were collected in intestine. However, the dominance was of nematode species, and the parasites had uniform or random dispersion. The parasitic infracommunities showed low Shannon-Wiener diversity (0.2 ± 0.3), low evenness (0.2 ± 0.3) and low species richness of parasites (1.1 ± 0.8). The abundance of *Contraecum* sp. presented a weak positive correlation with the weight of hosts, and relative condition factor was not affected by the parasitism. This first study about parasites of *M. lippincottianus* from Curiaú River basin is the first report of *N. pterodoridis* for this host.

Key words: infracommunity; parasites; Nematoda; Acanthocephala.

FATOR DE CONDIÇÃO E ECOLOGIA DE ENDOHELMINTOS EM *Metynnis lippincottianus* DO RIO CURIAÚ NA AMAZÔNIA ORIENTAL (BRASIL)

RESUMO

Os peixes estão entre os grupos de vertebrados mais suscetíveis as infecções parasitárias devido as características ambientais que podem favorecer o desenvolvimento de parasitos; além disso, a posição do hospedeiro na cadeia alimentar tem sido associada ao parasitismo. O objetivo deste estudo foi investigar a ecologia de parasitos endohelminthos em *Metynnis lippincottianus* do Rio Curiaú, na Amazônia oriental (Brasil), bem como avaliar as interações parasito-hospedeiro. De 110 espécimes de *M. lippincottianus* examinados, 76,3% estavam infectados por um ou mais espécies de parasitos, e um total de 146 parasitos como *Procamallanus (Spirocamallanus) inopinatus* (Nematoda), larvas de *Contraecum* sp. (Nematoda) e *Neoechinorhynchus pterodoridis* (Acanthocephala) foram coletados no intestino. No entanto, a dominância foi de espécies de nematoides, e os parasitos apresentaram dispersão uniforme ou aleatória. As infracomunidades parasitárias apresentaram baixo índice de diversidade de Shannon-Wiener ($0,2 \pm 0,3$), baixa uniformidade ($0,2 \pm 0,3$) e baixa riqueza de espécies ($1,1 \pm 0,8$). A abundância de *Contraecum* sp. apresentou correlação positiva fraca com o peso dos hospedeiros e o fator de condição não foi afetado pelo parasitismo. Este primeiro estudo sobre parasitos de *M. lippincottianus* da bacia do Rio Curiaú é o primeiro relato de *N. pterodoridis* para este hospedeiro.

Palavras chave: infracomunidade; parasitos, Nematoda; Acanthocephala.

INTRODUCTION

The Neotropical region has the most diversified fish fauna in the world, presenting more than 9100 species, equivalent to 27% of the fish species in the entire planet (Reis et al., 2016). A great part of these fish is in Amazon, in regions as the state of Amapá, which has a diversity of fish species with importance for the fishing. Among

Received: November 21, 2019

Accepted: July 22, 2020

these species are the fishes from family Serrasalminidae, which are widely distributed throughout the rivers of Amazon system, inhabiting mainly floodplains, flooded forests, lakes and rivers (Froese and Pauly, 2019). *Metynnis lippincottianus* Cope, 1870 is a Serrasalminidae popularly known as “pacu” or “pratinha” and can be found in the Brazilian basins and rivers of French Guiana, bordering rivers and lakes. Its diet consists of aquatic plants, seeds, phytoplankton, mollusks, crustaceans and detritus (Moreira et al., 2009; Yamada et al., 2012; Hoshino and Tavares- Dias, 2014; Froese and Pauly, 2019).

