An Acad Bras Cienc (2024) 96(Suppl. 1): e20231253 DOI 10.1590/0001-3765202420231253
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

ANIMAL SCIENCE

Ectoparasite crustaceans of ten fish species from the upper Araguari River in northern Brazil

MARCOS S.B. OLIVEIRA, PEDRO H. ESTEVES-SILVA, LUIZA PRESTES, WOLMAR B. WOSIACKI & MARCOS TAVARES-DIAS

Abstract: Fish parasites are an important part of aquatic biodiversity and knowing these species and their interactions with their hosts helps in monitoring the aquatic biota. The present study investigated the ectoparasite crustacean fauna of ten fish species from the upper Araguari River, in the state of Amapá, northern Brazil. A total of 508 fish were collected and analyzed from July to November 2014, of which 82.6% (109) were parasitized by one or more crustacean ectoparasite species. In the ten host fish species, a total of 308 ectoparasite specimens were collected, from 12 taxa, such as *Argulus multicolor* Stekhoven, 1937, *Argulus spinulosus* Silva, 1980, *Argulus* sp.1, *Argulus* sp.2, *Argulus* sp.3, *Dipteropeltis* sp., *Dipteropeltis hirundo* Calman, 1912, *Dolops bidentata* Bouvier, 1899, *Dolops striata* Bouvier, 1899 (Argulidae), *Braga fluviatilis* Richardson, 1911, *Braga amapaensis* Thatcher, 1996 (Cymothoidae) and *Excorallana berbicensis* Boone, 1918 (Corallanidae). Higher levels of prevalence and abundance were recorded for *Hoplias aimara* (Valenciennes, 1847) and *Tometes trilobatus* Valenciennes, 1850, respectively. These ectoparasites were found in the fins, integument, mouth, and anus of the host fish. *Argulus* sp.2 and *D. bidentata* were the most abundant parasites (65.1%), and had the highest species richness. This study registered 36 novel host-parasite interactions, and thus represents a new record for all host species here examined.

Key words: Branchiura, isopoda, freshwater fish, infestation, parasites.

INTRODUCTION

The state of Amapá has two great basins, the Amazon River basin system and the North Atlantic Ocean basin, which have high levels of connectivity through lakes, rivers channels and floodplains, with singular physical and chemical parameters pivotal for the maintenance of the fish community (Hoorn 1994, Latrubesse et al. 2010, Cavalcanti et al. 2013, Hurd et al. 2016, Santos et al. 2018). The Araguari River basin is the main basin in the state of Amapá, and acts as an estuarine drainage network between the Amazon River and North Atlantic Ocean, with an area of 38,000 km^2. The river rises from its headwaters in the Serra do Tumucumaque Mountains of the Guiana Shields, and discharges into the Atlantic Ocean throughout the Amazon delta. Along its course, it crosses the Amapá National Forest, the Amapá State Forest, the Lago Piratuba (Piratuba Lake) Biological Reserve (REBio), the municipalities of Porto Grande and Ferreira Gomes, includes three hydropower plants (Coaracy Nunes, Ferreira Gomes and Cachoeira Caldeirão), and drains almost all of its water volume into the Amazon River and a small portion into the Atlantic Ocean (Santos et al. 2018). Moreover, is characterized by rocky outcrops and small waterfalls, precluding its navigation, which is restricted to small boats used by the riverine population in their daily activities.

Anthropogenic factors, such as the building of hydroelectrical dams in the Araguari River basin, have caused long-term alterations to the course flow and water quality, binding the natural patterns of this aquatic ecosystem, as well as the native vegetation cover, river discharge, turbidity and oxygen level of water, and the submersion of microhabitats, resulting in changes in ecosystems, which can lead to alterations in the diversity and complex network of parasite-host interaction (Fearnside 2001, Thatcher 2006, Morley 2007, Cavalcanti et al. 2013, Santos et al. 2014, 2018, Sá-Oliveira et al. 2015). Among parasites of fish, crustacean species comprise three main taxa: Branchiura, Copepoda, and Isopoda. In general, these parasitic crustaceans have been reported on all the external body surfaces of the host fish, i.e., the integument, opercula, fins, eyes, oral cavity, gills, and/or anus (Thatcher 2006, Lima et al. 2013, Gentil-Vasconcelos & Tavares-Dias 2015, 2016, Oliveira et al. 2019). Fish are important hosts in the biological cycle of crustacean ectoparasites (Tavares-Dias et al. 2015, Oliveira et al. 2017). Parasitic crustaceans are widely distributed in freshwater watersheds, and often affect host biology and fitness, playing a crucial role in the regulation of the fish community (Alberto et al. 2009, Tavares-Dias et al. 2014).

Few studies on parasite crustaceans of fish in the Araguari River basin have been carried out. Those that have, in a reservoir area of the Coaracy Nunes hydropower plant, reported the occurrence of *Excorallana berbicensis* Boone, 1918; *Argulus chicomendesi* Malta & Varella, 2000 and *Ergasilus turucuyus* Malta & Varella, 1996 in *Psectrogaster falcata* Eigenmann & Eigenmann, 1889 (Curimatidae); *Ageneiosus ucayalensis* Castelnau, 1855 (Auchenipteridae); *Acestrorhynchus falcirostris* Cuvier, 1819 (Acestrorhynchidae); *Hemiodus unimaculatus* Bloch, 1794 (Hemiodontidae); *Serrasalmus gibbus* Castelnau, 1855 (Serrasalmidae) and *Geophagus proximus* Castelnau, 1855 (Cichlidae) (Gentil-Vasconcelos & Tavares-Dias 2015, Gentil-Vasconcelos & Tavares-Dias 2016). However, no other study has been carried out of fish in the Araguari River basin, despite the importance of knowledge about the diversity of parasitic crustaceans in host fish. Thus, the aim of the present study was to investigate parasite crustaceans in ten fish species from the Araguari River, in the state of Amapá, northern Brazil.

MATERIALS AND METHODS

Fish and collection site

The fish were collected in the upper stretch of the Araguari River, between the municipalities of Serra do Navio and Ferreira, in the state of Amapá, in northern Brazil, at geographic coordinates 1°4’26.11”N 51°59’1.94”W; 1°7’16.50”N 51°58’59.64”W; 1°12’43.59”N 52°0’8.70”W; 1°13’50.97”N 51°59’59.53”W; 1°16’52.75”N 51°59’47.51”W and 1°18’8.54”N 51°58’52.28”W (Figure 1). The fish were collected in July and November 2014. For fish collection, gill nets of different measures and hook lines were used. Afterwards, the weight (g) and total length (cm) were measured for each fish.

