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Diversity of parasites in wild *Astronotus ocellatus* (Perciformes, Cichlidae), an ornamental and food fish in Brazil

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ABSTRACT

The community composition of parasites was characterized in *Astronotus ocellatus* from a tributary of the Amazon River, northern Brazil. The prevalence was 87.9%, and a total of 526,052 parasites were collected, with a mean of 15,941 parasites per host. Nine taxa of ecto- and endo-parasites were identified, but *Ichthyophthirius multifiliis* was the dominant species, while *Piscinoodinium pillulare*, *Clinostomum marginatum* and *Argulus multicolor* were the least prevalent parasites. The parasite community was characterized by a low species richness, low diversity and low evenness. Host body size was not found to influence the composition of the parasite community, and there was no significant correlation between abundance of any parasite species and host body size. Papers published concerning the presence of parasites in this host in different hydrographic basins within Brazil indicate that 22 species of parasites are known to infect *A. ocellatus,* including species of ectoparasites and endoparasites. In Brazil, ectoparasites species, particularly crustaceans, have been found to parasitize *A. ocellatus* in relatively high numbers. This predominance of ectoparasites is typical of fish of lentic ecosystems. Finally, the presence of different endoparasites taxa suggest that *A. ocellatus* acts as an intermediate or definitive host.

Key words: aggregation, Amazon, ectoparasites, endoparasites, freshwater fish.

INTRODUCTION

Astronotus ocellatus Agassiz, 1831, commonly known as the Oscar, is a species of Cichlidae native to the Amazon River basin, including Brazil, Peru, Colombia and French Guyana (Soares et al. 2011, Tavares-Dias et al. 2014, Froese and Pauly 2017). This fish has also been introduced to some river basins in northeast and southern Brazil (Azevedo et al. 2007). The Oscar is of great economic interest, mainly for aquarium hobbyists and sport fishing, and is an important food item for riverine populations from the Amazon (Soares et al. 2011). It is popular as an ornamental fish due to its exotic coloration and natural reproduction in captivity, and as such it is cultured in countries around the world (Tavares-Dias et al. 2014).

Astronotus ocellatus is a benthopelagic cichlid that prefers lentic environments, finding protection under submerged branches and trunks. It is an omnivorous species, although its diet is heavily

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composed of fish, crustaceans, gastropods and larvae of aquatic insects, and its behavior includes ambush and capture of prey and avoiding predators by escaping over short distances (Azevedo et al. 2007, Soares et al. 2011, Tavares-Dias et al. 2014, Froese and Pauly 2017). In the Amazon region, spawning occurs between the onset of river flooding in the rainy season (December) and the beginning of the dry season, and first gonadal maturation occurs at a length of 25 cm, when the fish is between 15 and 24 months old (Soares et al. 2011).

Over 400 helminth species are known from cichlids, an underestimation of the actual diversity, with substantial differences in species richness between different continents and parasite taxa. Parasitic diseases are important drivers of ecological interactions and evolution (Vanhove et al. 2016). Owing to the almost worldwide distribution of this species due to introductions, its occurrence in a wide variety of habitats, its omnivorous nature and its central position in the food web, *A. ocellatus* has been much used as a model in ecological parasitology studies in South America, and particularly in some hydrographic basins in Brazil (Azevedo et al. 2007, Neves et al. 2013, Tavares-Dias et al. 2014). However, these studies have not yet been reviewed and analysed to synthesize information on parasite diversity in *A. ocellatus*. The first of these studies was conducted by Malta (1982a), who reported the presence of *Dolops bidentata* Bouvier, 1899 and *Dolops geayi* Bouvier, 1897 in *A. ocellatus* in the Amazon-Solimões River.

