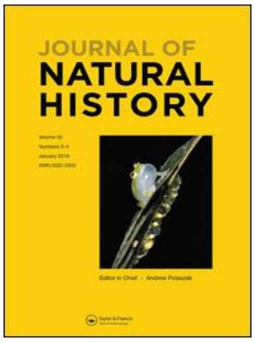

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Metazoan parasites of *Calophysus macropterus* (Siluriformes: Pimelodidae) in the Acre and Iaco rivers in the western Amazon region of Brazil: diversity, similarity and seasonal variation

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ABSTRACT

The diversity, similarity and seasonal variation of metazoan parasite communities in *Calophysus macropterus* in the Acre and Iaco rivers, in the western Amazon (Brazil), was investigated. Parasites from 13 taxa were collected from *C. macropterus* in both rivers: four species of monogeneans, four nematodes, two cestodes, one digenean, one crustacean and one pentastomid. In hosts from the Acre river, *Cucullanus pinnai* predominated; while in hosts in the Iaco river, *Monticellia amazonica* predominated. The component communities of the parasites among the hosts in the two rivers presented high similarity (100%). Prevalence of *Alinema amazonicum* was higher in hosts in the Acre river; while the prevalence of *C. pinnai* was higher in hosts in the Iaco river and the mean prevalence and abundance of *M. amazonica* were higher in fish from the Iaco river. Regarding *C. macropterus* from the Acre river, infection levels by *A. amazonicum* were higher during the rainy season, while *Demidospermus pinirampi* only occurred in the dry season and *Procamallanus* (*Spirocamallanus*) *inopinatus* only occurred in the rainy season. In hosts from the Iaco river, infections by larvae of Anisakidae gen. sp. were higher during the dry season, while infection by *Rudolphiella piracatinga* and *Sebekia* sp. only occurred in the rainy season. However, *P.* (*S.*) *inopinatus, Ergasilus callophysus, Ameloblastella unapi, Demidospermus luckyi, Demidospermus macropteri* and *D. pinirampi* only occurred in the dry season. High similarity of the component communities of the parasite was observed between the rainy and dry seasons. These results suggest that factors other than location and seasonality were influencing the communities and infracommunities of the parasites found. Lastly, *C. macropterus* is a new host for almost 50% of the parasite species found. In addition, the results from the present study have expanded the geographical range of these 13 species of parasites to the western Amazon region.

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Introduction

Parasites are important components of the biodiversity of various ecosystems and can provide valuable information on their hosts and the environment. They can play important

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roles in fish behaviour and migration patterns because they can negatively affect the survival, reproduction and structure of host communities (Tavares-Dias et al. 2014; Oliveira et al. 2017). The diversity of hosts infected by parasite species is a key factor that affects parasite transmission. Parasites that infect various host species (generalists) are more resistant to environmental changes (Tavares-Dias et al. 2014), including seasonal variation. In addition, parasite specificity in relation to hosts can limit spatial dispersion, since generalist parasites present higher chances of expanding their geographical distribution, thus indicating that parasite biogeography is not subject to a single factor (Yamada et al. 2017). Therefore, parasite diversity and geographical distribution are important issues in parasite ecology. In the Amazon region, these factors may undergo seasonal variation due to the rainfall regime. This knowledge provides relevant information on the various functions of parasite species within a community; and on whether parasitism levels are constant or whether variations are influenced by seasons and the availability of intermediate hosts and/or other factors (Marcogliese and Cone 1997; Tavares-Dias et al. 2014; Gonçalves et al. 2016; Yamada et al. 2017; Carvalho and Tavares-Dias 2017; Negreiros et al. 2018). However, it is hard to attribute variations in infection levels to a single cause associated with biotic or abiotic factors (Marcogliese et al. 2016).

In freshwater fish, diverse studies on species richness and similarity of parasite communities have focused on two different hierarchical levels: component community and infracommunities. This has mainly been done using descriptors such as the species richness, diversity, evenness and numerical dominance of parasite species (Moreira et al. 2009; Marcogliese et al. 2016; Oliveira et al. 2017; Yamada et al. 2017). Some studies have focused on evaluation of these important community parameters among Amazon fish species, and on the relationship with seasonality (Neves et al. 2013; Tavares-Dias et al. 2014; Gonçalves et al. 2016; Carvalho and Tavares-Dias 2017; Negreiros et al. 2018).

In the Amazon region, seasonality is divided into rainy and dry seasons. This dry/rainy season cycle may influence the lives of aquatic organisms and parasitic infection levels in host fish populations. Thus, infracommunities and the structure of the communities of various parasites of Amazonian fish species may or may not be influenced this seasonal cycle (Tavares-Dias et al. 2014; Gonçalves et al. 2016; Carvalho and Tavares-Dias 2017; Negreiros et al. 2018), depending on the parasite species and its biological cycle. Amazon fluvial systems present flooding and dry, dynamics that strongly influence the communities of intermediate invertebrate hosts and fish. Thus, there are significant differences in water quality in rivers, lakes and floodplains between the dry and rainy seasons. Moreover, the diversity of zooplankton and other invertebrates is higher during the rainy season, which provides fish with better feeding conditions (Tavares-Dias et al. 2014; Gonçalves et al. 2016).