Fish are among the vertebrate groups most susceptible to parasitic infections due to environmental characteristics that can favor the development of parasites. In addition, the position of the host fish in food web has also been a great influence in richness and communities of endohelminths (Silva et al., 2011; Neves et al., 2013; Gonçalves et al., 2014; Carvalho and Tavares-Dias, 2017). In freshwater fishes, more than 300 species of endohelminth parasites have been reported (Neves et al., 2013; Duarte et al., 2016; García-Lopez et al., 2016; Carvalho and Tavares-Dias, 2017; Oliveira et al., 2018). For *M. lippincottianus* from the upper Paraná River has been reported endohelminths such as digeneans *Dadayus pacupeva* Lacerda, Takemoto & Pavanelli, 2003; nematodes *Spinoxyuris oxydoras* Petter, 1994, *Procamallanus (Spirocamallanus) inopinatus* Travassos et al., 1928; larvae of *Contracaecum* sp. and *Raphidascaris (Sprentascaris) mahnerti* Petter & Cassone, 1984 (Moreira et al., 2009; Yamada et al., 2012). The endohelminths community in *M. lippincottianus* from the Igarapé Fortaleza basin (Macapá) was composed by

nematodes *P. (S.) inopinatus*, *Contracaecum* sp., *Procamallanus (Spirocamallanus)* sp. and *S. oxydoras* and metacercariae of digeneans (Hoshino and Tavares-Dias, 2014). However, has not been studied before the endohelminth parasites fauna of *M. lippincottianus* from the Curiaú River, state of Amapá, in eastern Amazon (Brazil) has not been studied before.

Studies on fish parasitic ecology are important to improve the knowledge of the relationships between host and parasites. This knowledge may assist in plan of management in wild fish populations (Moreira et al., 2010; Silva et al., 2011). In fish populations, body length and weight can be used to estimate the relative condition factor (Kn), a tool qualitative of body conditions that can be associated with the parasites load (Moreira et al., 2010; Camara et al., 2011; Silva et al., 2011; Tavares-Dias and Oliveira, 2017). Thus, the aim of this study was to investigate the ecology of the endohelminth parasites in *Metynnis lippincottianus* from the Curiaú River, in eastern Amazon, as well as to evaluate parasites-host relationship.

MATERIAL AND METHODS

Fish and study area

From September 2017 to August 2018, 110 specimens of *Metynnis lippincottianus* were collected in the Curiaú River, region of Environmental Protection Area from the Curiaú basin, in the State of Amapá, located in the municipality of Macapá (Figure 1). Fish were collected using gillnets of 20-30 mesh sizes and immediately transported alive in containers containing water to the Laboratory

