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Parasites of native Cichlidae populations and invasive *Oreochromis niloticus* (Linnaeus, 1758) in tributary of Amazonas River (Brazil)

Parasitos de populações de Cichlidae nativos e invasora *Oreochromis niloticus* (Linnaeus, 1758) em tributário do Rio Amazonas (Brasil)

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Abstract

This study provides the first investigation on acquisition of parasites in invasive *O. niloticus* by parasite species of native Cichlidae from the Igarapé Fortaleza basin, Northern Brazil. There were examined 576 specimens of 16 species of native cichlids and invasive *O. niloticus* collected in the main channel and the floodplain area of this tributary of Amazon River. The invasive *O. niloticus* was poorly parasitized having only *Ichthyophthirius multifiliis*, *Trichodina centrostrigata*, *Paratrichodina africana*, *Trichodina nobilis* (Protozoa) and *Cichlidogyrus tilapiae* (Monogenoidea), and this host has not acquired any parasite species common to the native ichthyofauna region. In contrast, species of native cichlids showed rich fauna of parasites with predominance of Monogenoidea species, larvae and adults of Nematoda, Digenea, Cestoidea and Acanthocephala, besides four species of Protozoa and four Crustacea. However, only *T. nobilis* was acquired by native fish, the *Aequidens tetramerus*, which is a new host for this exotic Trichodinidae. In *O. niloticus*, well established in the region, the small number of helminth species may be associated with its rusticity, good adaptation in the new environment and also the presence of native parasites with relative specificity, but without ability to complete its life cycle in this invasive host of this ecosystem.

Keywords: Colonization, biological invasion, fish parasites.

Resumo

Este estudo é a primeira investigação da aquisição de parasitos na invasora *O. niloticus* por espécies de parasitos Cichlidae nativos da bacia Igarapé Fortaleza, Norte do Brasil. Foram examinados 576 espécimes pertencentes a 16 espécies de ciclídeos nativos e à invasora *O. niloticus* coletados no canal principal e área da planície de inundação deste tributário do Rio Amazonas. A invasora *O. niloticus* foi pobremente parasitada, pois teve somente *Ichthyophthirius multifiliis*, *Trichodina centrostrigata*, *Paratrichodina africana* e *Trichodina nobilis* (Protozoa) e *Cichlidogyrus tilapiae* (Monogenoidea) e não adquiriu qualquer espécie comum à ictiofauna nativa da região. Em contraste, as espécies de ciclídeos nativos apresentaram uma rica fauna de parasitos com predominância de espécies de helmintos Monogenoidea, larvas e adultos de Nematoda, Digenea, Cestoidea e Acanthocephala, além de quatro espécies de Protozoa e quatro Crustacea. Porém, somente *T. nobilis* foi encontrado em peixe nativo, *Aequidens tetramerus*, que é um novo hospedeiro para esse Trichodinidae exótico. Em *O. niloticus*, já bem estabelecida na região, o reduzido número de espécies de helmintos pode estar associado à sua rusticidade, boa adaptação ao novo ambiente e também à presença de parasitos nativos com relativa especificidade, mas sem habilidade em completar seu ciclo de vida nesse hospedeiro invasor desse ecossistema.

Palavras-chave: Colonização, invasão biológica, parasitos de peixes.

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Introduction

Biological invasions are occurring worldwide at alarming rates being widely recognized as threats to the integrity and functioning of natural ecosystems (GALLI et al., 2007; POULIN et al., 2011). Whenever a species in a given region is moved to another one, there is always the possibility that its parasites can be taken with it (MENDOZA-FRANCO et al., 2006; GALLI et al., 2007) forming a biotic unit called symbiota by Galli et al. (2005).

In Brazil, despite the introduction of *Oreochromis niloticus* for culture purposes for over 40 years, some studies on this exotic fish fauna in the natural environment were performed (RANZANI-PAIVA et al., 2005), but studies on the transmission of parasites to native ichthyofauna are still scarce (GRAÇA; MACHADO, 2007). However, when a non-native fish is introduced, the exchange of parasites between native and non-native hosts can be expected depending on many factors related to the host-parasite system.