Collection procedures and analysis of parasites

Immediately after capture, each fish was transferred to a tray and the sites of infection, such as the mouth, gills, opercula, tegument, fins, and anus were analyzed to verify the presence of ectoparasite crustaceans. The crustaceans collected were then fixed in ethyl alcohol (70%) for 24 hours and preserved in ethyl alcohol (70%) with glycerin (10%). Parasites were clarified for analysis of morphological structures using potassium hydroxide 5%, as recommended by Oliveira et al. (2021). Small parasites (Branchiura)

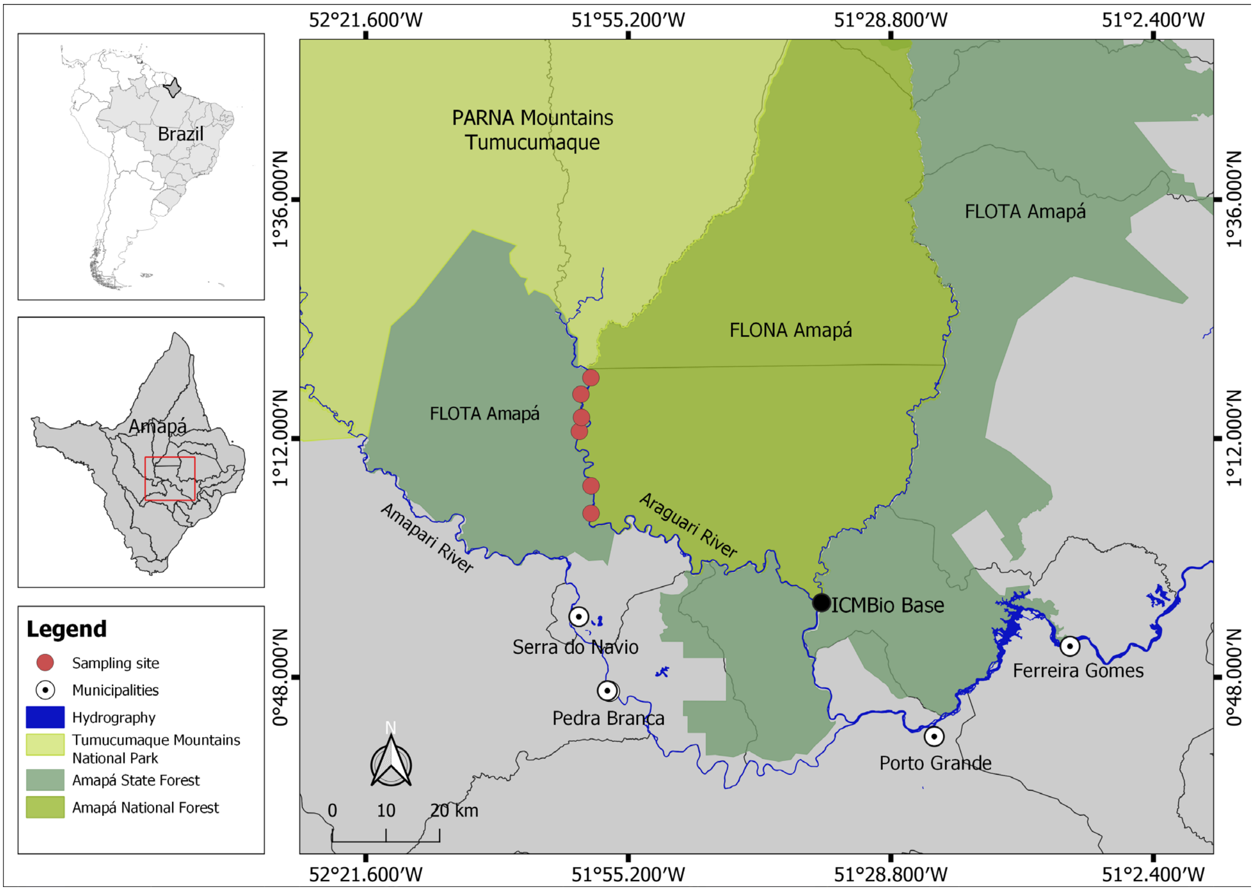

Figure 1. Geographic location of fish collection sites in the upper Araguari River, in the state of Amapá, northern Brazil.

were clarified whole and mounted on temporary slides containing glycerin for morphological visualization. Larger parasites (Isopoda) were dissected and parts of taxonomic interest were clarified in potassium hydroxide 5% and temporary slides were mounted. The parasites identification was carried out according to Van Name (1925), Lemos de Castro (1959), Silva (1980), Malta (1982), Lemos de Castro (1985), Lemos de Castro & Loyola-Silva (1985) and Thatcher (2006). The parasitological descriptors of prevalence, mean abundance and mean intensity were measured as recommended by Bush et al. (1997). Abundance data were subjected to normality analysis using the Shapiro-Wilk test from the "RVAideMemoire" package (Herve 2023), which showed a non-normal distribution. Spearman's correlation was used to assess the influence of fish length and weight on parasite abundance, using the tidyverse package (Wickham et al. 2019) in R software (R Core Team 2021). For this analysis, we considered three scenarios: (1) Isopoda abundance; (2) abundance of Branchiura and (3) the sum of the abundance of Isopoda and Branchiura, in order to evaluate the behavior of the results.

Ethics statement

Fish collection was authorized by ICMBio (Nº 42203-1), and the procedures involving animals were approved by the Ethics Committee on Animal Use of the Fish Biology Laboratory of the Federal University of Amapá (UNIFAP) approved the procedures involving animals (Protocol number 47757715.5.0000.0003).

RESULTS

A total of 558 specimens of fish distributed in 26 species were collected and analyzed (Table I). Of these, only 109 fish of 10 species were parasitized by crustacean ectoparasites (Tables I and II). Overall, 11.9% of *Acestrorhynchus microlepis* (Jardine, 1841), 14.7% of *Ageneiosus inermis* (Linnaeus, 1766), 4.6% of *Boulengerella cuvieri*, 3.7% of *Charax* sp., 14.7% of *H. aimara*, 6.4% of *M. asterias*, 9.2% of *M. ternetzi*, 8.2% of *P. rhomboidalis*, 11.0% of *S. rhombeus* and 15.6% of *T. trilobatus* were infested by one or more species of parasite crustaceans. Of the 109 fish specimens examined, 82.6% (n = 90) were infested by *Argulus multicolor* Stekhoven, 1937; *Argulus spinulosus* Silva, 1980; *Argulus* sp.1; *Argulus* sp.2; *Argulus* sp.3; *Dolops bidentata* Bouvier, 1899; *Dolops striata* Bouvier, 1899; *Dipteropeltis hirundo* Calman, 1912; *Dipteropeltis* sp. (Argulidae), *Braga fluviatilis* Richardson, 1911;

Table I. Fish species parasitized and not parasitized by Branchiura and Isopoda, collected from the upper Araguari River, Amapá, Brazil. N = Number of fish collected.

