

ORIGINAL ARTICLE

Diversity of ectoparasites and endoparasites infecting *Brachyplatystoma vaillantii* (Siluriformes: Pimelodidae), a large migratory catfish from the Amazon

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Brachyplatystoma vaillantii is a large migratory catfish widely distributed in the Amazon basin, but its parasitic fauna is still poorly known. As it is an important fishery resource in the region of the Amazonas River estuary, the aim of this study was to investigate the parasite community in *B. vaillantii* from a tributary of the Amazonas River estuary system, in Brazil. We examined 31 juvenile fish, of which 80.6% were parasitized, and a total of 586 parasites were collected. We identified *Dermidospermus brachyplatystimae* and *Dermidospermus araguensis* (Monogenea), *Genarchella genarchella* (Digenea), *Harriscolex piramutab* (Cestoda), *Pseudoterranova* sp. (Nematoda), *Ergasilus xinguensis* (Crustacea) and mites (Acarina). The dominance was of *Pseudoterranova* sp. larvae. The parasite community of *B. vaillantii* was composed of low values of species richness (2.0 ± 1.4), evenness (0.18 ± 0.21) and diversity (0.32 ± 0.37), with predominance of ectoparasite species with low prevalence, low abundance and overdispersion. Host body weight was the main correlate of parasite diversity and abundance, and a diet rich in crustaceans and other invertebrates may be important in structuring the parasite community of *B. vaillantii*. This is the first report of *Dermidospermus brachyplatystimae* and *D. araguensis*, *Pseudoterranova* sp. and *G. genarchella* for *B. vaillantii*.

KEYWORDS: fish, parasites, Laulao catfish, helminths, crustaceans, mites

Diversidade de ectoparasitos e endoparasitos infestando *Brachyplatystoma vaillantii* (Siluriformes: Pimelodidae), um grande bagre migratório da Amazônia

RESUMO

Brachyplatystoma vaillantii é um grande bagre migratório amplamente distribuído na bacia Amazônica, mas sua fauna parasitária ainda é pouco conhecida. Por ser um importante recurso pesqueiro na região do estuário do Rio Amazonas, o objetivo deste estudo foi investigar a comunidade parasitária em *B. vaillantii* de um afluente do sistema estuarino do Rio Amazonas, no Brasil. Foram examinados 31 peixes juvenis, dos quais 80,6% estavam parasitados, e um total de 586 parasitos foram coletados. Foram identificados *Dermidospermus brachyplatystimae* e *Dermidospermus araguensis* (Monogenea), *Genarchella genarchella* (Digenea), *Harriscolex piramutab* (Cestoda), *Pseudoterranova* sp. (Nematoda), *Ergasilus xinguensis* (Crustacea) e ácaros (Acarina). A dominância foi de larvas de *Pseudoterranova* sp. A comunidade parasitária de *B. vaillantii* foi composta por baixos valores de riqueza de espécies ($2,0 \pm 1,4$), equitabilidade ($0,18 \pm 0,21$) e diversidade ($0,32 \pm 0,37$), com predominância de espécies de ectoparasitos com baixa prevalência, baixa abundância e dispersão agregada. O peso corporal do hospedeiro foi o principal correlato da diversidade e abundância de parasitos, e uma dieta rica em crustáceos e outros invertebrados podem ser importante na estruturação da comunidade parasitária de *B. vaillantii*. Este foi o primeiro relato de *D. brachyplatystimae*, *D. araguensis*, *Pseudoterranova* sp. e *G. genarchella* para *B. vaillantii*.

PALAVRAS-CHAVE: ácaros, crustáceos, helmintos, parasitos, peixe, piramutaba**INTRODUCTION**

Brachyplatystoma vaillantii Valenciennes, 1840 (Siluriformes), is a Pimelodidae fish native to northern South America, known as piramutaba or laulao catfish, which is an important fishing resource in the region of the Amazonian estuary. It is one of

the large migratory catfishes with wide distribution in the Amazonas and Orinoco river basins, as well as river basins from the Guianas (Soares *et al.* 2011; Froese and Pauly 2019). This benthic species inhabits the channel of the Amazon River and its major tributaries. The young consume crustaceans (mainly prawns) and insects, and the adults are piscivorous