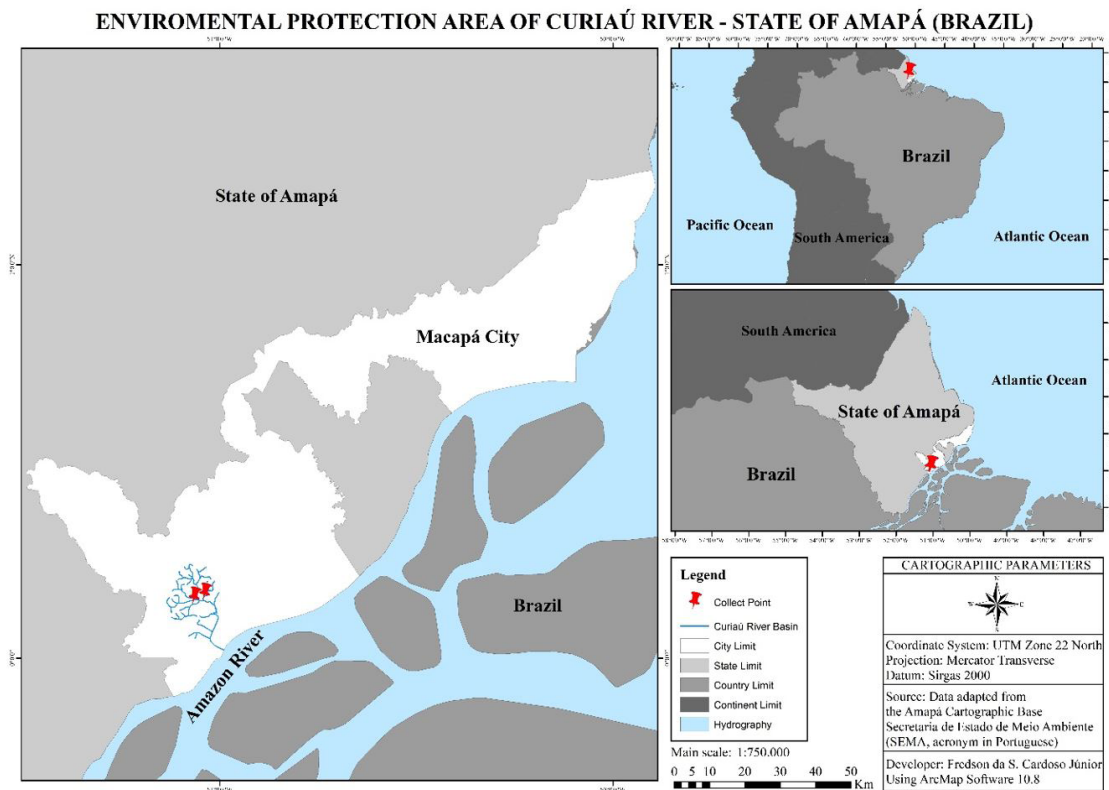


Figure 1. Collection sites of *Metynnis lippincottianus* in the Curiaú River basin, in eastern Amazon (Brazil).

of Morphophysiology and Animal Health (LABMORSA) of the State University of Amapá (UEAP), in Macapá (AP).

The Curiaú hydrographic basin is located in the estuarine coastal sector of the Amazon River. It is characterized as a river system with extensive floodplains that constitute physical systems connected via a silted-up river that forms a drain for freshwater. It is influenced by high rainfall and the daily tides of the Amazon River, to which it is connected. The main channel of the Curiaú basin transports rich organic matter that is brought in by the tides of the Amazon River and is carried to the floodplain, which is a protected environment. In this basin, during the rainy season, waters are rich in nutrients due to the fast decomposition of grass and animal remains and because the layer of humus produced by the forest is spread across the floodplain. This basin has dissolved oxygen levels of 2.5 mg L⁻¹ and pH of 5.6 (Takiyama et al., 2004; Torres and Oliveira, 2004). The region has a tropical climate; the rainy season occurs from December to May and the dry season, from June to November (Souza and Cunha, 2010).

Parasite sampling procedures

The fish were euthanized by medullary section, weighed (g) and measured for total length (cm) and then necropsied for collection and analysis of endoparasites. The viscera and gastrointestinal tract were examined for the presence of endoparasites and cysts. During the necropsy, small tissue fragments of organs were separated between slides and coverslips, where foci of parasite development were found for light microscope analysis. The collection, fixation, counting, preparation and staining of parasites for identification followed previous recommendations from Eiras et al. (2006). Nematodes were fixed in hot formalin (5%) and conserved in 70% alcohol, and then clarified in Faia's creosote. Acanthocephalans were fixed in formalin (5%), conserved in 70% alcohol and stained al alcoholic carmine of Langeron. The identification of parasites followed the recommendations of Moravec (1998) and Thatcher (2006). Ecological terms (prevalence, mean intensity and mean abundance) followed the recommendations of Bush et al. (1997).

The Ethics Committee for Animal Use from, Protocol N° 012-CEUA/CPAFAP and the System of Authorization and Information on Biodiversity (SISBIO) N° 50376-1 approved these procedures, besides the Secretary of the Environment of the State of Amapá (SEMA-AP), Letter N° 1014/2016, because it is an Environmental Protection Area from Curiaú River basin.

Data analyses

The following descriptors for the parasite component community were determined: species richness, diversity of Shannon-Wiener (*H*) and associated evenness (Magurran, 2004) using Diversity software (Pisces Conservation Ltda., UK). The frequency of dominance (percentage of infracommunities in which a species will be numerically dominant) was calculated according to Rohde et al. (1995). The dispersion index (ID) and the Poulin discrepancy index (D) calculated using 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 the ID, for each species of parasite, was tested by the statistical-*d* (Ludwig and Reynolds, 1988).

Body weight (g) and total length (cm) data were used to calculate the relative condition factor (Kn) of the fish (Le-Cren, 1951) that will be compared with the standard value (Kn = 1.0) using the test-*t*. The Spearman correlation coefficient (*rs*) was used to investigate correlation of parasites abundance with length and weight of hosts (Zar, 2010).