Host fish	N	Length (cm)	Weight (g)	Parasitized
Acestrorhynchus falcirostris (Acestrorhynchidae)	2	26.7 ± 1.8	205.5 ± 17.7	No
Acestrorhynchus microlepis (Acestrorhynchidae)	13	21.8 ± 1.9	114.3 ± 23.1	Yes
Ageneiosus inermis (Auchenipteridae)	57	31.8 ± 6.0	484.3 ± 311.7	Yes
Boulengerella cuvieri (Ctenoluciidae)	21	47.5 ± 8.7	1008.9 ± 593.4	Yes
Charax sp. (Characidae)	29	17.1 ± 2.6	107.0 ± 41.3	Yes
Cichla sp. (Cichlidae)	3	38.1 ± 9.8	1297.0 ± 971.2	No
Hoplias aimara (Erythrinidae)	42	44.7 ± 11.7	2075.5 ± 1698.4	Yes
Hoplias sp. (Erythrinidae)	3	29.5 ± 2.8	475.0 ± 114.0	No
Hypostomus sp. (Loricariidae)	2	16.3 ± 1.1	136.0 ± 29.7	No
Leporinus maculatus (Anostomidae)	13	21.8 ± 3.3	245.1 ± 110.5	No
Leporinus melanostictus (Anostomidae)	1	22.5	268.0	No
Leporinus pellegrini (Anostomidae)	7	22.8 ± 10.9	337.7 ± 221.5	No
Mylesinus paraschomburgkii (Serrasalmidae)	4	21.3 ± 1.9	364.3 ± 117.3	No
Prosomyleus rhomboidalis (Serrasalmidae)	26	29.1 ± 3.0	1082.5 ± 285.5	Yes
Myloplus asterias (Serrasalmidae)	50	14.6 ± 2.7	152.5 ± 53.2	Yes
Myloplus sp. (Serrasalmidae)	12	21.7 ± 6.7	566.0 ± 446.9	No
Myloplus ternetzi (Serrasalmidae)	29	18.2 ± 2.2	259.0 ± 48.3	Yes
Pimelodus sp.1 (Pimelodidae)	1	28.0	378.0	No
Pimelodus sp.2 (Pimelodidae)	2	25.5 ± 2.1	285.5 ± 43.1	No
Satanoperca sp. (Cichlidae)	1	19.0	200.0	No
Serrasalmus eigenmanni (Serrasalmidae)	6	13.1 ± 2.7	82.3 ± 63.1	No
Serrasalmus elongatus (Serrasalmidae)	12	14.4 ± 3.7	104.4 ± 92.6	No
Serrasalmus rhombeus (Serrasalmidae)	25	30.9 ± 5.1	1045.8 ± 478.3	Yes
Tometes trilobatus (Serrasalmidae)	67	36.1 ± 6.6	2170.0 ± 883.3	Yes
Triportheus angulatus (Triportheidae)	98	18.0 ± 2.4	103.9 ± 41.5	No
Triportheus brachypomus (Triportheidae)	32	19.7 ± 2.8	141.9 ± 49.2	No

Braga amapaensis Thatcher, 1996 (Cymothoidae) and *E. berbicensis* (Corallanidae). A total of 36 host-parasite associations were recorded. High prevalence, mean intensity and mean abundance values were reported for *D. bidentata* and *E. berbicensis* (Table I).

Argulidae presented the highest abundance and species richness (Figure 2). Among the host species, *A. microlepis* presented the highest species richness of the parasite crustaceans, followed by *H. aimara* (Figure 3).

There was positive correlation of branchiuran abundance with length and weight of the hosts (Figure 4). However, there was no correlation of isopod abundance with weight and length (Figure 5). There was also positive correlation of branchiuran + isopod with length and weight of the hosts (Figure 6).

DISCUSSION

Studies surveying the fauna of parasitic crustaceans and description of new species have revealed a richness of parasite crustaceans in the Amazon biome (Oliveira et al. 2017, Gaboardi et al. 2023). On the body surfaces of ten host fish species from the Araguari River we found ten species of Argulidae and three species of Isopoda, thus contributing 36 new records of host-parasite interactions. However, on the body surfaces of six fish species from an Araguari River reservoir, one species of Isopoda and two species of Argulidae have been reported (Vasconcelos & Tavares-Dias 2015).

Low (*A. microlepis*, *A. inermis*, *B. cuvieri*, *M. asterias* and *S. rhombeus*) to moderate (*H. aimara* and *T. trilobatus*) infestation of *E. berbicensis* occurred, with this parasite the most frequently occurring in the host fish studied herein. In the region of the present study, this species of isopod was previously reported in *A. falcirostris*, *H. unimaculatus*, *P. falcata* and *S. gibbus*, *A. ucayalensis* and *G. proximus,* with low infestation levels (Vasconcelos & Tavares-Dias 2016). Therefore, this parasite has no host specificity. *Excorallana* species are temporary parasites found in cryptic habitats and eventually parasitize fish species when emerging from

Table II. Ectoparasite crustaceans of ten fish species collected in the upper Araguari River, in eastern Amazon, northern Brazil. P (%): Prevalence, MA: Mean abundance, MI: Mean intensity, TNP: Total number of parasites.

Species of hosts and parasites	P (%)	MA	MI	TNP	Site of infestation
Acestrorhynchus microlepis **(n = 13)**					
Braga amapaensis	69.2	0.9	1.1	10	Mouth
Dolops striata	7.7	0.3	4.0	4	Tegument
Argulus multicolor	7.7	0.1	2.0	2	Mouth
Argulus sp.1	7.7	0.08	1.0	1	Mouth
Argulus sp.2	38.5	0.8	2.0	10	Tegument and Mouth
Dolops bidentata	7.7	0.08	1.0	1	Mouth
Excorallana berbicensis	7.7	0.08	1.0	1	Mouth
Ageneiosus inermis **(n = 16)**					
Argulus sp.2	25.0	0.2	1.0	4	Pectoral and caudal fins and tegument
Excorallana berbicensis	18.7	0.2	1.0	3	Tegument

Table II. Continuation.

***Boulengerella cuvieri* (n = 5)**					
Excorallana berbicensis	20.0	0.6	3.0	3	Tegument
Dolops bidentata	60.0	6.2	10.3	31	Tegument
Argulus sp.1	20.0	0.2	1.0	1	Mouth
***Charax* sp. (n= 4)**					
Argulus sp.2	50.0	0.5	1.0	2	Tegument
Braga fluviatilis	25.0	0.2	1.0	1	Anal fin
Dipteropeltis hirundo	25.0	0.2	1.0	1	Tegument
Dolops bidentata	25.0	0.2	1.0	1	Tegument
***Hoplias aimara* (n = 16)**					
Dolops striata	37.5	0.6	1.7	10	Mouth
Excorallana berbicensis	75.0	1.2	1.7	20	Anal and caudal fins, anus, mouth, and tegument
Dipteropeltis sp.	6.2	0.1	1.0	2	Pectoral fin
Dolops bidentata	12.5	0.2	1.5	3	Dorsal fin and tegument
Argulus sp.2	93.8	4.6	4.9	73	Caudal fin
***Myloplus asterias* (n = 7)**					
Excorallana berbicensis	14.3	0.1	1.0	1	Tegument
Dolops bidentata	28.6	0.3	1.0	2	Tegument
Argulus sp.3	28.6	0.4	1.5	3	Pectoral fin
Braga fluviatilis	28.6	0.4	1.5	3	Adipose fin and tegument
***Myloplus ternetzi* (n = 10)**					
Dipteropeltis sp.	40.0	0.4	1.0	3	Pelvic fin
Argulus spinulosus	10.0	0.1	0.25	1	Pelvic fin
Dolops bidentata	60.0	0.6	1.0	6	Caudal fin and tegument
Braga fluviatilis	50.0	0.5	1.0	5	Adipose fin e tegument
***Prosomyleus rhomboidalis* (n = 9)**					
Dolops bidentata	55.6	2.7	4.8	24	Pelvic and anal fin, mouth, eye and tegument
***Serrasalmus rhombeus* (n = 12)**					
Excorallana berbicensis	25.0	0.25	1.0	3	Mouth and tegument
Braga fluviatilis	8.3	0.08	1.0	1	Tegument
Dolops bidentata	25.0	0.4	1.3	5	Mouth and tegument
Dolops striata	8.3	0.08	1.0	1	Tegument
***Tometes trilobatus* (n = 17)**					
Excorallana berbicensis	56.25	0.7	1.2	11	Tegument
Dolops bidentata	100	3.4	3.4	54	Tegument
Dipteropeltis sp.	6.25	0.06	1.0	1	Pectoral fin