Studies of the parasites of fish improve knowledge of parasite-host-environment interactions (Tavares-Dias et al. 2014, Morozińska-Gogol 2015, Cirtwill et al. 2016), and can help to indicate the feeding habits of host fish. Most host fish species have particular associated parasite communities living within or on their bodies during different life-cycle stages, with species-specific variations in prevalence and abundance. The hosts provide food and other specific resources for obligate or temporary parasites (Azevedo et al. 2007, Neves et al. 2013, Tavares-Dias et al. 2014). Consequently, host fish are entire habitats for parasites, attending to all of the parasites' needs. Factors influencing parasite richness and abundance at the individual host level form the basis of parasitic infection patterns (Losee et al. 2014, Morozińska-Gogol 2015, Cirtwill et al. 2016).

This study has two main aims: 1) to characterize the parasite community of *A. ocellatus* in a tributary of the Amazon River, and 2) to gather and analyze data on the diversity of parasites in wild populations of this host, and the parasite infracommunity and community structure, described in studies conducted in Brazil.

MATERIALS AND METHODS

STUDY AREA

The study was conducted in the Fortaleza Igarapé basin (Figure 1), a tributary of the Amazon River in the state of Amapá (Brazil). The study area is influenced by semi-diurnal tidal inundations, and by large seasonal variation in rainfall levels. The waters that periodically spread out across the floodplain are rich in nutrients, because of the rapid decomposition of grasses, animal remains and the humus layer of the forest. This leads to growth of new vegetation (Poaceae, Cyperaceae, Fabaceae, Onagraceae, Araceae, Asteraceae, Convolvulaceae and Lentibulariaceae) and a high biomass of invertebrates (insects, zooplanktonic crustaceans and mollusks), which are important food items for fish. The basin of the Fortaleza Igarapé is highly complex and its regulation is a process that affects the river-floodplain system, as well as fish movement and community structure. Moreover, this tributary is suffering strong impacts

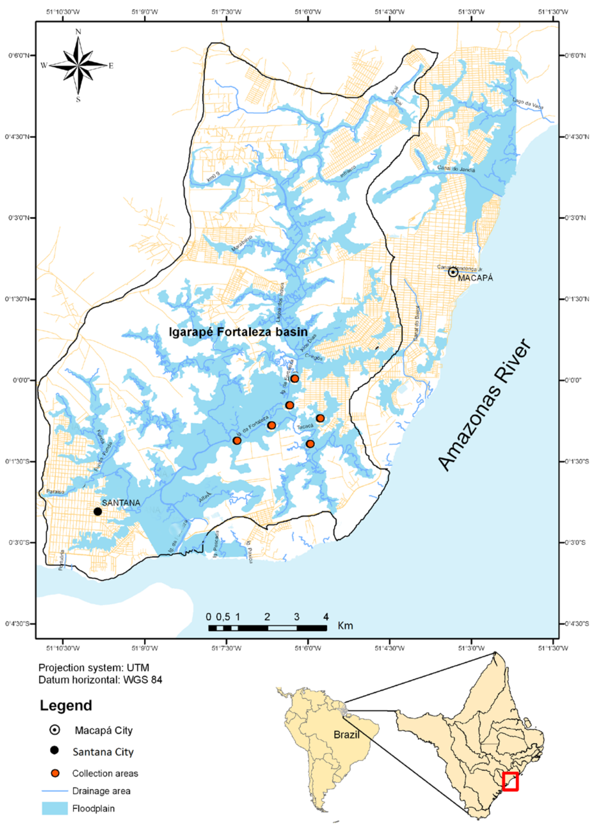

Figure 1 - Collection sites of *Astronotus ocellatus* from the Fortaleza Igarapé basin, in the eastern Amazon (Brazil).

of urbanization, principally in floodplain areas (Gama and Halboth 2004, Takiyama et al. 2012).

FISH COLLECTION

Between February and November 2013, 33 specimens of *A. ocellatus* were caught in gillnets of different mesh sizes (ICMBio authorization number: 23276-1), from the basin of the Fortaleza Igarapé. The fish were then transported to the Laboratory for Aquatic Organism Health at Embrapa Amapá in insulated boxes containing ice. This study was developed in accordance with the principles adopted by the Brazilian College of Animal Experimentation (COBEA) and with authorization from the Ethics Committee in the Use of Animals of Embrapa Amapá (# 004 - CEUA/CPAFAP) and ICMBio (# 23276-1).