CITE AS: Brito-Junior, I.A.; Tavares-Dias, M. 2021. Diversity of ectoparasites and endoparasites infecting *Brachyplatystoma vaillantii* (Siluriformes: Pimelodidae), a large migratory catfish from the Amazon. *Acta Amazonica* 51: 122-128.

and can reach up to 1.5 m in total length and weigh 10 kg. It performs annual migrations between its feeding grounds in the Amazonas River estuary and its reproduction grounds near the Brazil-Peru-Colombia border region. Females reach sexual maturity with 42 cm of length and, after spawning, larvae and juveniles drift until reaching the Amazonas estuary, which is the main growth environment for this fish. *Brachyplatystoma vaillantii* is heavily exploited by the artisanal and industrial fishery at the mouth of the Amazonas River (Soares *et al.* 2011; Barthem *et al.* 2015; Jimenez *et al.* 2017; Froese and Pauly 2019).

Despite the wide distribution of *B. vaillantii* in the Amazonas basin, there are only a few studies on its parasites, mostly on taxonomy. Studies on community aspects of its parasite fauna, however, are lacking, despite their interest related to the complexity of the life history and distribution of this fish. Studies on the diversity of fish parasites are important due to the role of parasites as indicators of environmental quality and ecosystem health, which are useful tools in the conservation and maintenance of local biodiversity (Cardoso *et al.* 2017; Oliveira *et al.* 2017; Leite *et al.* 2018). Parasites can change the composition and structure of the host community due to alterations in the environment that influence the functioning and stability of the ecosystems (Vasconcelos and Tavares-Dias 2016; Santos and Tavares-Dias 2017; Cardoso *et al.* 2017). Changes caused by parasites can lead to negative impacts on fishery production due to losses in quality and quantity of fish, reduction in body weight and injuries, which can result in the disposal of part of the catch (Cardoso *et al.* 2017) and reduce the potential economic benefits that fisheries may generate.

Reported parasites for *B. vaillantii* from the Brazilian Amazon are the cestodes *Pterobotrium crassicole* Diesing, 1850; *Goezeella siluri* Fuhrmann, 1916; *Amazotaenia yvettae* Chambrier, 2001; *Amphoteromorphus ninoi* Carfora, Chambrier & Vaucher, 2003; *Harriscolex piramutab* (Woodland, 1933) Chambrier, Kuchta & Scholz, 2015; *Nomimoscolex suspectus* Zehnder, Chambrier, Vaucher & Mariaux, 2000, and the coccidian *Calyptospora* sp. (Rego 1984; Silva *et al.* 2012; Alves *et al.* 2017a,b). In the Peruvian Amazon, *B. vaillantii* was found to be infected with the cestodes *Chambriella* sp. and *H. piramutab*, and monogeneans of the genus *Demidospermus* (Mendoza-Palmero *et al.* 2015; Chambrier *et al.* 2015). In Venezuela, the infection of *B. vaillantii* by *G. siluri* and *Harriscolex kaparari* (Woodland, 1935) Rego, 1987 (Alves *et al.* 2017a,b) was reported. To date, there has been no study reporting quantitative and qualitative descriptors of the parasite community in a wild *B. vaillantii* population. Therefore, the aim of this study was to describe the communities of ecto and endoparasites of *B. vaillantii* from a tributary of the Amazonas River estuary system, in the northern Brazilian, state of Amapá Region.

MATERIAL AND METHODS

Study area and fish collection

Between November and December 2017, 31 specimens of *B. vaillantii* juveniles (152.5 ± 76.7 g and 21.5 ± 3.7 cm total length) were collected in the Igarapé Fortaleza River basin, in the municipality of Macapá, Amapá state, northern Brazil (Figure 1) for parasitological analyses. The fish were captured using gill nets with mesh sizes from 30 to 70 mm. This study was approved by the ethics committee in the use of animal of Embrapa Amapá (Protocol No 004/2016 CEUA/Embrapa Amapá) and authorized by SISBIO license # 23276-1 issued by Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA).