these habitats to feed (Delaney 1989). Hence, it is believed that *E. berbicensis* is found in host fish when it performs vertical migrations in the water column (Gentil-Vasconcelos & Tavares-Dias 2015).

Cymothoidae species are obligate parasites from freshwater, brackish and marine teleost and chondrichthyan fish (Smit et al. 2014) and possess 46 genera and 386 valid species (WoRMS 2023). Thatcher (1996) described *B. amapaensis* in *A. microlepis* from the state of Amapá; however, since then, no record of this parasite species has been carried out, until now. Therefore, this second report of *B. amapaensis* shows a high prevalence and low abundance and represents the first study on parasitic infestation, which was similar to that reported for other Cymothoidae species (Oda et al. 2015, Tavares-Dias et al. 2015, Oliveira et al. 2017). Therefore, it seems that *B. amapaensis* has a high host specificity, emphasizing the need for further studies to elucidate this issue. Moreover, we found low

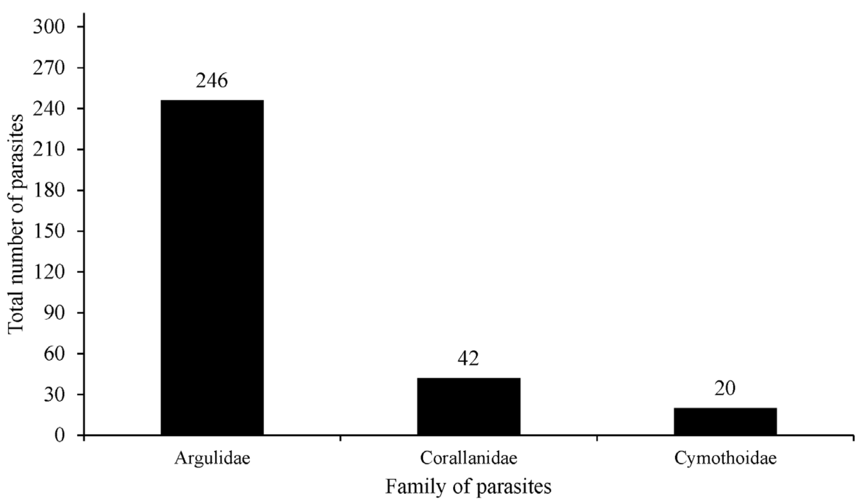

Figure 2. Total number of parasitic crustaceans collected from ten fish species from the upper Araguari River, in eastern Amazon, northern Brazil, according to parasite family.

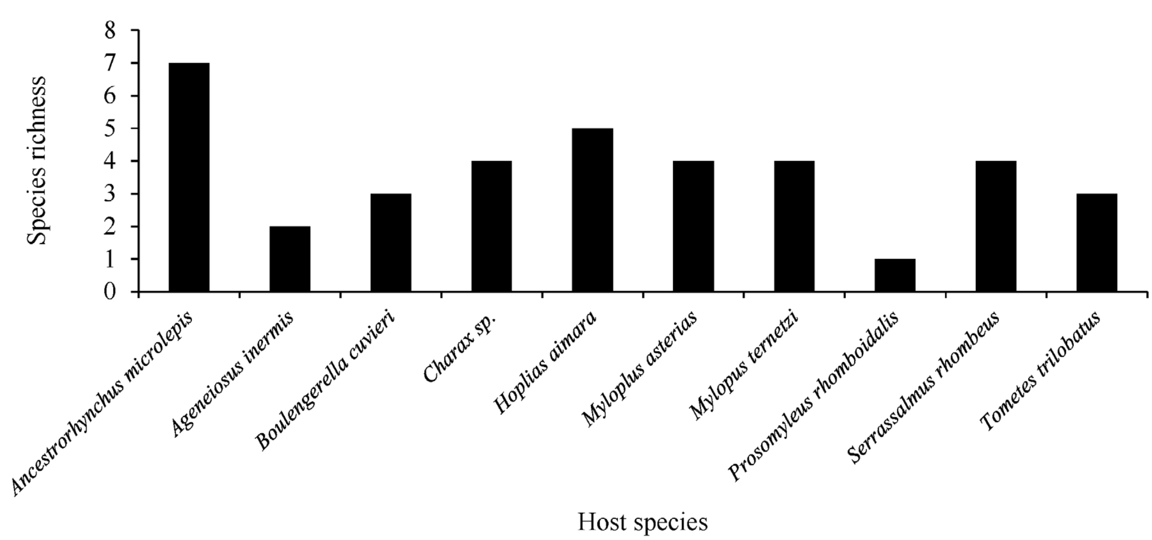

Figure 3. Parasite species richness in ten fish species from the upper Araguari River, in the eastern Amazon, northern Brazil.

infestation of *B. fluviatilis* on the body surface of *M. ternetzi*, *M. asterias*, *S. rhombeus* and *Charax* sp., but with a higher prevalence in *M. ternetzi*. Low infestation by *B. fluviatilis* has been reported for *Leporinus friderici* Bloch, 1794 from the Jari River basin, in the state of Amapá (Oliveira et al. 2017). *B. fluviatilis* has been also reported for Pimelodidae gen. sp.; *Serrasalmus spilopleura* Kner, 1858 (Hamann 1998), *Loricariichthys anus* Valenciennes, 1835, *Salminus brasiliensis* Cuvier, 1816 (Lemos de Castro 1959), *C. temensis* (Brasil-Lima & Barros 1998), *Cichlasoma* sp., *Hypostomus* sp., *Salminus* spp. and *Sorubim lima* Bloch & Schneider, 1801 (Thatcher 2006). However, this was the first report of *B. fluviatilis* for *M. ternetzi*, *M. asterias*, *S. rhombeus* and *Charax* sp.