RESULTS

From 110 specimens of *M. lippincottianus* examined, 76.3% were infected by one or more parasites. A total of 146 parasites were collected, such as *P. (S) inopinatus* (Camallanidae: Nematoda), *Contraecaecum* sp. larvae (Anisakidae: Nematoda) and *Neoechinorhynchus pterodoridis* Thatcher, 1981 (Neoechinorhynchidae: Acanthocephala) collected from the intestine. However, the dominance was of *P. (S) inopinatus* (Table 1).

Procamallanus (S.) inopinatus had a random pattern of distribution, while *Contraecaecum* sp. and *N. pterodoridis* presented an uniform pattern of distribution (Table 2). The mean species richness was 1.1 ± 0.8, diversity index was 0.2 ± 0.3 and evenness 0.2 ± 0.3 (Table 3), with predominance of individuals with one parasite (Figure 2).

In *M. lippincottianus*, only the abundance of *Contraecaecum* sp. had a weak positive correlation with weight of hosts (Table 4).

Table 1. Parasite endohelminths in *Metynnis lippincottianus* (N = 110) from the Curiaú River, in eastern Amazon (Brazil).

Parasites	P (%)	MI ± SD	MA ± SD	DF (%)	SI
<i>Procamallanus (Spirocamallanus) inopinatus</i>	42.7	1.4 ± 0.8	0.6 ± 0.9	45.0	Intestine
<i>Contraecaecum</i> sp. (larvae)	37.3	1.1 ± 0.5	0.4 ± 0.6	32.0	Intestine
<i>Neoechinorhynchus pterodoridis</i>	26.4	1.2 ± 0.6	0.3 ± 0.6	24.0	Intestine

P: Prevalence (P), MI: Mean intensity, MA: Mean abundance, SD: Standard deviation, DF: Dominance frequency, SI: Site of infection

Table 2. Dispersion index (DI), statistical index *d* and discrepancy index (D) of *Metynnis lippincottianus* parasites from the Curiaú River, eastern Amazon (Brazil).

Parasite species	DI	<i>d</i>	D	Dispersion type
<i>Procamallanus (Spirocamallanus) inopinatus</i>	1.09	0.68	0.65	Random
<i>Contraecaecum</i> sp. (larvae)	0.78	-1.7	0.65	Uniform
<i>Neoechinorhynchus pterodoridis</i>	0.95	-0.6	0.76	Uniform

Table 3. Body parameters and diversity indexes for the community of endohelminths in *Metynnis lippincottianus* from the Curiaú River, in eastern Amazon (Brazil).

Parameters	Mean ± SD	Range
Length (cm)	7.7 ± 0.8	5.9-9.6
Weight (g)	9.1 ± 2.9	4.0-16.0
Condition factor (Kn)	1.00 ± 0.08	0.77-1.26
Species richness of parasites	1.1 ± 0.8	0-3
Shannon-Wiener (H)	0.2 ± 0.3	0-1.1
Evenness (E)	0.2 ± 0.3	0-1.0

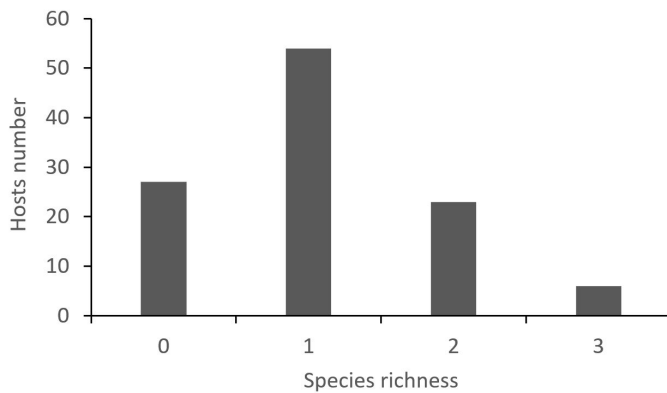


Figure 2. Species richness of parasites in *Metynnis lippincottianus* from the Curiaú River basin, in eastern Amazon (Brazil).