In the western Amazon region, in the state of Acre, the Acre and Iaco rivers are the main tributaries supplying the municipalities of Rio Branco and Sena Madureira with water, respectively. However, over the last few years, the Acre river basin has been strongly subjected to human impacts due to discharge of raw domestic sewage, sand extraction and agricultural and livestock-rearing activities that demand deforestation and use of pesticides (Pereira and Morais 2015; Duarte 2017). The Iaco river basin has been less affected. These human actions have contributed towards the communities and infracommunities of parasites of *Pimelodus blochii* Valenciennes, 1840 in the Acre and Iaco rivers (Negreiros et al. 2018). The fish species of these two basins are diverse (Vieira

2008), and it is known that fish play a significant role in the life cycle of a variety of parasite species. However, no studies on this subject have been conducted in relation to *Calophysus macropterus* Lichtenstein, 1819, in the Acre and Iaco rivers.

Calophysus macropterus is a member of Pimelodidae with wide geographical distribution in the Amazon basin, with high abundance in the white water rivers and lakes of this basin. It is a migratory fish that inhabits benthic environments and is most active at dusk, with omnivorous-opportunistic feeding habits. It feeds voraciously on animal and plant species, and on dead fish carcases. It reproduces during the rainy season and females begin their sexual maturation process when they are approximately 28 cm long, at ages of between 19 and 24 months (Córdoba et al. 2000). It is important to the economy of the state of Acre, in addition to being consumed locally, it because it is exported to Colombia and Peru.

Until now, little was known about the diversity of parasites of *C. macropterus*. Regarding *C. macropterus* in Brazil, occurrences of the following species has been reported: *Eustrongylides* sp.; *Procamallanus* (*Spirocamallanus*) *inopinatus* Travassos, Artigas and Pereira, 1928; *Alinema amazonicum* Travassos, 1960 and *Procamallanus* (*Spirocamallanus*) sp. (Luque et al. 2011); and the cestodes *Rudolphiella piracatinga* Gil de Pertierra and Chambrier 2000 (Alves et al. 2017) and *Monticellia amazonica* Chambrier and Vaucher, 1997 (Chambrier and Vaucher 1997). Regarding *C. macropterus* in Peru, the following parasites have been described: the monogeneans *Ameloblastella unapi* Mendoza-Franco and Scholz 2009, *Demidospermus macropteri* Mendoza-Franco & Scholz, 2009 (Mendoza-Franco and Scholz 2009) and *Pavanelliella pavanelli* Kritsky and Boeger, 1998 (Kritsky and Boeger 1998); the digenean *Goeldamphistomum peruanum* Pantoja, Scholz, Luque and Jones, 2018 (Pantoja et al. 2018); the cestodes *M. amazonica* (Chambrier and Vaucher, 1997) and *R. piracatinga* (Alves et al. 2017); and the crustacean *Ergasilus callophysus* Thatcher and Boeger, 1984 (Thatcher et al. 1984). However, the structure of the communities and infracommunities of parasites and the influence of the rainy and dry seasons on these infracommunities in *C. macropterus* are unknown.

The hypothesis for the present study was that there would be differences in the community, prevalence and abundance of metazoan parasites in *C. macropterus* between the Acre and Iaco rivers, and that the rainy and dry seasons would lead to variations in these parameters. Therefore, the diversity, similarity and seasonal variations in communities of metazoan parasites of *C. macropterus* in the Acre and Iaco rivers, in the western Amazon region of northern Brazil, was investigated.

Material and methods

Study area, fish and parasite sampling

Between June 2015 and April 2017, specimens of *C. macropterus* were sampled with help from local fishermen in the Acre river, municipality of Rio Branco, and the Iaco river, municipality of Sena Madureira, both in the state of Acre, Brazil (Figure 1). A total of 160 specimens of *C. macropterus* was sampled: 80 specimens from the Acre river (40 during the rainy season and 40 during the dry season); and 80 specimens from the Iaco river (40 during the rainy season and 40 during the dry season). All the samples were proportionally distributed within each study month in relation to seasonal periods. These fish