PARASITE COLLECTION AND ANALYSIS

The fish specimens were weighed (g) and their total length was measured (cm). Each specimen was then evaluated macroscopically, observing the body surface, mouth, eyes, opercula and gills. The gills were removed to collect ectoparasites. The gastrointestinal tract and viscera was removed and examined in order to collect endoparasites. The parasite specimens were collected, fixed, quantified and stained for identification (Eiras et al. 2006).

The ecological terms used followed previous recommendations (Rohde et al. 1995, Bush et al. 1997). The Brillouin index (*HB*), evenness (*E*) and species richness (Magurran 2004) were calculated for each component of the parasite community, using the software Diversity (Pisces Conservation Ltd, UK). The dispersion index (ID) and discrepancy index (D) were calculated using the software Quantitative Parasitology 3.0, in order to detect the distribution pattern of the parasite infracommunities (Rózsa et al. 2000), for species with prevalence >10%. The significance of ID, for each infracommunity, was tested using the *d*-statistic (Ludwig and Reynolds 1988).

The body mass (Wt; g) and total length (Lt; cm) data were used to calculate the relative condition factor (Kn) of the host fish using the length-weight relationship ($W = aL^b$) after logarithmic transformation of length and weight and subsequent adjustment of two straight lines, thereby obtaining $\ln y = \ln A + B \ln x$ (Le Cren 1951). Spearman's coefficient (*rs*) was used to investigate the correlation between: i) host body length and parasite species richness, ii) *HB* and parasite abundance, and iii) host relative condition factor and parasite species richness (Zar 2010).

A review on the parasites of *A. ocellatus* in Brazil by searching databases (SciELO, ISI, Scopus, Science Direct and Google Scholar) was performed, and available data regarding the parasitic fauna were added to Table.

TABLE I
Parasite infracommunities of *Astronotus ocellatus* from Igarapé Fortaleza basin, in the eastern Amazon (Brazil). P: Prevalence; MA: Mean abundance; SI: Site of infection. MI: Mean intensity, FD: Frequency of dominance, TNP: Total number of parasites.

Parasite taxa	SI	P (%)	MI (Range)	MA ± SD	FD (%)	TNP
Ichthyophthirius multifiliis	Gills	51.5	30,614.4 (2646-148896)	15,771 ± 34,759.1	0.99	520,444
Piscinoodinium pillulare	Gills	3.0	3818 (0-3818)	115.7 ± 664.6	0.007	3818
Gussevia asota	Gills	57.7	56.5 (1-201)	32.5 ± 48.8	0.002	1073
Postodiplostomum sp. (metacercariae)	Gills	48.5	34.2 (1-150)	16.6 ± 30.6	0.001	547
Clinostomum marginatum (metacercariae)	Intestine	3.0	2.0 (0-2)	0.1 ± 0.3	-	2
Thometrema sp. (metacercariae and adults)	Intestine	9.1	33.3 (4-91)	3.0 ± 15.8	0.0002	100
Contracaecum sp. (larvae)	Intestine	24.2	1.9 (1-4)	0.5 ± 1.0	-	15
Proteocephalus gibsoni (larvae)	Intestine	33.3	4.7 (1-16)	1.6 ± 3.6	-	52
Argulus multicolor	Gills	3.0	1.0 (0-1)	0.03 ± 0.2	-	1

RESULTS

PARASITE COMMUNITY OF *A. ocellatus* IN THE FORTALEZA IGARAPÉ BASIN

Nine taxa of ecto- and endo-parasites were found in the 33 specimens of *A. ocellatus*, prevalence was 87.9% and a total of 526,052 parasites were collected. The mean number of parasites per fish was 15,941, with a strong predominance of ectoparasites (mean of 15,935.8 per fish, cf. mean of 2.1 endoparasites per fish). Species of Protozoa, Monogenoidea, Digenea, Cestoda, Nematoda and Crustacea were collected from host specimens. The dominant species was *Ichthyophthirius multifiliis* Fouquet 1876, followed by metacercariae (*Posthodiplostomum* sp.) and *Gussevia asota* Kritsky, Thatcher and Boeger 1989, while *Piscinoodinium pillulare* Schäperclaus, 1954, Lom 1981, *Clinostomum marginatum* Rudolphi, 1819 and *Argulus multicolor* Stekhoven, 1937 were the least prevalent parasites (Table I).