The Igarapé Fortaleza hydrographic basin (Figure 1) has an area of 195 km² which drains from the north into the estuary system of the Amazon River (Takiyama *et al.* 2004, Silva *et al.* 2009). It is a river system with extensive floodplains and is influenced by high rainfall and the daily tides of the Amazon River. During the rainy season, the waters are rich in nutrients due to the fast decomposition of plant and animal remains and the layer of forest humus from the inundated floodplain forests, leading to the increase of vegetation and invertebrate biomass (insects, crustaceans and mollusks), which are used as food by fish (Takiyama *et al.* 2004). The margins of the floodplain are vegetated by species of diverse vegetation species, along with macrophytes of Cabombaceae, Lentibulariaceae, Salviniaceae and Cyperaceae (Thomaz *et al.* 2004). The area of the basin is under pressure from urban land occupation and buffalo ranching, associated with deforestation, burning of vegetation and solid waste dumping. The pH of the water varies from 5.5 to 7.5 and the oxygen levels from 2.5 to 6.0 mg/L, depending on the area of the basin and the season (Takiyama *et al.* 2004).

Collection and analysis of parasites

The collected fish were weighed (g) and measured in total length (cm) and necropsied for parasitological analysis. We examined the mouth, opercula, gills, viscera and gastrointestinal tract of each fish. Gills were removed for collection of ectoparasites, and the gastrointestinal tract and viscera were removed and examined for endoparasites under a stereomicroscope (Zeiss). The collection, fixation, preservation, counting and staining of the parasites for identification followed Eiras *et al.* (2006). The identification of parasites was according to Moravec (1998) and Thatcher (2006). Voucher specimens were deposited at Instituto de Pesquisas Científicas e Tecnológicas do Estado do Amapá (IEPA), Macapá, Amapá, Brazil, in the Scientific Collection Curation Office for the Fauna of Amapá, under accession number IEPA 160-165P.

We calculated the ecological indices (prevalence, mean intensity and mean abundance) following Bush *et al.* (1997). We used the Diversity software (Pisces Conservation