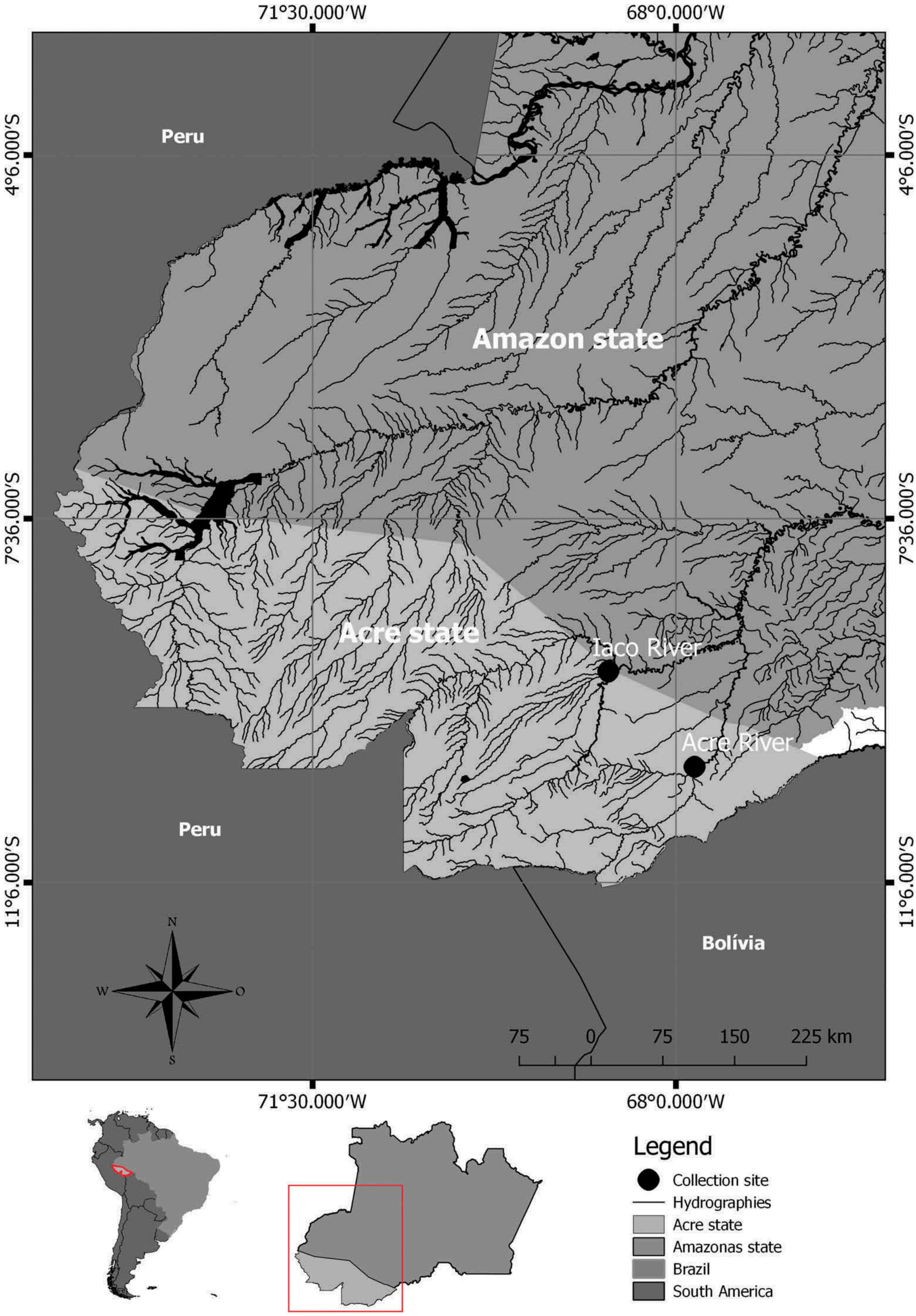

Figure 1. Collection sites of *Calophysus macropterus* of two basins from the State of Acre, in western Amazon, Brazil.

were transported alive, in an aerated tank, to the Aquaculture Laboratory of the Federal Institute of Education, Science and Technology of the state of Acre (IFAC), in Rio Branco, for parasitological analyses.

According to the Brazilian National Meteorological Service (INMET), the mean rainfall during the rainy season (November through May) of the study period was approximately 252.0 ± 96.8 mm; while during the dry season (June through October) it was 70.4 ± 58.9 mm.

In the laboratory, the fish were sacrificed by means of spinal cord transection and were then measured, weighed and analysed for parasites. The gills, opercula, skin, viscera and gastrointestinal tract were examined using a stereomicroscope. Parasites were collected, fixed, preserved, quantified and processed for identification in accordance with the methods described by Eiras et al. (2006). Voucher specimens were deposited in the Zoological Reference Collection of the Federal University of Mato Grosso do Sul (ZUFMS).

Fish sampling was done under authorisation from the Chico Mendes Institute for Biodiversity Conservation (SISBIO: No. 60899–1) and the study was approved by the Ethics Committee for Animal Use of Embrapa Amapá (Protocol N° 002, CEUA-CPAFAP).

Data analysis

The parasitological terminology used in the present study followed the recommendations proposed by Bush et al. (1997). The Diversity software (Pisces Conservation Ltd., UK) was used to calculate the following parasite community descriptors: species richness, Brillouin diversity index (*HB*), evenness (*E*) and relative frequency (percentage of infracommunities in which the species was numerically dominant) (Rohde et al. 1995; Magurran 2004). The Shapiro-Wilk test was used to determine whether the parasite abundance data followed a normal distribution pattern. The differences in parasite prevalence between rivers and between seasons (rainy and dry) were evaluated using the chi-square test (χ^2) with Yates's correction, and the abundance was calculated using the Mann-Whitney test (*U*). Differences in parasite species diversity between rivers and between seasons (rainy and dry) were also evaluated using the Mann-Whitney test (*U*). Spearman's coefficient (*rs*) was used to determine possible correlations between fish length and parasite abundance for species with prevalence ≥ 10%. Host body weight (g) and total length (cm) in the two rivers were compared using the t-test (Zar 2010).