The parasite species of *A. ocellatus* presented an aggregated dispersion (Table II), which is a common distribution pattern for freshwater fish.

Brillouin diversity index varied from 0.0005-0.89, evenness from 0.0002-0.41 and parasite species richness varied from 1-6 parasites (Table III), but the predominance was of hosts infected by between 2 and 4 species (Figure 2). There was no significant correlation between host length and the Brillouin index ($rs = 0.11$, $p = 0.55$), or parasite species richness ($rs = 0.22$, $p = 0.22$). There was also no significant correlation between host relative condition factor and parasite species richness ($rs = 0.29$, $p = 0.09$).

The relative condition factor of the hosts varied from 0.93-1.06 (Table III), and there was no difference ($t = -0.02$, $p = 0.99$) in the standard value ($K = 1.00$). In *A. ocellatus*, the weight-length relationship of parasitized and non-parasitized fish showed negative allometric growth (Figure 3), which indicates a larger increase in body mass than length.

There was a weak correlation between the abundance of *Postodiplostomum* sp. and host weight and Kn, and between the abundance of *Contracaecum* sp. and host weight and length (Table IV).

TABLE II
Index of dispersion (ID), *d*-statistic and discrepancy index (D) for the parasite infracommunities of *Astronotus ocellatus* from the Fortaleza Igarapé basin, in the eastern Amazon (Brazil).

Parasite taxa	ID	*d*	D	Dispersion
Ichthyophthirius multifiliis	3.38	6.77	0.63	Aggregated
Gussevia asota	3.26	6.51	0.59	Aggregated
Postodiplostomum sp.	2.95	5.79	0.63	Aggregated
Contracaecum sp.	1.74	2.60	0.79	Aggregated
Proteocephalus gibsoni	2.33	4.26	0.74	Aggregated

TABLE III
Descriptors of diversity and body parameters for parasites communities of *Astronotus ocellatus* from the Fortaleza Igarapé basin, in the eastern Amazon (Brazil).

Mean indices	Mean ± SD (Range)
Length (cm)	20.7 ± 2.7 (13.3-25.0)
Weight (g)	207.6 ± 66.1 (59.4-330.0)
Condition factor (Kn)	0.99 ± 0.03 (0.93-1.06)
Species richness	2.3 ± 1.6 (1-6)
Brillouin (*HB*)	0.11 ± 0.22 (0.0005-0.89)
Evenness (*E*)	0.05 ± 0.10 (0.0002-0.41)

TABLE IV
Spearman's correlation coefficient (*rs*) for the abundance of parasites with the total length, body weight and relative condition factor (Kn) of *Astronotus ocellatus* from the Fortaleza Igarapé basin, in the eastern Amazon (Brazil).

	Length		Weight		Kn	
Parasites	*rs*	p	*rs*	p	*rs*	p
Ichthyophthirius multifiliis	0.10	0.57	0.15	0.39	0.08	0.63
Gussevia asota	-0.09	0.62	-0.003	0.98	0.16	0.37
Postodiplostomum sp.	0.19	0.28	0.39	**0.02**	0.44	**0.01**
Contracaecum sp.	0.35	**0.04**	0.38	**0.03**	0.14	0.44
Proteocephalus gibsoni	0.08	0.66	0.06	0.74	0.14	0.43

TABLE V
List of parasites in *Astronotus ocellatus* from different hydrographic basis in Brazil.