Table 4. Spearman correlation coefficient (*rs*) of the parasite abundance with the length and weight of endohelminths in *Metynnis lippincottianus* from the Curiaú River, in eastern Amazon (Brazil).

Body parameters Parasite species	Length		Weight	
	<i>rs</i>	<i>p</i>	<i>rs</i>	<i>p</i>
<i>Procamallanus</i> (<i>Spirocamallanus</i>) <i>inopinatus</i>	0.04	0.66	-0.07	0.44
<i>Contracaecum</i> sp. (larvae)	0.13	0.18	0.22	0.02
<i>Neoechinorhynchus pterodoridis</i>	0.002	0.98	-0.12	0.23

DISCUSSION

The patterns among parasitic communities of host fish populations can be detected through quantitative and qualitative descriptors (Magurran, 2004). In *M. lippincottianus*, the endohelminth community was composed only by two species of nematodes *P. (S.) inopinatus* and *Contracaecum* sp. and one species of acanthocephalan *N. pterodoridis*, but with dominance of nematodes. In addition, the Shannon diversity, evenness and species richness of parasites were low. In contrast, for *M. lippincottianus* from the Fortaleza Igarapé basin (Macapá, AP) the endohelminths reported were *P. (S.) inopinatus*, *Procamallanus* (*S.*) sp., *Contracaecum* sp., *S. oxydoras* and metacercariae of digeneans (Hoshino and Tavares-Dias, 2014). In the Paraná River, *M. lippincottianus* was infected by *S. oxydoras*, *P. (S.) inopinatus*, *Contracaecum* sp., *Raphidascaris*

(*Sprentascaris mahnerti* and *D. pacupeva* (Moreira et al., 2009; Yamada et al., 2012). However, in wild fish populations, the parasite diversity and richness depend directly on the population dynamics, age and diet of the hosts, presence of infective forms, environment quality, seasonality and geographical factors, among other biotic and abiotic factors (Hoshino and Tavares-Dias, 2014; Tavares-Dias and Oliveira, 2017).

In *M. lippincottianus* from Curiaú River, we found random dispersion for *P. (S.) inopinatus* and uniform dispersion for *Contracaecum* sp. and *N. pterodoridis*. In contrast, for this same host from Igarapé Fortaleza River the dispersion of *P. (S.) inopinatus* and *Contracaecum* sp. was aggregated (Hoshino and Tavares-Dias, 2014), a typical pattern for freshwater fish (Guidelli et al., 2003; Poulin (2013); Hoshino and Tavares-Dias, 2014). Uniform distribution pattern is expected for parasites species. However, random dispersion pattern may be related to a reduced opportunity to colonize this host (Guidelli et al., 2003). Pathogenicity of parasite, individual differences in immunological reaction and susceptibility to infection might have also caused these patterns of parasite distribution.

In *M. lippincottianus* from the Curiaú River basin, the total prevalence of parasites (76.3%) was similar to that observed in the same host (72.7%) from the upper Paraná River (Moreira et al., 2009; Yamada et al., 2012), but this was lower (98.7%) than that reported by Hoshino and Tavares-Dias (2014). Therefore, these differenced results are related to differences in environmental characteristics. In addition, the infections by *P. (S.) inopinatus* were also similar to that found by Hoshino and Tavares-Dias (2014), for same host from the Igarapé Fortaleza basin. In contrast, infection levels of larvae of *Contracaecum* sp. were lower than that observed in *M. lippincottianus* from the Igarapé Fortaleza basin (Hoshino and Tavares-Dias, 2014). Both nematode species present low host specificity, but *P. (S.) inopinatus* uses fish species as definitive hosts, while larvae of *Contracaecum* sp. use fish species as intermediate or paratenic hosts, and piscivorous birds are definitive hosts (Gonçalves et al., 2014; Pinheiro et al., 2019). Therefore, the presence of *Contracaecum* sp. larvae is related to the low position of *M. lippincottianus* in food web and trophic level. Larvae of *Contracaecum* sp. belong to family Anisakidae, which has zoonotic potential to humans (Pinheiro et al., 2019), when there is ingestion of raw or under-cooked fish infected with this nematode.