Argulidae is the richest and most abundant taxon of parasitic crustaceans, and this may be associated to the lifestyle of these ectoparasite crustaceans. This pattern has also been reported in previous studies in fish from central Amazon (Malta 1984) and eastern Amazon (Oliveira et al. 2017, Neves & Tavares-Dias 2019). Among argulids, low to moderate infestations by *D. bidentata* occurred on the body surface of *A. microlepis*, *B. cuvieri*, *Charax* sp., *H. aimara*, *M. asterias*, *M. ternetzi*, *P. rhomboidalis*, *S. rhombeus* and *T. trilobatus*, all new hosts for this argulid species. *Dolops bidentata* is known to parasitize the body surface of Anostomidae, Serrasalmidae, Prochilodontidae and Cichlidae fish species (Malta 1982, Luque et al. 2013). Therefore, *D. bidentata* has no host-specificity, as well as other fish lice species found herein. Moreover, *D. striata* occurred only in *A. microlepis*, *H. aimara* and *Hoplias aimara*, and had a low infestation level. This argulid species has also been reported infesting other species of fish with this same pattern of infestation on the body surface, due to lack of host-specificity (Malta & Varella 1983, Malta 1984, Luque et al. 2013, Pereira et al. 2017). *Argulus* sp. infested only *A. microlepis* and *B. cuvieri*, while *Argulus* sp.2 infested *A. microlepis*,

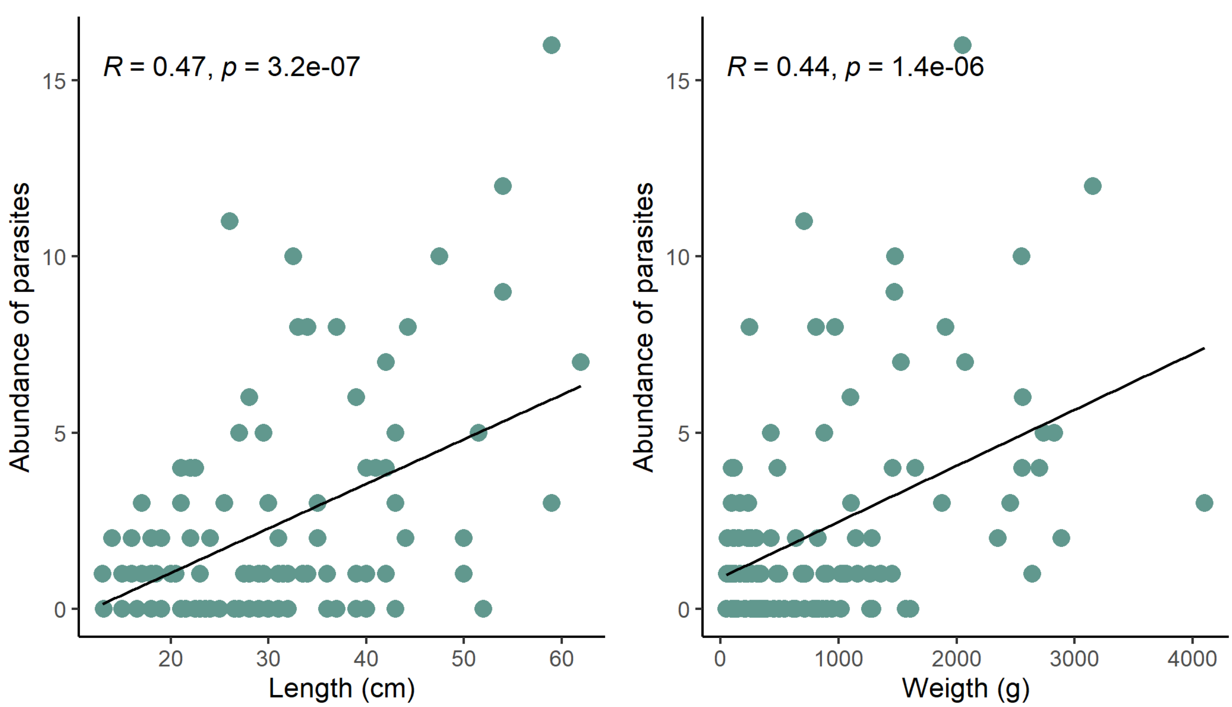

Figure 4. Spearman correlation to evaluate the relationship between Branchiura abundance and host length and weight.

Charax sp., *A. inermis* and *H. aimara*, and *Argulus* sp.3 infested only *M. asterias*.

The *Dipteropeltis* genus has only three valid species, and is found exclusively in Neotropical region, namely, *Dipteropeltis campanaformis* Neethling, Malta & Avenant-Oldewage (Neethling et al. 2014), *Dipteropeltis longicaudatus* Gaboardi, Reeves, Morey, Stanton & Carney, 2023 (Gaboardi et al. 2023) and *D. hirundo* (Calman, 1912). *Dipteropeltis hirundo* occurred only in *Charax* sp. and with low infestation and was a new host for parasite species. A new species of *Dipteropeltis* sp. (which will be described in another study) was found infesting *H. aimara*, *T. trilobatus* and *M. ternetzi*. Low infestation levels of *D. hirundo* have also been reported for *Acestrorhynchus* sp.; *Astyanax fasciatus* Cuvier, 1819; *Brycon melanopterus* Cope, 1872; *Luciopimelodus pati* Valenciennes, 1835; *Mylossoma aureum* Spix & Agassiz, 1829; *S. brasiliensis*; *Salminus franciscanus* Lima & Britski, 2007 and *Pygocentrus piraya* Cuvier 1819, which were the only host fish known for this argulid species (Lemos de Castro 1985, Luque et al. 2013). Carvalho 1941 reports *D. hirundo* in two species of lambarí, the yellowtail (*Tetragonopterus aureus*) and the redtail (*Tetragonopterus rutilus*). However, *Tetragonopterus aureus* was possibly misnamed by this author, and based on reclassifications of the group, it is possible that the hosts mentioned are actually *Astyanax lacustris* (yellow-tailed lambari) and *Astyanax rutilus* (red-tailed lambari). Therefore, the present study enlarged the host fish species for *D. hirundo*.