Parasite taxa	Locality of collection	References
Protozoa		
Ichthyophthirius multifiliis Fouquet, 1866	Pracuúba Lake (AP)	Neves et al. (2013)
Piscinoodinium pillulare Schaperclaus, 1954	Pracuúba Lake (AP)	Neves et al. (2013)
Trichodina sp.	Pracuúba Lake (AP)	Neves et al. (2013)
Monogenoidea		
Gussevia asota Kritsky, Thatcher and Boeger, 1989	Janauacá Lake (AM)	Kritsky et al. (1989)
	Guandu River (RJ)	Azevedo et al. (2007, 2010, 2011), Abdallah et al. (2008)
	Pracuúba Lake (AP)	Neves et al. (2013)
Gussevia astronoti Kritsky, Thatcher and Boeger, 1989	Janauacá Lake (AM)	Kritsky et al. (1989)

TABLE V (continuation)

Parasite taxa	Locality of collection	References
	Guandu River	Azevedo et al. (2007, 2011), Abdallah et al. (2008)
	Pracuúba (AP)	Neves et al. (2013)
Gussevia rogersi Kritsky, Thatcher and Boeger, 1989	Solimões River (AM)	Kritsky et al. (1989)
	Pracuúba (AP)	Neves et al. (2013)
Nematoda		
Contracaecum sp. larvae	Guandu River (RJ)	Azevedo et al. (2007, 2010, 2011)
	Pracuúba (AP)	Neves et al. (2013)
	Coari Grande River (AM)	Tavares-Dias et al. (2014)
Procamallanus (*Spirocamallanus*) *inopinatus* Travassos, Artigas and Pereira, 1928	Coari Grande River (AM)	Tavares-Dias et al. (2014)
Digenea		
Posthodiplostomum sp.	Pracuúba Lake (AP)	Neves et al. (2013)
	Coari Grande River (AM)	Tavares-Dias et al. (2014)
Herpetodiplostomum sp.	Pracuúba Lake (AP)	Neves et al. (2013)
Acanthocephala		
Polimorphus sp.	Guandu River (RJ)	Azevedo et al. (2007, 2010, 2011)
Cestoda		
*Proteocephalus gibson*i Rego and Pavanelli, 1990	Amazon River (AM)	Rego and Pavanelli (1990)
Crustacea		
Dolops bidentata Bouvier, 1899	Solimões River (AM)	Malta (1982a, 1984)
Dolops geayi Bouvier, 1897	Solimões River (AM)	Malta (1982b, 1984)
Dolops discoidalis Bouvier, 1899	Solimões River(AM)	Malta (1984)
Dolops nana Lemos de Castro, 1959	Pracuúba Lake (AP)	Neves et al. (2013)
Lamproglena monodi Capart, 1944	Guandu River (RJ)	Azevedo et al. (2007, 2010, 2011, 2012)
Argulus sp.	Solimões River (AM)	Malta (1984)
Hirudinea		
Placobdella sp.	Guandu River (RJ)	Azevedo et al. (2007, 2010, 2011)

PARASITE INFRACOMMUNITY STRUCTURE, ACROSS BRAZIL

The parasite fauna reported is composed by 2 species of Protozoa, 3 Monogenoidea, 2 Nematoda, 2 Digenea, 1 Acanthocephala, 1 Cestoda, 6 Crustacea and 1 Hirudinea (Table V).

DISCUSSION

The parasite community of *A. ocellatus* in the Fortaleza Igarapé basin was found to be composed of 9 parasites species: 2 species of protozoans, 1 monogenoidean, 3 digeneans, 1 nematode, 1 cestode and 1 crustacean, and presented an overdispersion distribution pattern, low species richness, low diversity and low evenness. *Ichthyophthirius multifiliis* was the dominant parasite. About 65% of the parasites found here are in common with previous records of the parasite community of this host species. However, the results of this study represent the first record of *A. multicolor*, *Thometrema* sp., C. *marginatum* and *P. gibsoni* as parasites of *A. ocellatus*. Species of protozoans, monogenoideans, nematodes, digeneans, acanthocephalans, cestodes,