Differences in the similarities of component parasite communities were tested by using analysis of similarity (ANOSIM). Differences between the two rivers and between the seasons (rainy and dry) were analysed by using the Jaccard similarity index (presence/absence) and the Bray-Curtis dissimilarity index (abundance). ANOSIM was based on ordered matrices that were generated from the Jaccard index and the Bray-Curtis distance (Magurran 2004), with 10,000 permutations.

Results

Component communities of parasites in the Acre and Iaco rivers

The fish in the Acre river (25.2 ± 3.6 cm) were shorter ($t = -5.29$; $p = 0.0001$) than those in the Iaco River (28.4 ± 4.3 cm). The weight of *C. macropterus* in the Acre river (241.1 ± 82.1 g) was lower ($t = -3.03$; $p = 0.003$) than the weight of those in the Iaco river (294.6 ± 130.7 g).

In *C. macropterus* in the Acre River, the prevalence of parasitism was 73.7% and a total of 523 parasites were sampled. The hosts were parasitized by one or more species of the 13 taxa found. The predominant species was *Cucullanus pinnai* Travassos, Artigas and Pereira, 1928; followed by larvae of Anisakidae gen. sp. In *C. macropterus* in the Iaco River, the prevalence of parasitism was 76.2% and a total of 792 parasites were sampled. The hosts were parasitized by one or more species of the 13 taxa found. The predominant species was *M. amazonica*, followed by Anisakidae gen. sp. The prevalence of *A. amazonicum* was higher in hosts in the Acre river, and the prevalence of *C. pinnai* was higher in hosts in the Iaco river. Regarding prevalence and mean abundance of *M. amazonica*, values were higher in the Iaco river. However, the prevalence and mean abundance of the other species of parasite that were found did not differ between the hosts in the two rivers (Table 1).

In *C. macropterus* in the Acre river, the abundance of metacercariae of *Diplostomulum* type presented a weak positive correlation with the length of hosts ($rs = 0.24$; $p = 0.03$), but no significant correlation of the abundance of monogeneans ($rs = 0.20$; $p = 0.08$), *C. pinnai* ($rs = 0.02$; $p = 0.87$), *A. amazonicum* ($rs = 0.11$; $p = 0.32$), Anisakidae gen. sp. ($rs = 0.16$; $p = 0.16$) and *R. piracatinga* ($rs = 0.04$; $p = 0.75$) with the length of hosts was found.

In *C. macropterus* in the Iaco river, the abundance of monogeneans *Demidospermus luckyi* Kritsky, Thatcher and Boeger, 1987; *Demidospermus macropteri*, 1987; *D. pinirampi* and *A. unapi* presented a weak positive correlation with the length of hosts ($rs = 0.21$; $p = 0.05$). A weak negative correlation of abundance of Anisakidae gen. sp. with the length of hosts ($rs = -0.23$; $p = 0.04$) was found. However, no significant correlation of abundance of *A. amazonicum* ($rs = 0.02$; $p = 0.83$), metacercariae of *Diplostomulum* type ($rs = 0.21$; $p = 0.05$), *M. amazonica* ($rs = 0.15$; $p = 0.19$) or *R. piracatinga* ($rs = -0.02$; $p = 0.98$) with the length of hosts were observed.

The ANOSIM results indicated that there was qualitative homogeneity (Jaccard = 1.0) and quantitative (Bray-Curtis = 0.58), in comparing the component communities of parasites in the Acre and Iaco rivers (Jaccard $R = 0.037$; $p = 0.0002$; and Bray-Curtis $R = 0.029$; $p = 0.006$).

The results regarding Brillouin diversity, parasite species richness and evenness were similar for *C. macropterus* in the Acre and Iaco rivers (Figure 2).

In *C. macropterus* in the Acre river, hosts parasitized by two species predominated, while in *C. macropterus* in the Iaco river, hosts parasitized by zero to two species predominated (Figure 3).

Seasonal variation in infracommunities of parasites in the Acre and Iaco rivers

Regarding hosts in the Acre River, the prevalence and abundance of *A. amazonicum* were higher during the rainy season; while *D. pinirampi* only occurred during the dry season and *P.* (*S.*) *inopinatus* only occurred during the rainy season. In turn, regarding hosts in the Iaco river, the prevalence and abundance of larvae of Anisakidae gen. sp. were higher during the dry season; while *R. piracatinga* and larvae of *Sebekia* sp. only occurred during the rainy season and *P.* (*S.*) *inopinatus, A. unapi, D. luckyi, D. macropteri, D. pinirampi* and *E. callophysus* only occurred during the dry season (Table 2).

Regarding *C. macropterus* in the Acre river, host weight and length, parasite species richness, Brillouin diversity and evenness were similar between the rainy and dry

Table 1. Metazoan parasites in *Calophysus macropterus* of two basins from the State of Acre, in western Amazon (Brazil). P: Prevalence, MA: Mean abundance, MI: Mean intensity, FD: Frequency of dominance, TNP: Total number of parasites, *U* = Mann–Whitney test, χ2 = chi–square test, *p < 0.05, **p < 0.001.