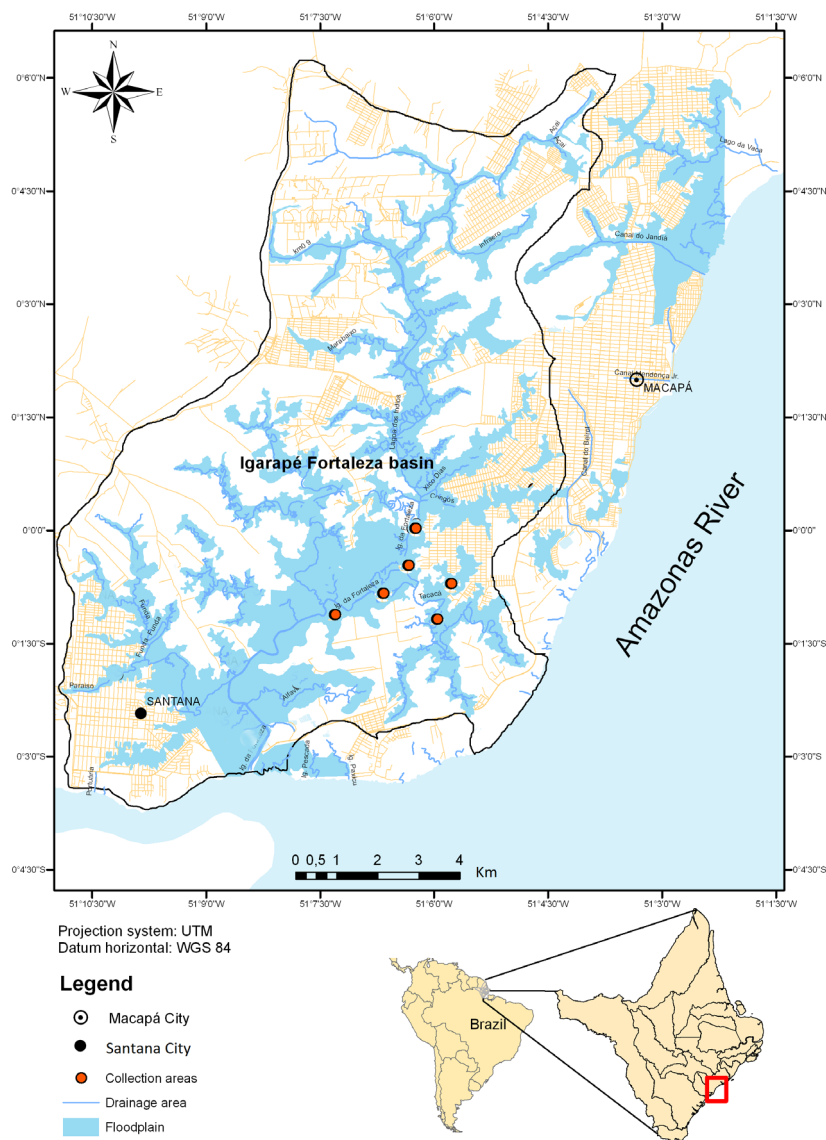


Figure 1. Collection sites of *Brachyplatystoma vaillantii* in the Igarapé Fortaleza river basin, a tributary of the Amazonas River estuary system, in Brazil. This figure is in color in the electronic version.

Ltd., UK) to calculate the following descriptors for the parasite component community: species richness of parasites, the Brillouin diversity index (HB), evenness (E) in association with the diversity index, and the dominance frequency (percentage of the infracommunities in which a parasite species is numerically dominant) (Rohde *et al.* 1995; Magurran 2004). In order to detect the distribution pattern of the parasite infracommunities (Rózsa *et al.* 2000), the index of dispersion (ID) and the Poulin discrepancy index (D) were calculated for species with prevalence >10 % using the Quantitative Parasitology 3.0 software. The ID significance for each infracommunity was tested using the d -statistics (Ludwig and Reynolds 1988). The correlation of parasite abundance with the length and weight of hosts, as well as with species

richness and the Brillouin diversity index was analyzed using the Spearman correlation coefficient (Zar 2010).

RESULTS

Overall, 80.6% of the 31 fish were parasitized. Parasites belonged to two species of Monogenea, one Digenea, one Nematoda, one Cestoda, one Crustacea and one unidentified species of Acarina (Table 1). A total of 586 individual parasites were collected, of which 71.4% were ectoparasites, and 28.6% endoparasites, thus the component community was dominated by ectoparasites, that were characterized by low prevalence, low abundance and overdispersion (Tables 1; Table 2). The monogeneans were identified to genus level (*Dermidospermus*) by standard stereomicroscopic examination,

and a partial microscopic examination of the sample revealed the presence of *Dermidospermus brachyplatystimae* Cepeda & Luque, 2016 and *Dermidospermus araguensis* Cepeda & Luque. As not all individuals were identified to species level, we used the pooled sample of *Dermidospermus* sp. for analysis and parameter calculation. The dominant species was *Pseudoterranova* sp. (Nematoda) and all individuals were larvae (Table 1). The parasites presented an aggregate dispersion, except for *Ergasilus xinguensis* Taborda, Paschoal & Luque, 2016 (Crustacea), which showed random dispersion (Table 2). There was a predominance of hosts with one and three species of parasites (Figure 2).

The species richness of parasites per host was 2.0 ± 1.4 (0-5), the Brillouin diversity index was 0.32 ± 0.37 (0 - 1.21) and the evenness was 0.18 ± 0.21 (0 - 0.68). The Brillouin index showed no correlation with the length of hosts ($r_s = 0.31$, $p = 0.09$, $n = 31$), while species richness showed a weak positive correlation with host length ($r_s = 0.38$, $p = 0.03$, $n =$

31). Host weight was positively correlated with the Brillouin diversity ($r_s = 0.43$, $p = 0.01$, $n = 31$) and the species richness of parasites ($r_s = 0.50$, $p = 0.004$, $n = 31$).

The abundance of *Dermidospermus* spp. was positively correlated with the length of hosts ($r_s = 0.43$, $p = 0.02$, $n = 31$). There was no correlation between the length of hosts and the abundance of the crustacean *E. xinguensis* ($r_s = 0.27$, $p = 0.14$, $n = 31$), the digenean *Genarchella genarchella* Travassos, Artigas & Pereira, 1928 ($r_s = 0.20$, $p = 0.27$, $n = 31$) and the nematode *Pseudoterranova* sp. ($r_s = -0.18$, $p = 0.32$, $n = 31$). The abundance of *Dermidospermus* spp. also presented a positive correlation ($r_s = 0.59$, $p = 0.0005$, $n = 31$) with the weight of hosts, while the abundance of *E. xinguensis* was weakly positively correlated with host weight ($r_s = 0.36$, $p = 0.04$, $n = 31$). The abundance of *G. genarchella* ($r_s = 0.18$, $p = 0.31$, $n = 31$) and of *Pseudoterranova* sp. ($r_s = -0.19$, $p = 0.31$, $n = 31$) presented no correlation with the length of hosts.