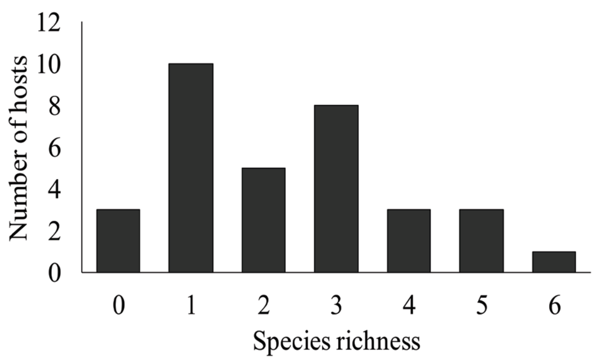

Figure 2 - Species richness of parasites in *Astronotus ocellatus* from the Fortaleza Igarapé basin, in eastern Amazon (Brazil).

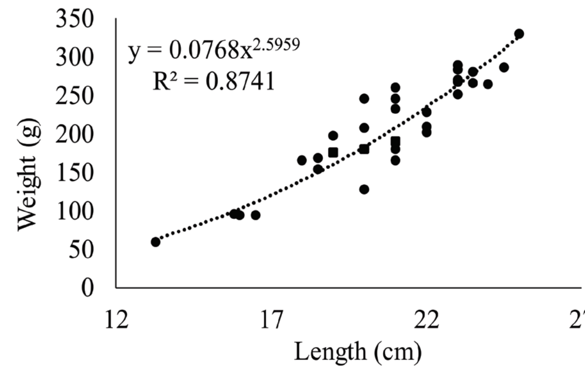

Figure 3 - Weight-length relationship for *Astronotus ocellatus* from the Fortaleza Igarapé basin, in the eastern Amazon (Brazil) parasitized (l) and non-parasitized (n).

crustaceans and hirudineans constitute the parasite community of wild *A. ocellatus* across Brazil, and the presence of these parasites differs between basins, due to geographic variation in abiotic and biotic environmental factors. Fish are the vertebrates that host the highest diversity of parasite species, as aquatic systems facilitate parasite reproduction, dispersion, survival and life history, and abundant host species like *A. ocellatus* usually tend to harbour a richer parasitofauna (Morozińska-Gogol 2015).

There are 22 parasite species known for *A. ocelaltus* in Brazil, and this is probably an underestimation of the actual diversity, due to differences in species richness of parasites for different hydrographic basins. Some composition and structural patterns were here detected in the parasite community of *A. ocellatus* in the different basins in Brazil, including: (a) dominance of *G. asota* and *Gussevia astronoti* Kritsky, Thatcher and Boeger 1989; (b) dominance of ectoparasite species with crustacean infracommunities more diverse than other ectoparasites; (c) overdispersion of ectoparasites and endoparasites, (d) interspecific associations in the ectoparasite infracommunities, specifically a combination of generalist and specialist parasites that should contribute to host population control (e.g. *G. asota*) and (f) correlation between parasites abundance and host total body size at the infracommunity level.

Structure and composition of the parasite community in individual hosts of any given fish population are made up of a set of parasite species available in the environment (Marcogliese et al. 2006, 2016, Losee et al. 2014), and are influenced by many local factors, including environmental and climatic conditions, intensity of food capture by the host, structure of the local food chain, availability of parasites in larval stages, and the presence of adequate intermediate hosts in the environment (Marcogliese et al. 2006, 2016, Losee et al. 2014, Cirtwill et al. 2016). Therefore, although endoparasites acquisition is strongly related to host diet, other factors that vary among different ecosystems also influence the relationship between parasite species richness, parasite load and host fish diet (Cirtwill et al. 2016).