		Acre River (n = 80)				Iaco River (n = 80)					
Parasite species	Site of infection	P (%)	MA ± SD	TNP	FD (%)	P (%)	MA ± SD	TNP	FD (%)	χ^2	*U*
Monogenea											
Ameloblastella unapi	Gills	10.0	0.2 ± 1.0	23	4	3.7	0.2 ± 1.7	20	3	2.44	3003.0
Demidospermus luckyi	Gills	3.7	0.06 ± 0.3	5	1	6.2	0.1 ± 0.7	14	2	0.53	0.00
Demidospermus macropteri	Gills	16.2	0.6 ± 1.9	54	10	18.7	1.1 ± 2.9	89	11	0.17	3097.0
Demidospermus pinirampi	Gills	6.2	0.1 ± 0.5	10	2	8.7	0.2 ± 0.8	20	3	0.36	3113.0
Nematoda											
Alinema amazonicum	Stomach and Small intestine	20.0	0.7 ± 2.4	57	11	35.0	0.7 ± 1.4	63	8	4.51*	2748.0
Cucullanus pinnai	Large intestine	16.2	1.5 ± 9.9	124	24	3.7	0.1 ± 0.6	8	1	6.94*	2797.0
Procamallanus (*Spirocamallus*) *inopinatus*	Small intestine	2.5	0.07 ± 0.4	6	1	1.2	0.01 ± 0.1	1	0.1	0.34	3159.0
Anisakidae gen. sp. (larvae)	Mesentery	35.0	1.5 ± 4.4	123	23	26.2	2.2 ± 8.5	179	23	1.44	2908.0
Digenea											
Metacercariae type-*Diplostomulum*	Gills and large intestine	21.2	1.1 ± 5.3	91	17	12.5	0.4 ± 1.4	34	4	2.18	2930.5
Cestoda											
Monticellia amazonica	Large intestine	2.5	0.03 ± 0.2	3	6	27.5	3.9 ± 20.6	316	40	19.0**	2393.0**
Rudolphiella piracatinga	Large intestine	18.7	0.2 ± 0.5	18	3	10.0	0.3 ± 1.3	26	3	2.49	2946.0
Crustacea											
Ergasilus calophysus	Gills	5.0	0.1 ± 0.4	8	2	7.5	0.2 ± 1.0	19	2	0.43	3117.5
Pestastomida											
Sebekia sp. (larvae)	Gills	2.5	0.02 ± 0.1	2	4	2.5	0.03 ± 0.2	3	0.4	0.00	3199.0

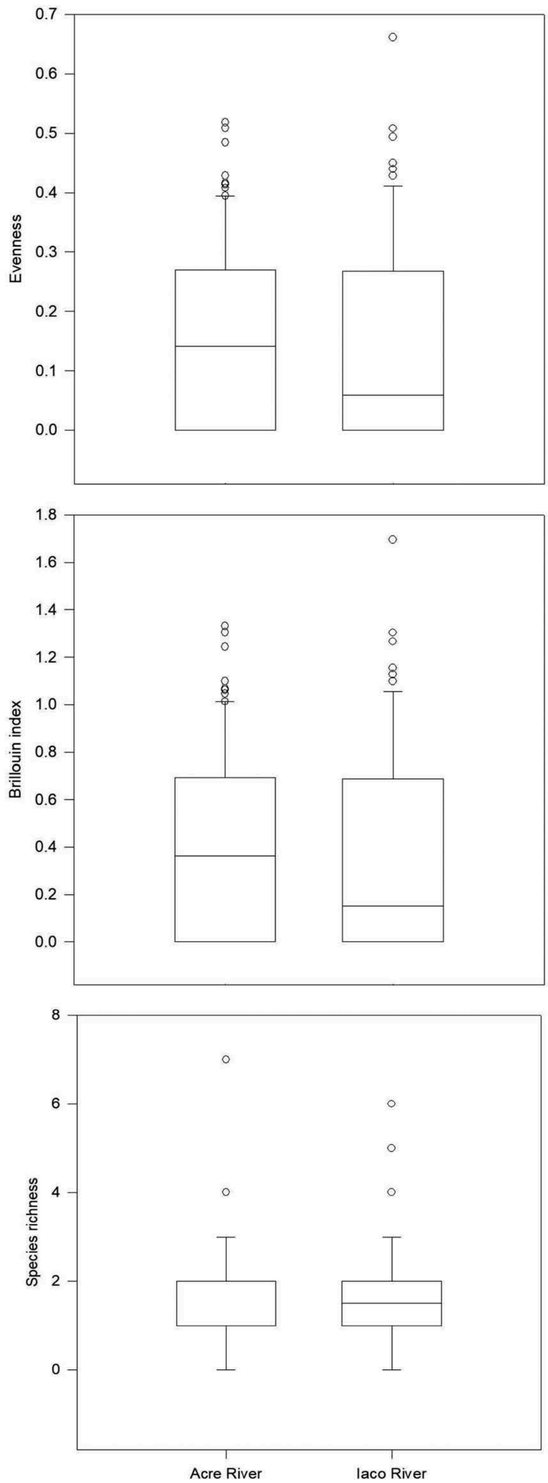

Figure 2. Diversity parameters of the parasites in *Calophysus macropterus* of two basins from the State of Acre, in western Amazon, Brazil (Box plots represent medians, interquartile ranges, minimum–maximum ranges and outliers). Equal mean values according to the Mann-Whitney test ($p > 0.05$).