Aspects inherent to the host, such as size and weight, are important variables that explain part of the abundance of parasites in host fish population (Poulin 2007, Poulin & Leung 2011, Baia et al. 2018). Our results clearly show this, since there was a positive correlation between the abundance of crustacean ectoparasites and the length and weight of the host fish. Therefore, fish size plays an important role

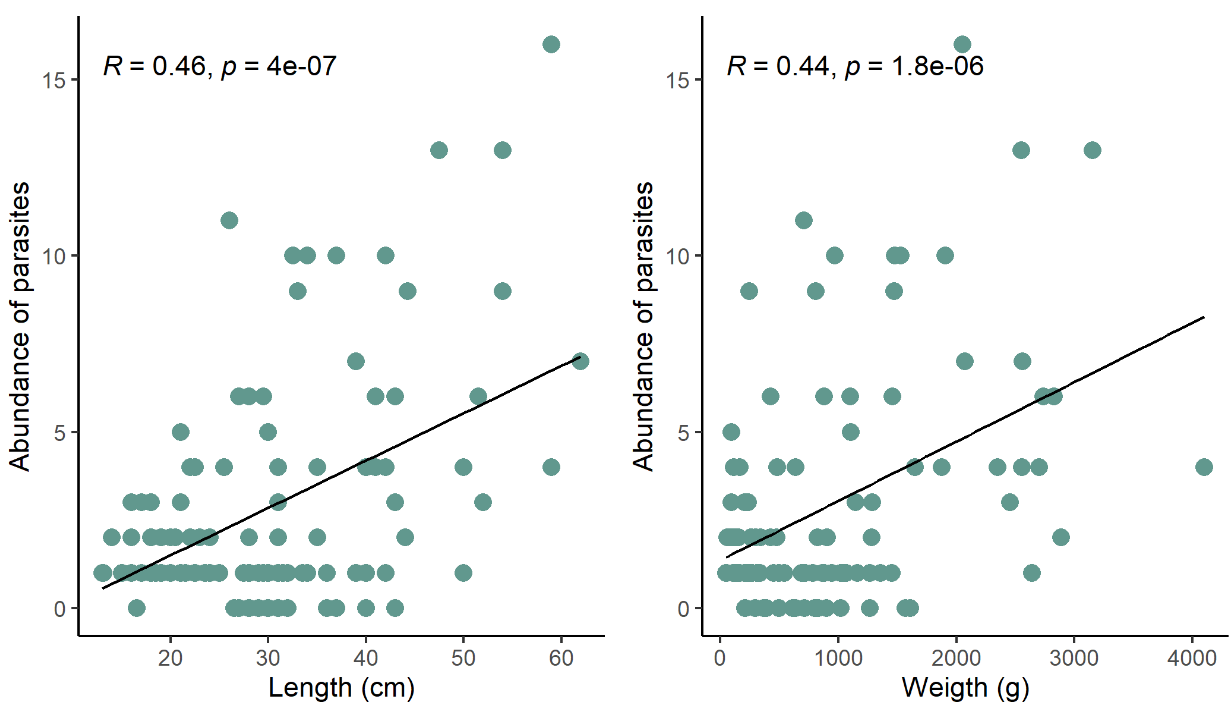

Figure 5. Spearman correlation to evaluate the relationship between Isopoda abundance and host length and weight.

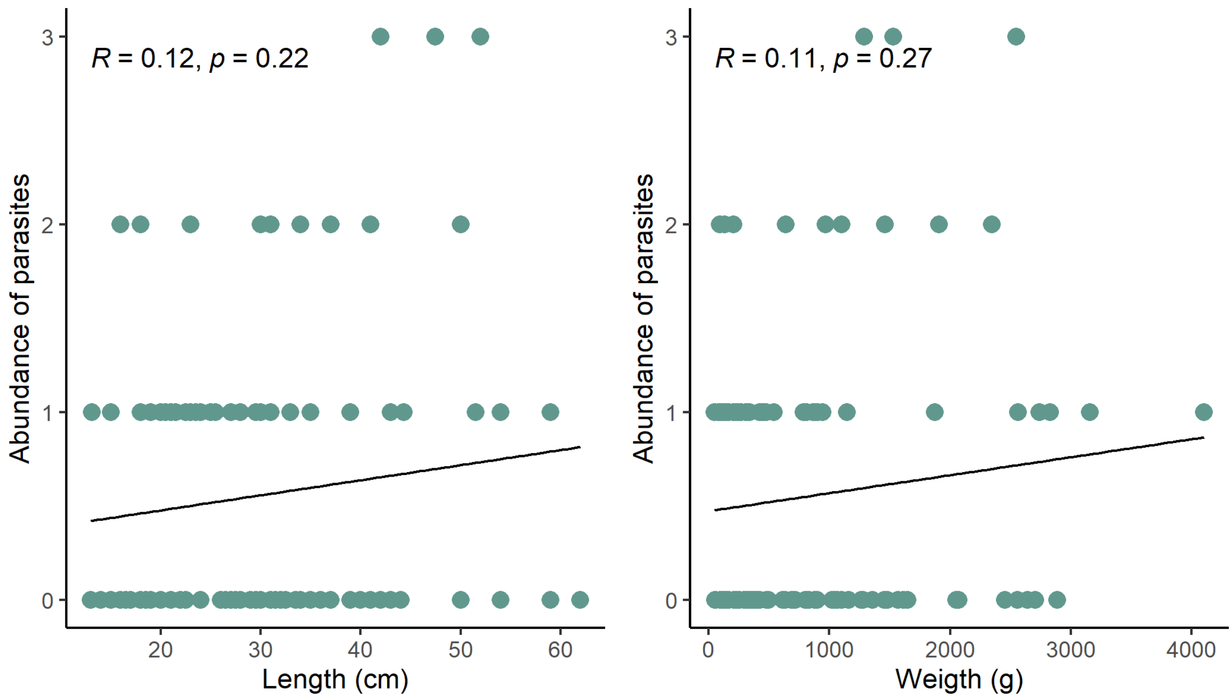

Figure 6. Spearman correlation to evaluate the relationship between Branchiura + Isopoda abundance and host length and weight.

in the abundance of parasites in a host population, and as the fish grows, either in length and/or weight, it becomes a potential target for the colonization of new crustacean parasites. This is probably because larger fish have a greater surface area to establish a larger population of these ectoparasites. We observe positive correlation between the abundance of branchiurans and the size host fish, similar correlation was reported for ectoparasites in Amazonian fish (Baia et al. 2018).

In conclusion, 308 parasite crustaceans were found on the body surfaces of the ten host fish species examined, being argulids the richest taxa in the community of these ectoparasites. Furthermore, most fish examined had a low abundance of ectoparasites, except for *A. microlepis* and *H. aimara*, which were the most parasitized hosts. Lastly, the present study reports new hosts for parasite crustacean species.

Acknowledgments

The Fundação de Amparo à Pesquisa do Amapá (FAPEAP) for its financial support under the project Monitoramento da Atividade Pesqueira no Médio Rio Araguari (Process number 004/2013 and 005/2014). The authors thank Conservação Internacional do Brazil (CI), Walmart Brazil and the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), for their support under the Biology and Ethnoecology of Ichthyofauna in the Amapá National Forest (FLONA) project. To the Conselho Nacional de Pesquisa e Desenvolvimento Tecnológico (CNPq), for the productivity grant to Tavares-Dias, M. (Grant 303013/2015-0) and the Financiadora de Estudos e Projetos (FINEP) (Grant 0117005600). To the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for granting a doctoral scholarship to Oliveira, MSB (Process number 88882.430002/2019-01), to the Conselho Nacional de Pesquisa e Desenvolvimento Tecnológico (CNPq) for granting a master degree scholarship to Esteves-Silva, PH. The authors thank Msc. Raissa Alves Gonçalves for the immense contribution during field activities on the Araguari River.