Other ecological factors and attributes of the host population can also influence the abundance and diversity of parasites infecting fish at the individual level, including host age or size (Neves et al. 2013, Cirtwill et al. 2016). Here however, the correlation between *A. ocellatus* size and the abundance of larvae of *Postodiplostomum* sp. and *Contracaecum* sp., was only weakly positive. Fish are hosts to diverse ecto - and endoparasite species that can significantly affect their behavior, metabolism, fecundity, growth, survival and body condition. Studies on body condition or welfare generally use length and body mass relationships of hosts, assuming that heavier fish of a given length are in better condition (Guidelli et al. 2011, Losee et al. 2014, Lagrue and Poulin 2015). However, fish welfare is a complex concept and it can be approached from nutritional, biological and health perspectives. While high intensity or abundance of parasites can have pathological effects that reduce growth and condition of hosts (Guidelli et al. 2011), other results suggest that diversity of parasites, but not their overall intensity or abundance is related to fish growth and body condition (Losee et al. 2014). In this study, for *A. ocellatus* individuals infected with predominantly ectoparasites, body condition was not affected. Although, currently, our understanding on aspects of fish body condition is growing (see Guidelli et al. 2011, Losee et al. 2014, Lagrue and Poulin 2015), we still have a limited understanding of the consequences of parasite load on body condition of hosts. Indeed, a better understanding of these potential impacts on wild fish populations could help to mitigate economic losses in fisheries and encourage fish farmers to implement interventions that enhance the welfare of fish, increasing productivity and profits.

In this study, the *A. ocellatus* specimens collected from the Fortaleza Igarapé basin were mainly collected from the floodplains, which provide important feeding and nursery zones for this species. The floodplains are influenced by semidiurnal tidal inundations that carry organic matter from the Amazon River, and are being strongly affected by urban eutrophication (Gama and Halboth 2004, Taiyama et al. 2012) and invasion of *Oreochromis niloticus* (Bittencourt et al. 2014). In this population of *A. ocellatus* we found a predominance of ectoparasites such as *G. asota, I. multifiliis* and *Posthodiplostomum* sp. (but not *P. pillulare*). Infection levels by *Posthodiplostomum* sp., *G. asota* and *I. multifiliis* were similar to those reported by Neves et al. (2013) for *A. ocellatus* from Pracuúba Lake, another area that is strongly influenced by seasonal variation in Amazonian rainfall. Poor environmental conditions favor the dispersal and survival of some ectoparasite species with free-swimming stages in their life cycles (Dogiel 1961, Marcogliese et al. 2006, Neves et al. 2013). Parasites are frequent in wild populations, including in ornamental fish, and may cause economic losses to the aquarium and fishing industries. Thus, identifying which processes influence parasite distribution among host populations, and host susceptibility to infection, is a central question in parasite ecology (Losee et al. 2014, Morozińska-Gogol 2015, Cirtwill et al. 2016). Recently, Šmiga et al. (2016) described massive infection of *G. asota* in *A. ocellatus* in pet-shops and aquarium fish breeders in Slovakia, Europe. In addition, these authors reported that the fish presented visible asphyxia, neurological symptoms, uncoordinated locomotion and sudden death, and high mortality of juveniles.

In this study, infestation of *A. multicolor* on gills of *A. ocellatus* was low and sporadic accidental. Monogenoideans and *I. multifiliis* are common ectoparasites in freshwater fish and can infect species of all major fish groups worldwide (Dogiel 1961, Neves et al. 2013), but *I. multifiliis* is an opportunistic parasite (Dogiel 1961, Neves et al. 2013). *Gussevia* Kohn and Paperna, 1964 are Neotropical monogenoideans that include ectoparasites mainly of cichlid species (Abdallah et al. 2008). For *A. ocellatus*, *Gussevia asota*, *G. astronoti* and *G. rogersi* are common monogenoidean parasites; however, in the basin of the Fortaleza Igarapé we found only *G. asota*. Infection by these ectoparasites often gives an indication of the quality of the environment, as parasite abundance and diversity generally increase or decrease in more highly modified environments, such as the Fortaleza Igarapé basin. Therefore, environmental stress plays a major role in parasite abundance, and disease outbreaks may occur due to sudden environmental changes.