Neoechinorhynchus pterodoridis, an acanthocephalan described of *Pterodoras granulosus* Valenciennes, 1821 (Siluriformes) from Amazon River system (Thatcher, 1981) whose cycle is unknown, was also reported in *Chaetobranchopsis orbicularis* Steindachner, 1875 from a tributary of the Amazon River system, a definite host (Tavares-Dias and Oliveira, 2017). However, in the present study *N. pterodoridis* is being reported for the first time in *M. lippincottianus*, representing a new host record.

Variation in the health status of host fish populations, such as alteration in body condition due to nutritional deficiency can lead to parasitic infections (Moreira et al., 2010; Hoshino and Tavares-Dias, 2014; Tavares-Dias and Oliveira, 2017). However, in *M. lippincottianus* infected by few endohelminth species, the condition factor indicated good body condition. The body size of

the fish can play an important role in determining the infection susceptibility of hosts, growth, and consequently has great implications in the dynamics of infection and the ecology of host-parasites interactions (Silva et al., 2011; Hoshino and Tavares-Dias, 2014; Tavares-Dias and Oliveira, 2017). In contrast, the body size of *M. lippincottianus*, had little influence in abundance of parasites, indicating that host body size was not an important determinant of variations in abundance of parasites species.

CONCLUSIONS

This first study on *M. lippincottianus* endohelminth parasites from the Curiaú River basin showed that the parasitic fauna was composed by a low diversity of endohelminth species, predominantly by nematodes and with low abundance and intensity. This low abundance of parasites did not influence the body conditions of host population. For *M. lippincottianus*, host size does not explain the species abundance of parasites. Lastly, other factors that were not analyzed herein are responsible for parasite richness, low diversity, intensity and abundance.