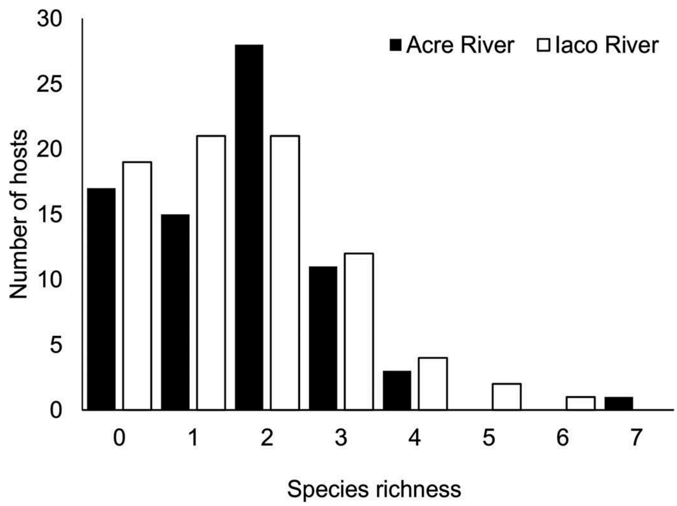

Figure 3. Species richness of parasites in *Calophysus macropterus* of two basins from he State of Acre, in western Amazon (Brazil).

seasons. In turn, regarding *C. macropterus* in the Iaco river, host weight and length were also similar, but parasite species richness, Brillouin diversity and evenness were higher during the dry season (Table 3).

The ANOSIM results indicated that there was qualitative dissimilarity (Jaccard = 0.85) and quantitative dissimilarity (Bray-Curtis = 0.52) in comparing the component communities of parasites in the Acre river during the rainy and dry seasons (Jaccard R = 0.015; p = 0.119; and Bray-Curtis R = 0.006; p = 0.294). Moreover, the ANOSIM results indicated that there was qualitative dissimilarity (Jaccard = 0.38) and quantitative dissimilarity (Bray-Curtis = 0.28), in comparing the component communities of parasites in the Iaco river during the rainy and dry seasons (Jaccard R = 0. 121; p = 0.0001; and Bray-Curtis R = 0.179; p = 0.0001).

Discussion

In wild fish populations, several factors can influence diversity, species richness and parasite infection levels. Since all species present spatial distribution, it is very important to determine the processes that limit this distribution, in order to understand the ecology of parasites. Diversity, species richness and parasite infection levels are commonly correlated with various widely discussed biotic and abiotic factors (Moreira et al. 2009; Tavares-Dias et al. 2014; Marcogliese et al. 2016; Oliveira et al. 2017; Yamada et al. 2017; Negreiros et al. 2018). Studies that focused on geographical distance as a determinant factor for diversity, community and species richness have indicated that this factor, together with environmental factors, was determinant among the ecological parameters for the same host species (Marcogliese et al. 2016; Oliveira et al. 2017; Negreiros et al. 2018).

Infracommunities of parasites are considered to be random communities (Yamada et al. 2017). However, similarity of communities and infracommunities of parasites is not expected for host species that live in allopatry (Oliveira et al. 2017; Negreiros et al. 2018), since they do not overlap spatially. On the other hand, high Jaccard similarity (100%) was

Table 2. Seasonal variation of the prevalence (P) and mean abundance (MA) ± standard deviation (SD) of metazoan parasites in *Calophysus macropterus* of two basins from the State of Acre, in western Amazon (Brazil). *U* = Mann–Whitney test, χ2 = chi–square test, *p < 0.05, **p < 0.001.