Table 1. Parasites of *Brachyplatystoma vaillantii* (n = 31) from the Igarapé Fortaleza basin, on the northern margin of the Amazonas River estuary system, in Brazil. P = prevalence; MI = mean intensity; MA = mean abundance; FD = frequency of dominance; TNP = total number of parasites. Values for MA are the mean followed by the standard deviation.

Parasites	P (%)	MI	MA	Range	TNP	FD (%)	Infection site
Monogenea							
<i>Dermidospermus</i> spp.*	48.4	4.8	2.3 ± 3.4	1-11	72	12.0	Gills
Digenea							
<i>Genarchella genarchella</i> (metacercariae)	16.1	3.2	0.5 ± 1.6	1-8	16	3.0	Gills
Nematoda							
<i>Pseudoterranova</i> sp. (larvae)	54.8	27.2	14.9 ± 24.0	1-78	462	79.0	Intestine
Cestoda							
<i>Harriscolex piramutab</i> (larvae)	9.7	2.3	0.2 ± 0.9	1-78	7	1.0	Intestine
Crustacea							
<i>Ergasilus xinguensis</i>	38.7	2.3	0.8 ± 1.5	1-7	27	5.0	Gills
Acarina							
Acarina gen. sp.	3.2	1.0	0.03 ± 0.18	1-1	1	0.2	Gills

* The sample includes *Dermidospermus brachyplatystimae* and *D. araguensis*

Table 2. Dispersion index (ID), d-statistics and discrepancy index (D) for the parasites in *Brachyplatystoma vaillantii* (n = 31) from the Igarapé Fortaleza basin, on the northern margin of the Amazonas River estuary system, in Brazil.

Species	ID	d	D	Dispersion type
<i>Dermidospermus</i> spp.*	2.065	3.32	0.631	Aggregated
<i>Genarchella genarchella</i> **	1.881	2.81	0.847	Aggregated
<i>Pseudoterranova</i> sp.	2.425	4.25	0.601	Aggregated
<i>Ergasilus xinguensis</i>	1.416	1.41	0.676	Random

* The sample includes *Dermidospermus brachyplatystimae* and *D. araguensis*
** metacercariae

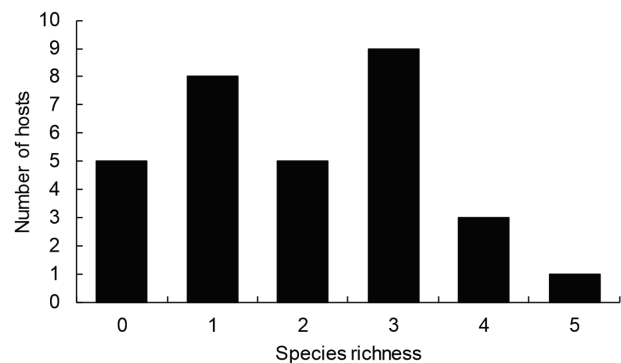


Figure 2. Species richness of parasites found in 31 individuals of *Brachyplatystoma vaillantii* (Pimelodidae) in the Igarapé Fortaleza river basin, a tributary of the Amazonas River estuary system, in Brazil.

DISCUSSION

In wild populations of fish, species richness of parasites is considered a reflection of the number of host species present in the environment and the local capacity for transmission and infection of intermediate and definitive hosts (Bellay *et al.* 2013; Santos and Tavares-Dias 2017; Oliveira *et al.* 2017; Cardoso *et al.* 2017). Abundance and diversity of invertebrates that act as intermediate hosts to parasites are key components in the composition of endoparasite communities in wild fish populations (Luque *et al.* 2013; Bellay *et al.* 2013; Cardoso *et al.* 2017; Santos and Tavares-Dias 2017; Oliveira *et al.* 2017). The *B. vaillantii* of Igarapé Fortaleza examined in this study had low parasite species richness and diversity for ecto and endoparasites, probably due to the low availability of invertebrates that act as intermediate hosts for the endoparasites. All diversity indices and evenness had low values, indicating an uneven distribution of parasite species diversity across the host sample and specific species dominance in abundance (*Pseudoterranova* sp. in our sample). This is a common pattern in communities of fish parasites with a relatively low species diversity, but with low abundance (Cardoso *et al.* 2017; Oliveira *et al.* 2017; Santos and Tavares-Dias 2017; Leite *et al.* 2018).