REFERENCES

ALBERTO RMF, MACIEL PC & ARAÚJO PB. 2009. Infestation by the freshwater cymothoid *Artystone trysibia* Schioedte (Crustacea, Isopoda): Parasite and host behaviour. J Nat Hist 43: 47-56.

BAIA RRJ, FLORENTINO AC, SILVA LMA & TAVARES-DIAS M. 2018. Patterns of the parasite communities in a fish assemblage of a river in the Brazilian Amazon region. Acta Parasitol 63(2): 304-316.

BRASIL-LIMA IM & BARROS CML. 1998. Malacostraca - Peracarida. Freshwater Isopoda. Flabellifera and Asellota. In: Young PS (Ed), Catalogue of Crustacea of Brazil. Rio de Janeiro: Museu Nacional, p. 645-651.

BUSH AO, LAFFERTY KD, LOTZ JM & SHOSTAK AW. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. J Parasitol 83(4): 575-583.

CALMAN WT. 1912. "On *Dipteropeltis**, a new genus of the crustacean. Order Branchiura". Proc Zool Soc Lond 82(4): 763-766.

CAVALCANTI AC, CUNHA HFA & PINHEIRO LAR. 2013. Modelagem e simulaçao do escoamento e sispersão azonais de agentes passivos no Rio Araguari AP: Cenários para o AHE Ferreira Gomes-I- Amapá/Brasil. RBRH – Rev Bras Recur Hídricos 18: 67-85.

CARVALHO JP. 1941. Sobre *Dipteropeltis hirundo* Calman, Crustáceo (Branchiura) parasito de peixes d'água doce. Bol Fac Filos Ciênc Let Univ São Paulo Zool 5(5): 265-277.

DELANEY PM. 1989. Phylogeny and Biogeography of the Marine Isopod Family Corallanidae (Crustacea, Isopoda, Flabellifera). LACM 409: 1-75.

FEARNSIDE PM. 2001. Environmental impacts of Brazil's Tucuruí Dam: Unlearned lessons forh hydroelectric development in amazonia. Environ Manag 27: 377-396.

GABOARDI LM, REEVES LE, MOREY GAM, STANTON DL & CARNEY RM. 2023. A new species of the fish louse genus *Dipteropeltis* Calman, 1912 (Crustacea: Branchiura) from Peru. Zootaxa 5315(2): 101-121.

GENTIL-VASCONCELOS HC & TAVARES-DIAS M. 2015. First study on infestation of *Excorallana berbicensis* (Isopoda: Corallanidae) on six fishes in a reservoir in Brazilian Amazon during dry and rainy seasons. Lat Am J Aquat Res 43(5): 936-943.

GENTIL-VASCONCELOS HC & TAVARES-DIAS M. 2016. Host-parasite interaction between crustaceans of six fish species from the Brazilian Amazon. Acta Sci Biol Sci 38(1): 113-123.

HAMANN MI. 1998. Aspectos ecológicos de la relácion parasitaria entre juveniles de *Braga fluviatilis* Richardson, 1911 (Crustacea, Cymothoidae) y *Serrasalmus spilopleura* Kner, 1860 (Pisces, Characidae) en poblaciones naturales del Nordeste Argentino. Physis 55: 15-22.

HERVE M. 2023. RVAideMemoire: Testing and plotting procedures for biostatistics. R package version 0.9-82-2[online] 2023 [cited 2023 Jul 18]. Available from: https://CRAN.R-project.org/package=RVAideMemoire.

HOORN C. 1994. An environmental reconstruction of the palaeo-Amazon River system (Middle-Late Miocene, NW Amazonia). Palaeogeogr Palaeoclimatol Palaeoecol 112: 187-238.

HURD LE, SOUSA RGC, SIQUEIRA-SOUZA FK, COOPER GJ, KAHN JR & FREITAS CEC. 2016. Amazon floodplain fish communities : Habitat connectivity and conservation in a rapidly deteriorating environment. Biol Conserv 195: 118-127.

LATRUBESSE EM, COZZUOL M, SILVA-CAMINHA SAF, RIGSBY CA, ASSY ML & JARAMILL C. 2010. The Late Miocene paleogeography of the Amazon Basin and the evolution of the Amazon River system. Earth Sci Rev 99: 99-124.

LEMOS DE CASTRO A. 1959. Sobre as espécies sul-americanas do gênero *Braga* Schioedte et Meinert, 1881 (Isopoda: Cymothoidae). Arch Mus Nac Rio de Janeiro 59: 69-77.

LEMOS DE CASTRO A. 1985. Branchiura. In: Schaden R (Ed), Manual de Identificação de Invertebrados Límnicos do Brasil, Brasília: CNPq/MCT, BR, p. 1-23.

LEMOS DE CASTRO A & LOYOLA-SILVA J. 1985. Isopoda. In: Schaden R (Ed), Manual de Identificação de Invertebrados Límnicos do Brasil, Brasília: CNPq/MCT, p. 1-20.

LIMA JTAX, COSTA E FS, NASCIMENTO WS & CHELLAPPA S. 2013. Tendências evolutivas do parasito isópodo *Livoneca redmanni* Leach, 1818 (Crustacea, Isopoda, Cymothoidae) em duas espécies de peixes marinhos do Rio Grande do Norte, Brasil. Biota Amaz 3(1): 66-73.

LUQUE JL, VIEIRA FM, TAKEMOTO RM, PAVANELLI GC & EIRAS JC. 2013. Checklist of Crustacea parasitizing fishes from Brazil. Check List 9(6): 1449-1470.

MALTA JCO. 1982. Os argulídeos (Crustacea: Branchiura) da Amazônia Brasileira. Aspectos da ecologia de *Dolops discoidalis* Bouvier, 1899 e *Dolops bidentata* Bouvier, 1899. (1). Acta Amaz 12(3): 521-528.

MALTA JCO. 1984. Os peixes de um lago de várzea da Amazônia Central (Lago Janauacá, Rio Solimões) e suas relações com os crustáceos ectoparasitas (Branchiura: Argulidae). Acta Amaz 14: 355-372.

MALTA JCO & VARELLA A. 1983. Os argulíddeos (Crustacea: Branchiura) da Amazônia brasileira 3. Aspectos da ecologia de *Dolops striata* Bouvier, 1899 e *Dolops carvalhoi* Castro, 1949. Acta Amaz 13: 299-306.

MORLEY NJ. 2007. Anthropogenic effects of reservoir construction on the parasite fauna of aquatic wildlife. Ecohealth 4: 374-383.

NEETHLING LAM, MALTA JCO & AVENANT-OLDEWAGE A. 2014. Additional morphological information on *Dipteropeltis hirundo* Calman, 1912, and a description of *Dipteropeltis campanaformis* n. sp. (Crustacea: Branchiura) from two characiform benthopelagic fish hosts from two Northern rivers of the Brazilian Amazon. Zootaxa 3755(2): 179-193.

NEVES LR & TAVARES-DIAS M. 2019. Low levels of crustacean parasite infestation in fish species from the Matapi River in the state of Amapá, Brazil. Braz J Vet Parasitol 28(3): 493-498.