	Acre River						Iaco River					
	Rainy season (n = 40)		Dry season (n = 40)				Rainy season (n = 40)		Dry season (n = 40)			
Parasite species	P (%)	MA ± SD	P (%)	MA ± SD	χ^2	*U*	P (%)	MA ± SD	P (%)	MA ± SD	χ^2	*U*
Ameloblastella unapi	10.0	0.6 ± 2.3	10.0	0.4 ± 1.2	0.00	794.0	–	–	7.5	0.5 ± 2.3	–	–
Demidospermus luckyi	12.5	0.3 ± 1.1	5.0	0.1 ± 0.4	0.35	700.0	–	–	12.5	0.3 ± 1.04	–	–
Demidospermus macropteri	12.5	0.5 ± 1.6	20.0	0.8 ± 2.1	0.83	737.0	–	–	37.5	2.2 ± 3.8	–	–
Demidospermus pinirampi	–	–	12.5	0.2 ± 0.7	–	–	–	–	17.5	0.5 ± 1.1	–	–
Alinema amazonicum	32.5	1.1 ± 3.1	7.5	0.2 ± 1.03	7.81*	1423.5*	27.5	0.7 ± 1.6	42.5	0.8 ± 1.2	1.99	1709.5
Cucullanus pinnai	20.0	0.5 ± 1.3	12.5	2.6 ± 13.8	0.83	1569.0	2.5	0.1 ± 0.9	5.0	0.5 ± 0.2	0.35	1639.0
Procamallanus (*S.*) *inopinatus*	5.0	0.1 ± 0.6	–	–	–	–	–	–	2.5	0.02 ± 0.1	–	–
Anisakidae gen. sp. (larvae)	40.0	2.0 ± 5.7	30.0	1.07 ± 2.04	0.88	1554.0	10.0	1.0 ± 5.1	42.5	3.4 ± 10.7	10.9**	1878.5*
Metacercariae type -*Diplostomulum*	25.0	1.6 ± 7.3	17.5	0.6 ± 1.6	0.67	1571.0	7.5	0.4 ± 1.6	17.5	0.4 ± 1.2	1.83	1694.5
Monticellia amazonica	2.5	0.5 ± 0.3	2.5	0.02 ± 0.1	0.00	1619.5	30.0	7.3 ± 28.5	25.0	0.5 ± 1.2	0.25	1560.5
Rudolphiella piracatinga	22.5	0.3 ± 0.7	15.0	0.15 ± 0.3	0.74	1557.0	20.0	0.6 ± 1.8	–	–	–	–
Ergasilus callophysus	2.5	0.05 ± 0.3	7.5	0.1 ± 0.5	1.05	1660.0	–	–	15.0	0.05 ± 1.3	–	–
Sebekia sp.	2.5	0.02 ± 0.1	2.5	0.02 ± 0.1	0.00	800.0	5.0	0.07 ± 0.3	–	–	–	–

Table 3. Body and diversity parameters between dry and rainy seasons for metazoan parasites of *Calophysus macropterus* of two basins from the State of Acre, in western Amazon (Brazil). *U* = Mann–Whitney test. *p*: Probability, Ranges between parentheses.

	Acre River				Iaco River			
Diversity indices	Rainy season (n = 40)	Dry season (n = 40)	*U*	*p*	Rainy season (n = 40)	Dry season (n = 40)	*U*	*p*
Length (cm)	25.9 ± 3.5 (22.5–44)	24.5 ± 3.7 (18.5–37)	1600.5	0.21	311.7 ± 132.5 (18–40)	277.5 ± 128.2 (20–38)	1260.5	0.45
Weight (g)	238.3 ± 46.6 (158–370)	243.9 ± 107.1 (127–689)	1366.0	0.72	28.8 ± 4.3 (90–750)	27.9 ± 4.3 (105–605)	1960.5	0.35
Species richness of parasites	1.77 ± 1.44 (0–7)	1.42 ± 1.11 (0–4)	1723.5	0.32	1.00 ± 0.96 (0–3)	2.25 ± 1.42 (0–6)	1228.0	0.002
Brillouin diversity index (*HB*)	0.43 ± 0.44 (0–1.32)	0.37 ± 0.40 (0–1.30)	1688.5	0.51	0.21 ± 0.29 (0–0.84)	0.55 ± 0.49 (0–1.69)	1940.5	0.002
Evenness (*E*)	0.17 ± 0.17 (0–0.51)	0.14 ± 0.15 (0–0.50)	1689.5	0.51	0.08 ± 0.11 (0–0.33)	0.21 ± 0.19 (0–0.66)	1299.0	0.002

observed between the component communities of *C. macropterus* in the Acre and Iaco rivers, with Bray-Curtis quantitative similarity of 42%. Despite *C. macropterus* is a migratory fish (Córdoba et al. 2000; Soares et al. 2011), the geographic distance between the Acre and Iaco rivers was not sufficient to determine a parasitic dissimilarity.

The results from this first study on parasite fauna in *C. macropterus* showed that there was similarity of the parasite communities between hosts in the Acre and Iaco rivers, which consisted of four species of monogeneans, four nematodes, two cestodes, one digenean, one crustacean and one pentastomid. However, the hosts in the Acre river showed predominance of *C. pinnai* and larvae of Anisakidae gen. sp.; while those in the Iaco river showed predominance of *M. amazonica* and Anisakidae gen. sp. In addition, in *C. macropterus* in both the Acre and the Iaco river, endoparasites predominated and most of them (71.4%) it was of adults. This indicates that this omnivorous pimelodid (Soares et al. 2011) is a definitive host for the nematodes *A. amazonicum, C. pinnai* and *P.* (*S.*) *inopinatus*; and for the cestodes *M. amazonica* and *R. piracatinga*, which are endoparasites that have different life cycles and transmission mechanisms.