The aggregated distribution pattern of parasites observed in *B. vaillantii* followed the same pattern reported for other freshwater host species (Guidelli *et al.* 2003; Vasconcelos and Tavares-Dias 2016; Cardoso *et al.* 2017; Oliveira *et al.* 2017; Santos and Tavares-Dias 2017; Leite *et al.* 2018). This pattern is related to random environmental variables, such as heterogeneity in host susceptibility to infections, direct reproduction of the parasite within the host and heterogeneity in the host ability to eliminate parasites by immunological response (Guidelli *et al.* 2003; Santos and Tavares-Dias 2017; Oliveira *et al.* 2017; Leite *et al.* 2018). The random distribution of *E. xinguensis* in *B. vaillantii* has also been reported for the congeneric *Ergasilus turucuyus* Malta & Varella, 1996 in *Acestorhynchus falcirostris* Cuvier, 1819 and for *Excorallana berbicensis* Boone, 1918 in *Serrasalmus gibbus* Castelnau, 1855 (Vasconcelos and Tavares-Dias 2016). The random dispersion pattern may be related to a reduced opportunity to colonize this host in the environment (Guidelli *et al.* 2003; Vasconcelos and Tavares-Dias 2016).

The parasite fauna of *B. vaillantii* consisted mainly of ectoparasites, particularly monogeneans. The lentic environment inhabited by the examined fishes favors dispersal and reproduction of ectoparasites with free-living stages during some phases of its direct life cycle (Santos and Tavares-Dias 2017; Leite *et al.* 2018). Monogeneans are helminths with a high host specificity when compared to other groups of helminths, occurring only on one host, or a few hosts that are phylogenetically very closely related. Hence, the structuring of their communities is related to both ecological and historical

constraints (Braga *et al.* 2014; Santos and Tavares-Dias 2017). *DermidospERMUS brachyplatystimae* and *D. araguensis*, both parasites of *Brachyplatystoma filamentosum* Lichtenstein, 1819 (Cepeda and Luque 2010) were also found in gills of *B. vaillantii*. This is the first report of *D. brachyplatystimae* and *D. araguensis* for *B. vaillantii*.

Young individuals of *B. vaillantii*, which composed our sample, consume crustaceans and insects (Soares *et al.* 2011; Barthem *et al.* 2015; Jimenez *et al.* 2017; Froese and Pauly 2019), the environment from Igarapé Fortaleza basin with diversity of several invertebrate species (Takiyama *et al.* 2004; Thomaz *et al.* 2004) play an important role by providing feeding grounds. At the same time, these factors increase the possibilities that this host population will acquire endoparasites, as *G. genarchella*, *Harriscolex piramutab* (Woodland, 1933) Chambrier, Kuchta & Scholz, 2015 and *Pseudoterranova* sp. Digeneans were found for the first time parasitizing the gills of *B. vaillantii* in this study. Digeneans are parasites with complex life cycle, generally involving two or three hosts (Martorelli 1989; Poulin and Cribb 2002; Cardoso *et al.* 2017). *Genarchella genarchella* normally has a snail as intermediate host and a fish as definitive host (Martorelli 1989; Poulin and Cribb 2002). The level of infection by metacercariae of *G. genarchella* in the gills of *B. vaillantii* was low when compared to *Triporthes rotundatus* Jardine, 1841 (Santos and Tavares-Dias 2017), which seem to be a paratenic host for this species of digenean.

This is the first report of *Pseudoterranova* sp. parasitizing *B. vaillantii*. This nematode, which can be a serious threat to human health, had a higher prevalence in *B. vaillantii* than that reported in *B. filamentosum* from the state of Pará, Brazil (Rodrigues *et al.* 2015). *Pseudoterranova* are nematodes that infect different marine and freshwater fish species (McClelland 2002; Hernández-Orts *et al.* 2013; Rodrigues *et al.* 2015). Marine *Pseudoterranova* species have invertebrates (e.g., polychaetes, decapods, copepods, mysids, isopods, etc.) as primary hosts, while fish species are secondary hosts and mammals are definitive hosts (McClelland 2002; Hernández-Orts *et al.* 2013). The life cycle of these endoparasites in freshwater fish is yet unknown but considering what is known of their life cycle in marine environments, the prevalence of *Pseudoterranova* sp. in *B. vaillantii* may be related to the benthonic habit of this fish, and the fact that crustaceans, mainly prawns, and insects (Soares *et al.* 2011; Barthem *et al.* 2015; Froese and Pauly 2019) are part of its juvenile diet.