Endohelminth parasites have complex life cycles that are embedded within food webs, relying on consumption of infected prey by predators, in order to reach their next host. Consequently, richness and abundance of these trophically transmitted parasites can be largely explained by the diversity and number of different prey consumed, or intermediate hosts that are prey items within the diet of fish populations (Cirtwill et al. 2016). *Proteocephalus gibsoni*, a proteocephalid cestode of cichlid species (Rego and Pavanelli 1999, Chambrier et al. 2006), was found at moderate levels of infection in *A. ocellatus* in this study. However, *Goezia spinulosa* Diesing, 1839, an endoparasite of *Arapaima gigas* that infected *A. ocellatus* in fish farms has not been found in wild populations of this cichlid. Indeed, the infection of farmed *A. ocellatus* occurred because they were fed with plankton from ponds of *A. gigas* containing larvae of *G. spinulosa* (Freitas and Lent 1946). Therefore, such results indicate the complex life cycle of this nematode species, as well as its low host specificity. The trematodes of freshwater fish from Brazil have been studied for almost a century. Larval stages (metacercariae) of trematodes are most commonly associated with intermediate hosts. However, life cycle stages of digenean species are generally little-known, limiting knowledge on trematodes infecting fish. The most well documented metacercariae in South American fish belong mainly to the families Diplostomidae, Heterophyidae and Echinostomatidae, which in general use fish-eating birds and aquatic mammals as definitive hosts (Choudhury et al. 2016). In this study, metacercariae of *Posthodiplostomum* sp. were found on the gills, and of *C. marginatum* in the intestine of *A. ocellatus*. However, these 2 larval digeneans did not exhibit similar prevalence and abundance, probably because of differences in specificity of primary intermediate hosts and asexual reproduction, although both parasites use fish-eating birds as definitive hosts (Ritossa et al. 2013, Pinto et al. 2015). This is the first report of *C. marginatum* for *A. ocellatus*.

Studies on digenean parasites of South American fish have recorded the presence of *Thometrema overstreeti* Brooks, Mayes and Thorson, 1979 and *Thometrema magnificum* Szidat, 1954, Gibson and Bray, 1979, *Thometrema bonariense* Lunaschi, 1989 in characid, erythrinid, pimelod and loricariid fish (Kohn et al. 2007). Furthermore, recently, Rassier et al. (2015) found *T. overstreeti* infecting the cichlid *Geophagus brasiliensis* in an estuary in the state of Rio Grande do Sul (Brazil). In North America *Thometrema lotzi* Curran, Overstreet and Font, 2002 was described infecting centrarchid fish of freshwater and brackish areas in coastal Mississippi and Louisiana, USA (Curran et al. 2002). *Thometrema lotzi* is the single species of a genus commonly found in various centrarchid species in the northern Gulf of Mexico drainages (Choudhury et al. 2016). However, this study reports *Thometrema* sp. as a parasite of *A. ocellatus* for the first time, and this is a new species of this derogenid.

CONCLUSIONS

The parasite community of *A. ocellatus* was characterized by a low species richness, low diversity and low evenness, with a predominance of ectoparasite species and presence of endohelminths in the larval stage, indicating that the diet of this fish includes mollusks and crustaceans. Furthermore, the low richness of endohelminths suggest that this host is occupying a low position in food web, serving as an intermediate and definitive host. The abundance of some parasite species was weakly correlated (correlation coefficient <50%) with host body size, while most species exhibited no correlation with host body size. Finally, the results of the reviewed papers published concerning the presence of parasites in *A. ocellatus* in different basins of Brazil indicate that, so far, 22 species of parasite, belonging to the Protozoa, Monogenoidea, Nematoda, Digenea, Acanthocephala, Cestoda, Crustacea and Hirudinea have been reported for this host. No correlation between parasite infection and fish mortality has been reported. Ectoparasites are by far more common than endoparasites, and Crustacea are the most commonly reported ectoparasites in studies of *A. ocellatus*. Differences observed among studies can be attributed to abiotic and biotic environmental factors resulting from the geographic separation of basins with occurrence of *A. ocellatus*.

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