Chambrier et al. (2015) reported that the definitive hosts of proteocephalids such as *M. amazonica* and *R. piracatinga* are species of Pimelodidae. Although the life cycle of *A. amazonicum* is unknown, the intermediate hosts of Philometridae are copepod species, which become infected after ingesting free-living larvae that are released in the water by pregnant females (Moravec and Buron 2013). The primary hosts of larvae of Anisakidae are microcrustaceans and fish-eating birds are the definitive hosts during the adult phase, while fish are usually paratenic or intermediate hosts (Moravec 2009; Moreira et al. 2009). The primary hosts of larvae of *Cucullanus* spp. are also microcrustaceans and fish-eating birds or fish are the definitive hosts during the adult phase (Moravec 1998; Moreira et al. 2009). Species of Chironomidae are intermediate hosts of *P.* (*S.*) *inopinatus* (Moreira et al. 2009), while *C. macropterus* was the definite host in the present study. Therefore, these results suggest that *C. macropterus* was feeding on intermediate or paratenic host fish of these endoparasites, which were found in the environments of the study area.

Most (almost 77%) of the infracommunities of parasites of *C. macropterus* in the Acre and Iaco rivers presented similar prevalence and abundance values. However, the prevalence of *C. pinnai* was higher in hosts in the Acre river, while the prevalence and abundance of *M. amazonica* were higher in hosts in the Iaco river, which is less impacted by human activities than is the Acre river (Pereira and Morais 2015; Duarte 2017; Negreiros et al. 2018). Parasites with complex life cycles may have prevalences and abundances that depend on populations of intermediate hosts in the environment (Marcogliese and Cone 1997; Gonçalves et al. 2016). These differences relating to these endoparasites in *C. macropterus*, from the two different locations studied, suggest that differences regarding the ingestion of intermediate hosts exist.

In addition, among the main determinants of parasite infection levels, host body size has also been reported to be a relevant factor (Marcogliese and Cone 1997; Neves et al. 2013; Yamada et al. 2017). Although the hosts in the Iaco river were larger than those from the Acre River, the abundance of metacercariae of Digenea, abundance of monogeneans and abundance of larvae of Anisakidae alone presented weak correlations with the host size. Therefore, differences in environmental quality seemed to be a determinant factor regarding the prevalence and abundance of parasites in the present study, as also reported by Negreiros et al. (2018) in relation to *P. blochii*, also in the Acre and Iaco rivers.

Since the rainy season strongly influences Amazonian ecosystems, it plays an important role in relation to the similarity and structure of communities and infracommunities of parasites (Neves et al. 2013; Tavares-Dias et al. 2014; Gonçalves et al. 2016; Carvalho and Tavares-Dias 2017; Negreiros et al. 2018), given that during the rainy season, there is greater hydrological connectivity between habitats. The similarity between component communities will therefore depend on the geographical proximity of host populations and on the possibility of exchange between populations (Yamada et al. 2017). Although the Acre and Iaco rivers are part of the same basin system and have similar limnological characteristics (Silva et al. 2008), infection by *A. amazonicum* in *C. macropterus* in the Acre river was more frequent during the rainy season. On the other hand, *D. pinirampi* only occurred during the dry season and *P.* (*S.*) *inopinatus* only occurred during the rainy season. However, in *C. macropterus* in the Iaco river, infection by Anisakidae was more frequent during the dry season, when infection by *D. luckyi, D. macropteri, D. pinirampi, A. unapi, P.* (*S.*) *inopinatus* and *E. callophysus* also occurred. Contrary to this, *R. piracatinga* only occurred during the rainy season. Because rainfall increases water flow in rivers in the Amazon region, this may have facilitated transportation and recruitment of free-living larval stages or intermediate hosts infected by *A. amazonicum, P.* (*S.*) *inopinatus* and *R. piracatinga*. In addition, since *C. macropterus* presents generalist feeding behaviour in both seasons (Soares et al. 2011), this facilitates ingestion of intermediate hosts that carry the infecting forms of these endoparasites during the rainy season. On the other hand, lower rainfall and consequent lower water flow usually reduce the water quality and the extent of Amazon river environments, thereby increasing fish aggregation (Neves et al. 2013; Tavares-Dias et al. 2014; Carvalho and Tavares-Dias 2017). This facilitates encounters between *C. macropterus* and the ectoparasite species *D. luckyi, D. macropteri, D. pinirampi, A. unapi* and *E. callophysus*.

In conclusion, approximately half of the parasite species found in *C. macropterus* in the Acre and Iaco rivers were previously described infecting this host in various other locations in South America. However, *D. luckyi, D. pinirampi, C. pinnai*, larvae of Anisakidae gen. sp., metacercariae of diplostomulum type and *Sebekia* sp. are new records for *C. macropterus*. The present study also expands the geographical range of the 13 parasites that were found, into the western Amazon region, in Brazil. The results from the present study do not corroborate the hypothesis that there would be a difference in the structure of metazoan parasite communities in *C. macropterus* between the Acre and Iaco rivers. In addition, these results based on a two-year sampling timescale indicated that behaviours differed between locations and between seasons, regarding diversity and some infracommunities of parasites. This suggests that factors other than location and seasonality are influencing these parameters. Lastly, the influence of the rainy and dry seasons on the structure of communities and infracommunities of parasites was less strong than expected.

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