South American catfishes, of the order Siluriformes, are definitive hosts of a vast diversity of Proteocephalidae Cestoda species (Alves *et al.* 2017a,b). Hence, Cestoda is the endohelminth taxon most known for infecting *B. vaillantii* (Rego 1984; Alves *et al.* 2017a,b). The prevalence of *H. piramutab* in *B. vaillantii* was lower than that reported by Chambrier *et al.* (2015) for this same host from the Peruvian

Amazon, and the species also occurred in low mean abundance and intensity in our sample. Our study expands the occurrence of *H. piramutab* to the eastern Amazon.

Ergasilidae is one of the largest families of Cyclopoida, and most species are found on freshwater fish (Tavares-Dias *et al.* 2015). Only adult females of ergasilids are parasites on gills, fins, the interior nasal fossae, or embedded in host tissues or in the urinary bladder of teleost fish species, and rarely on the gills of elasmobranchs and bivalve mollusks (Taborda *et al.* 2016). *Ergasilus xinguensis* was described initially on the cichlids *Geophagus argyrostictus* Kullander, 1991 and *Geophagus altifrons* Heckel, 1840 from the western Amazon (Taborda *et al.* 2016). Its record, albeit at low infection levels, in gills of *B. vaillantii*, indicates that this crustacean ectoparasite has no host specificity.

Mites (Acarina) are usually found on the gills, integument and digestive tract of fish (Olmeda *et al.* 2011; Lizama *et al.* 2013). The habitat and behavior of fish do not contribute to mite infestation, and some authors consider mites to be unusual parasites of fish, whereas for others, mites are not fish parasites at all (Olmeda *et al.* 2011; Lizama *et al.* 2013). Under certain environmental conditions, however, mites may proliferate and colonize weak or stressed fish causing serious damage. Several genera of mites have been isolated from fish species in Europe, Australia, and North America, in some cases associated with high host mortality (Olmeda *et al.* 2011; Lizama *et al.* 2013).

Species richness of parasites and the abundance of *Dermidospermus* spp. in the gills increased with fish weight and length in our study, in agreement with the general pattern described for parasites in fish (Cardoso *et al.* 2017; Oliveira *et al.* 2017; Santos and Tavares-Dias 2017). In wild fish populations, body size is correlated with age, which has been considered a determinant of parasite abundance and species richness in fish, explaining in part the variation of parasitic infracommunities (Poulin 2001; Poulin 2004; Cardoso *et al.* 2017; Oliveira *et al.* 2017; Santos and Tavares-Dias 2017). Larger fish provide parasites with more diverse niches and larger colonization areas, allowing larger hosts to harbor a higher species richness and load of parasites (Poulin 2001; Poulin 2004; Oliveira *et al.* 2017), mainly ectoparasites such as monogeneans, as observed in this study.

CONCLUSIONS

This was the first study on parasite communities in *B. vaillantii* and revealed a low species richness and diversity of parasites in juvenile fish in a northern tributary of the Amazonas River estuary system. The parasite component community consisted predominantly of ectoparasite species with low prevalence, low abundance and overdispersion distribution. Species richness and diversity of parasites was more strongly correlated to host weight than to host length. Only the abundance of *Dermidospermus* spp. was strongly correlated with fish size. Our findings increase the knowledge on the parasite diversity in the Amazon system.

ACKNOWLEDGMENTS

The authors thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the productivity research grant awarded to M. Tavares-Dias (# 303013/2015-0). The authors also would like to thank Dr. Philippe Bisaggio Pereira of the Laboratory of Animal Parasitology at Universidade Federal de Mato Grosso do Sul (UFMS) for the identification of nematodes.

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RECEIVED: 29/03/2019

ACCEPTED: 02/10/2020

ASSOCIATE EDITOR: Linda Basson



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