In a new habitat, the establishment success of an exotic parasite species depends on the acceptable abiotic conditions and complexity of the parasites' life cycle (GALLI et al., 2005; RIBEIRO; LEUNDA, 2012). The transmission of exotic parasites depends, primarily, on biological factors, host-parasite interaction, congeniality of host species and parasite specificity (JIMÉNEZ-GARCÍA et al., 2001; GALLI et al., 2005; ROCHE et al., 2010; RIBEIRO; LEUNDA, 2012). Thus, the intensity and type of native parasites (ectoparasites and endoparasites) acquired vary among different invasive exotic hosts (PATERSON et al., 2012).

The consequences of acquiring new parasites are also difficult to predict, but severe illness may occur in native fish at the beginning, because they do not share a co-evolutionary history with new parasites (ROCHE et al., 2010; GENDRON et al., 2012) and may even suffer a dynamics change of their relationship with their native parasites (PATERSON et al., 2012). Invasive fish may lose parasites from their place of origin during translocation and, then its parasitic fauna may be dominated by native species of parasites common to the local ichthyofauna (ROCHE et al., 2010; PATERSON et al., 2012). In this case, they may represent a very important role in the life cycle of species of endohelminthic parasites (POULIN et al., 2011) depending on lifestyle and diet of invasive fish. The omnivorous feeding habit of *O. niloticus* favors the occurrence of endohelminthic species and indicates this fish as part of intermediate levels in the food web (GRAÇA; MACHADO, 2007). Regarding fish, one of the factors influencing the composition of parasites fauna is its origin in the area, that is, whether it is a native or exotic host.

The biological invasions can still cause a sudden increase in the incidence or severity diseases in previously existing native host, due to the pressure on these populations (GALLI et al., 2007; POULIN et al., 2011; GENDRON et al., 2012), when they change their behavior or their immunocompetence. However, when these impacts cause the extinction of essential hosts in the life cycle of a native parasite, the population of this area will decline considerably, thus, benefiting other native hosts of this parasite (POULIN et al., 2011). Nonetheless, these negative impacts on native populations are only detected late, due to the difficulty of quick perception of the transition of exotic parasites in the natural

aquatic environment. Therefore, since future consequences of invasion of exotic parasites are difficult to estimate (ROCHE et al., 2010), it is necessary to monitor the establishment of exotic parasites in order to identify species translocated from its area of origin and transmitted to local ichthyofauna. By doing this, it will be possible to understand and predict potential impacts caused to native ichthyofauna in invaded natural ecosystem.

In the State of Amapá, Northern Brazil, 18 years after the introduction of *O. niloticus* in several fish farms there were invasion and establishment of this fish in the Igarapé Fortaleza basin, an important tributary of the Amazon River. This invasion is causing strong pressure on the biomass of Cichlidae species of the local ichthyofauna, due to competition for food and occupation of breeding areas, shelter and feeding (BITTENCOURT person communication). However, it has not been investigated yet the impacts of introducing Nile tilapia on the fauna of parasites in native ichthyofauna of this natural ecosystem with important species of scientific and applied interest. However, the introduction of trichodinids *Paratrichodina africana* Kazubski & El-Tantawy, 1986 (PANTOJA et al., 2012) was reported recently for *O. niloticus* farmed in this same region of Brazil.

The aim of this study was to investigate the parasites of *O. niloticus* and species of native Cichlidae from the Igarapé Fortaleza basin (State of Amapá) and to identify whether there was transfer of parasites between such ecologically similar fish species inhabiting the same environment.