ODA FH, GRAÇA RJ, TENCATT LFC, TAVARES LER, FROEHLICH O & TAKEMOTO RM. 2015. The poorly known Riggia *acuticaudata* (Crustacea: Isopoda) parasitizing *Ancistrus* sp. (Siluriformes: Loricariidae) from the Paraguay River Basin, Brazil, with comments on its reproductive biology. Comp Parasitol 82(1): 25-28.

OLIVEIRA MSB, CORRÊA LL, ADRIANO EA & TAVARES-DIAS M. 2021. Integrative taxonomy of a new species of *Therodamas* (Ergasilidae) infecting the Amazonian freshwater fish *Leporinus fasciatus* (Anostomidae). Parasitol Res 120(9): 3137-3147.

OLIVEIRA MSB, CORRÊA LL, FERREIRA DO, NEVES LR & TAVARES-DIAS M. 2017. Records of new localities and hosts for crustacean parasites in fish from the eastern Amazon in northern Brazil. J Paras Dis 41(2): 565-570.

PEREIRA, JN, MOREY GAM, MALTA & JCO. 2017. First record of *Dolops striata* (Branchiura: Argulidae) on *Arapaima gigas* from a fish farm in state of Pará, Brazil. Folia Amazón 26(2): 205-208.

POULIN R. 2007. Evolutionary Ecology of Parasites. 2nd ed. New Jersey: Princeton University Press, 465 p.

POULIN R & LEUNG TLF. 2011. Body size, trophic level, and the use of fish as transmission routes by parasites. Oecologia 166(3): 731-738.

R CORE TEAM. 2021. A language and environment for statistical computing. R Foundation for Statistical Computing.

SÁ-OLIVEIRA JC, HAWES JE, ISAAC-NAHUM VJ & PERES CA. 2015. Upstream and downstream responses of fish assemblages to an eastern Amazonian hydroelectric dam. Freshwater Biol 60: 2037-2050.

SANTOS ES, CUNHA AC & CUNHA EDS. 2014. Análise Espaço-sazonal da Qualidade da Água na Zona Flúvio-Marinha do Rio Araguari-Amazônia Oriental-Brasil. Rev Bras Rec Hidric 19(3): 215-226.

SANTOS ES, LOPES PPP, PEREIRA HH, PEREIRA HHS, NASCIMENTO OO, RENNIE CD, STERNBERG LSLO & CUNHA AC. 2018. The impact of channel capture on estuarine hydro-morphodynamics and water quality in the Amazon delta. Sci Total Environ 624: 887-899.

SILVA NMM. 1980. *Argulus spinulosus* sp. n. (Branchiura, Argulidae), em peixes de água doce do Rio Grande do Sul, Brasil. Iheringia, Série Zoologia (56): 15-23.

SMIT NJ, BRUCE NL & HADFIELD KA. 2014. Global diversity of fish parasitic isopod crustaceans of the family Cymothoidae. Int J Parasitol Parasites Wildl 3(2): 188-197.

TAVARES-DIAS M, ARAÚJO CSO, BARROS MS & VIANA GM. 2014. New Hosts and distribution records of *Braga patagonica*, a parasite Cymothoidae of fishes from the Amazon. Braz J Aquat Sci Technol 18: 91-97.

TAVARES-DIAS M, DIAS-JÚNIOR MBF, FLORENTINO AC, SILVA LMA & CUNHA AC. 2015. Distribution pattern of crustacean ectoparasites of freshwater fish from Brazil. Braz J Vet Parasitol 24(2): 136-147.

THATCHER VE. 1996. *Braga amapaensis* n. sp. (Isopoda: Cymothoidae) a mouth cavity parasite of the Amazonian fish, *Acestrorhynchus guyanensis* Menezes, with a redefinition of the genus *Braga*. Amaz Oecologia Reg Syst Fluminis Amaz 14(1/2): 121-129.

THATCHER VE. 2006. Amazon fish parasites. 2nd ed, Sofia: Pensoft Publishers, 508 p.

VAN NAME BWG. 1925. The isopods of Kartabo. Bartica district, British Guiana. Zoologica 5: 461-503.

WICKHAM H ET AL. 2019. Welcome to the Tidyverse. J Open Source Softw 4(43): 1686.

WORMS. 2023. World Register of Marine Species. http://www.marinespecies.org (accessed 27 September 2023).

How to cite

OLIVEIRA MSB, ESTEVES-SILVA PH, PRESTES L, WOSIACKI WB & TAVARES-DIAS M. 2024. Ectoparasite crustaceans of ten fish species from the upper Araguari River in northern Brazil. An Acad Bras Cienc 96: e20231253. DOI 10.1590/0001-3765202420231253.

Manuscript received on December 5, 2023;
accepted for publication on March 4, 2024

MARCOS S.B. OLIVEIRA[1,6]
https://orcid.org/0000-0002-4421-9608

PEDRO H. ESTEVES-SILVA[2]
https://orcid.org/0000-0002-7735-0696

LUIZA PRESTES[3]
https://orcid.org/0000-0002-4942-5777

WOLMAR B. WOSIACKI[4]
https://orcid.org/0000-0002-4013-8501

MARCOS TAVARES-DIAS[1,5]
https://orcid.org/0000-0002-8376-1846

[1]Universidade Federal do Amapá (UNIFAP), Programa de Pós-Graduação em Biodiversidade Tropical, Departamento de Ciências Biológicas e da Saúde, Rodovia Juscelino Kubitschek Km 2, 68903-419 Macapá, AP, Brazil

[2]Universidade Federal do Amapá (UNIFAP), Departamento de Ciências Biológicas, Rodovia Juscelino Kubitschek Km 2, 68903-419 Macapá, AP, Brazil

[3]Universidade Federal do Pará (UFPA), Núcleo de Ecologia Aquática e Pesca da Amazônia, Av. Perimetral, 2651, Montese, 66077-530 Belém, PA, Brazil

[4]Museu Paraense Emílio Goeldi (MPEG), Departamento de Zoologia, Setor de Ictiologia, Av. Governador Magalhães Barata, 376, 66040-170 São Braz, Belém, PA, Brazil

[5]Embrapa Amapá, Departamento de Aquicultura e Pesca, Rodovia Juscelino Kubitschek Km 5, 2600, 68903-419 Macapá, AP, Brazil

[6]Universidade do Estado do Amapá (UEAP), Avenida Presidente Vargas, 650, 68900-070 Macapá, AP, Brazil

Correspondence to: **Marcos Oliveira**
E-mail: marcosidney2012@hotmail.com

Author contributions

MARCOS S. B. OLIVEIRA: contributed with research conceptualization, methodology, investigation, data analysis, original draft preparation. PEDRO H. ESTEVES-SILVA: contributed with data analysis, review, and editing. LUIZA PRESTES: contributed with supervision and funding acquisition, review, and editing. MARCOS TAVARES-DIAS and WOLMAR B. WOSIACKI: contributed with research conceptualization, project administration, supervision, and funding acquisition. All authors have discussed the results and contributed to the final manuscript.