REFERENCES

- Bush, A.O.; Lafferty, K.D.; Lotz, J.M.; Shostak, W. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. *The Journal of Parasitology*, 83(4): 575-583. <http://dx.doi.org/10.2307/3284227>.
- Camara, E.M.; Caramaschi, E.P.; Petry, A.C. 2011. Fator de condição: bases conceituais, aplicações e perspectivas de uso em pesquisas ecológicas com peixes. *Oecologia Australis*, 5(2): 249-274. <http://dx.doi.org/10.4257/oeco.2011.1502.05>.
- Carvalho, A.A.; Tavares-Dias, M. 2017. Diversity of parasites in *Cichlasoma amazonarum* Kullander, 1983 during rainy and dry seasons in eastern Amazon (Brazil). *Journal of Applied Ichthyology*, 33: 1178-1183. <http://dx.doi.org/10.1111/jai.13451>.
- Duarte, R.; Daniele, M.; Carvalho, M. 2016. Endohelminthes of *Salminus hilarii* Valenciennes (Actinopterygii: Bryconidae) and their ecological descriptors in the upper São Francisco River, Brazil. *Brazilian Journal of Veterinary Medicine*, 38: 151-156.
- Eiras, J.C.; Takemoto, R.M.; Pavanelli, G.C. 2006. Métodos de estudo e técnicas laboratoriais em parasitologia de peixes. 2ª ed. Maringá: Ed. EDUEM.
- Froese, R.; Pauly, D. (Ed.). 2019. FishBase. Available from: <www.fishbase.org> Access on: 12 jan. 2019.
- García-López, M.L.; Salguero-Vargas, G.; García-Prieto, L.; Osorio-Sarabia, D.; Pérez-Ponce de León, G. 2016. Endohelminths of some species of fishes from Lake Xochimilco, Mexico. *Revista Mexicana de Biodiversidad*, 87(4): 1360-1364. <http://dx.doi.org/10.1016/j.rmb.2016.06.018>.
- Gonçalves, R.A.; Oliveira, M.S.B.; Santos, E.F.; Tavares-Dias, M. 2014. Aspectos ecológicos da comunidade de parasitos em duas espécies de Loricariidae da bacia Igarapé Fortaleza, estado do Amapá, Brasil. *Biota Amazônia*, 4(1): 15-21. <http://dx.doi.org/10.18561/2179-5746/biotaamazonia.v4n1p15-21>.
- Guidelli, G.M.; Isaac, A.; Takemoto, R.M.; Pavanelli, G.C. 2003. Endoparasite infracommunities of *Hemisorubim platyrhynchos* (Valenciennes, 1840) (Pisces: Pimelodidae) of the Baía River, upper Paraná River floodplain, Brazil: specific composition and ecological aspects. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, 63(2): 261-268. <http://dx.doi.org/10.1590/S1519-69842003000200011>.
- Hoshino, M.D.F.G.; Tavares-Dias, M. 2014. Ecology of parasites of *Metynnis lippincottianus* (Characiformes: Serrasalmidae) from the eastern Amazon region, Macapá, State of Amapá, Brazil. *Acta Scientiarum. Biological Sciences*, 36(2): 249-255. <http://dx.doi.org/10.4025/actasciobiolsci.v36i2.19876>.
- Le-Cren, E.D. 1951. The length-weight relationship and seasonal cycle in gonadal weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20(2): 201-219. <http://dx.doi.org/10.2307/1540>.
- Ludwig, J.A.; Reynolds, J.F. 1988. *Statistical ecology: a primer on methods and computing*. New York: Wiley-Interscience.
- Magurran, A.E. 2004. *Measuring biological diversity*. Oxford: Blackwell Science. 256p.
- Moravec, F. 1998. *Nematodes of freshwater fishes of the Neotropical Region*. Praha: Academia. 464p.
- Moreira, L.H.A.; Takemoto, R.M.; Yamada, F.H.; Ceschini, T.L.; Pavanelli, G.C. 2009. Ecological aspects of metazoan endoparasites of *Metynnis lippincottianus* (Cope, 1870) (Characidae) from upper Paraná River floodplain, Brazil. *Helminthologia*, 46(4): 214-219. <http://dx.doi.org/10.2478/s11687-009-0040-9>.
- Moreira, L.H.A.; Yamada, F.H.; Ceschini, T.L.; Takemoto, R.M.; Pavanelli, G.C. 2010. The influence of parasitism on the relative condition factor (K_n) of *Metynnis lippincottianus* (Characidae) from two aquatic environments: the upper Parana river floodplain and Corvo and Guairacá rivers, Brazil. *Acta Scientiarum. Biological Sciences*, 32(1): 83-86. <http://dx.doi.org/10.4025/actasciobiolsci.v32i1.3668>.
- Neves, L.R.; Pereira, F.B.; Tavares-Dias, M.; Luque, J.L. 2013. Seasonal Influence on the Parasite Fauna of a Wild Population of *Astronotus ocellatus* (Perciformes: Cichlidae) from the Brazilian Amazon. *The Journal of Parasitology*, 99(4): 718-721. <http://dx.doi.org/10.1645/12-84.1>.
- Oliveira, M.S.B.; Corrêa, L.L.; Prestes, L.; Neves, L.R.; Brasiliense, A.R.P.; Ferreira, D.O.; Tavares-Dias, M. 2018. Comparison of the endoparasite fauna of *Hoplias malabaricus* and *Hoplerythrinus unitaeniatus* (Erythrinidae), sympatric hosts in the eastern Amazon region (Brazil). *Helminthologia*, 55(2): 157-165. <http://dx.doi.org/10.2478/helm-2018-0003>.
- Pinheiro, R.H.S.; Furtado, A.P.; Santos, J.N.; Giese, E.G. 2019. *Contracaecum* larvae: morphological and morphometric retrospective analysis, biogeography and zoonotic risk in the amazon. *Revista Brasileira de Parasitologia Veterinária*, 28(1): 12-32. <http://dx.doi.org/10.1590/s1984-29612019002>.
- Poulin, R. 2013. Explaining variability in parasite aggregation levels among host samples. *Parasitology*, 140(4): 541-546. <http://dx.doi.org/10.1017/S0031182012002053>. PMID:23343821.
- Reis, R.E.; Albert, J.S.; Di Dario, F.; Mincarone, M.M.; Petry, P.; Rocha, L.A. 2016. Fish biodiversity and conservation in South America. *Journal of Fish Biology*, 89(1): 12-47. <http://dx.doi.org/10.1111/jfb.13016>.