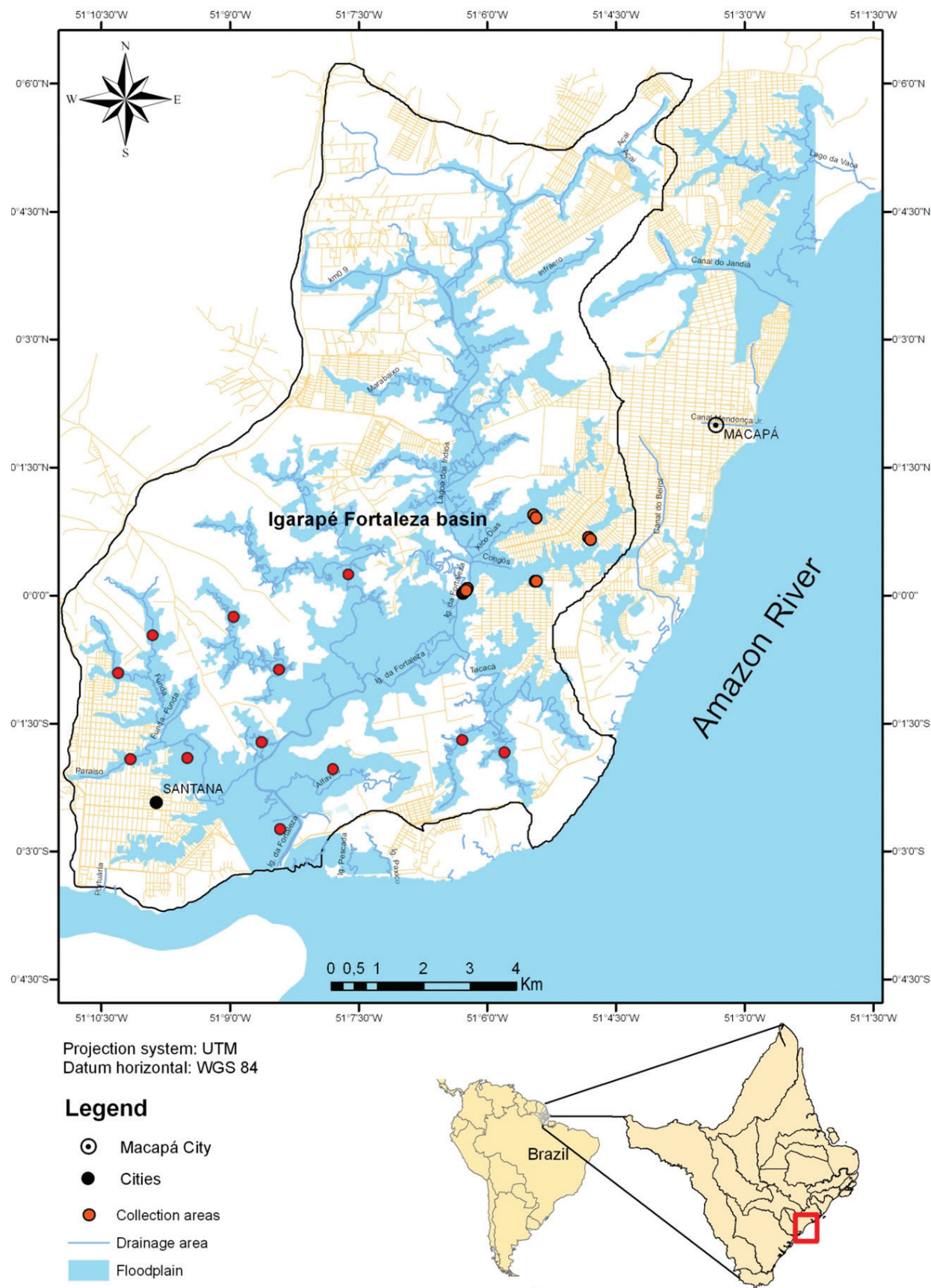
Materials and Methods

Characterization of the studied area

The Igarapé Fortaleza basin, in the State of Amapá, (Eastern Amazon), is composed by a main channel and the floodplain area (Figure 1). This basin is a tributary of the Amazon River, and then the main channel of the basin and Amazon River are both responsible for forming the floodplain area. This floodplain area is a fluvial physical system drained by freshwater and influenced by high rainfall and tides of the Amazon River (TAKYAMA et al., 2004). Several fish, including Cichlidae species are known throughout this basin (main channel and floodplain area), because the floodplain area form a propitious environment to the development of small and medium size fish species being important to subsistence fishing and aquarium. In the rainy season (December to June), waters spread over the plain, when favorable conditions lead to most fish to reproduce earlier in the season. This is the main period for feeding, growth and accumulation of energy reserves used to support the short food supply during the drainage season (GAMA; HALBOTH, 2004) from June to November.