- Rohde, K.; Hayward, C.; Heap, M. 1995. Aspects of the ecology of metazoan ectoparasites of marine fishes. *The Journal of Parasitology*, 25: 945-970. [http://dx.doi.org/10.1016/0020-7519\(95\)00015-T](http://dx.doi.org/10.1016/0020-7519(95)00015-T).
- Rózsa, L.; Reiczigel, J.; Majoros, G. 2000. Quantifying parasites in samples of hosts. *The Journal of Parasitology*, 86(2): 228-232. [http://dx.doi.org/10.1645/0022-3395\(2000\)086\[0228:QPISOH\]2.0.CO;2](http://dx.doi.org/10.1645/0022-3395(2000)086[0228:QPISOH]2.0.CO;2).
- Silva, A.M.O.; Tavares-Dias, M.; Jerônimo, G.T.; Martins, M.L. 2011. Parasite diversity in *Oxydoras niger* (Osteichthyes: Doradidae) from the basin of Solimões River, Amazonas state, Brazil, and the relationship between monogenoidean and condition factor. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, 71(3): 791-796. <http://dx.doi.org/10.1590/S1519-69842011000400026>.
- Souza, E.B.; Cunha, A.C. 2010. Climatologia de precipitação no estado do Amapá e mecanismos climáticos de grande escala. In: Cunha, A.C.; Souza, E.B.; Cunha, H.F.A. (Eds.). *Tempo, clima e recursos hídricos: resultados do Projeto REMETAP no estado do Amapá*. Macapá: IEPA. p. 177-195.
- Takiyama, L.R.; Silva, A.Q.; Costa, W.J.P.; Nascimento, H.S. 2004. Qualidade das águas das ressacas das bacias do Igarapé da Fortaleza e do Rio Curiaú. In: Takiyama, L.R.; Silva, A.Q. (Eds.). *Diagnóstico das ressacas do estado do Amapá: bacias do Igarapé da Fortaleza e Rio Curiaú*. Macapá: CPAQ/IEPA e DGEO/SEMA. pp. 99-122.
- Tavares-Dias, M.; Oliveira, M.S.B. 2017. Structure of parasites community in *Chaetobranchopsis orbicularis* (Cichlidae), a host from the Amazon River system in northern Brazil. *Parasitology Research*, 116(8): 2313-2319. <http://dx.doi.org/10.1007/s00436-017-5539-2>.
- Thatcher, V.E. 1981. *Neoechinorhynchus pterodoridis* n. sp. (Acanthocephala: Neoechinorhynchidae) do bacu liso (*Pterodoras granulosus*) da Amazônia Brasileira. *Acta Amazonica*, 11(3): 445-448. <http://dx.doi.org/10.1590/1809-43921981113445>.
- Thatcher, V.E. 2006. *Amazon fish parasites*. 2th ed. Sofia, Moscow: Pensoft Publishers. v. 1, 508p.
- Torres, A.M.; Oliveira, D.M. 2004. Caracterização sedimentológica e variáveis ambientais das áreas úmidas costeiras das bacias hidrográficas do Igarapé da Fortaleza e do Rio Curiaú, Municípios de Santana e Macapá. In: Takiyama, L.R.; Silva, A.Q. (Eds.). *Diagnóstico das ressacas do estado do Amapá: bacias do Igarapé da Fortaleza e Rio Curiaú*. Macapá: CPAQ/IEPA e DGEO/SEMA. p. 169-180.
- Yamada, F.; Moreira, L.; Ceschini, T.; Lizama, M.; Takemoto, R.; Pavanelli, G.C. 2012. Parasitism associated with length and gonadal maturity stage of the freshwater fish *Metynnis lippincottianus* (Characidae). *Neotropical Helminthology*, 6(2): 247-253.
- Zar, J.H. 2010. *Biostatistical analysis*. 5th ed. New Jersey: Prentice Hall. 944p.