Fish and sampling procedures

In the period from December 2009 to June 2011, in the main channel of the Igarapé Fortaleza and area under the floodplain action, specimens of *O. niloticus* and Cichlidae species were captured by using cast nets of 30 and 40 mm and gill nets of 20, 25 and 30 mm (ICMBio License: 23276-1). The caught fish were then



transported on ice to the Laboratory of Aquaculture and Fisheries of Embrapa Amapá, Macapá (AP) for parasitological analysis.

Parasitological analysis

For each caught fish, the mouth and gills were examined for ectoparasites, and gastrointestinal tract for collection of endoparasites. The techniques used for collection, fixation, conservation and staining of parasites were according to previous recommendations (AMATO et al., 1991; EIRAS et al., 2006). For Trichodinidae identification, gills smears were carried out, dried at room temperature and impregnated with silver nitrate using the Klein's method (VAN AS; BASSON, 1989) and other samples were stained with Giemsa (LOM, 1958). The parasitological terminology used throughout follows that described by Rohde et al. (1995) and Bush et al. (1997).

Physicochemical parameters

Water physicochemical analyses were performed in main channel of the Igarapé Fortaleza and the floodplain area during the mornings and certain pH (pH: YSI-100), dissolved oxygen levels and temperature (DO: 200-YSI) of water, ammonia and nitrite levels (HI93715-Hanna) by using digital devices for each purpose. In the main channel of the Igarapé Fortaleza, water temperature ranged from 27.8 to 28.5°C; pH 6.4 to 6.9; dissolved oxygen levels 1.5 to 2.4 mg/L; total ammonia levels 0.121 to 0.364 mg/L and nitrite 0.030 to 0.032 mg/L. In floodplain area, the water temperature ranged from 26.0 to 33°C; pH 6.2 to 7.5; dissolved oxygen levels from 0.5 to 4.7 mg/L; total ammonia levels from 0.243 to 0.486 mg/L and nitrite 0.010 to 0.098 mg/L.

Results

A total of 576 fish was collected in Igarapé Fortaleza basin, out of which 218 were *O. niloticus* and 358 were species of native cichlids occurring in higher number of species in the main channel of this basin compared to floodplain area (Table 1).

The fauna of parasites of *O. niloticus* was about seven times lower than of the 16 native cichlids species and it consists of monogenean species and protozoan ciliates. However, 79.0% of parasites were helminthes species in native cichlids; 10.5% were protozoans and the other 10.5% were species of ectoparasite crustaceans (Table 2). This reduced parasitic fauna in *O. niloticus* occurred exclusively in the gills (ectoparasites). In the native host, there was also high parasitism in the gills, but more than half of helminthes were parasites of the gastrointestinal tract, parasitizing the intestine, pyloric cecum and/or liver of hosts (Figure 2).

The richness of parasite species and infection levels have differed comparing fish (native and exotic) examined in the floodplain area and the main channel of Igarapé Fortaleza basin. In floodplain area, the dominance was of protozoan species due to the predominance of *O. niloticus* in this environment and with infection caused by *Ichthyophthirius multifiliis* Fouquet, 1876, *Paratrichodina africana*, *Trichodina nobilis* Chen, 1963 and *Trichodina centrostrigata* Basson, Van As & Paperna, 1983. However, in the main channel, where there is higher prevalence and diversity of native cichlids species, it was higher the level of infection and the richness of helminthes ecto- and endoparasites. These hosts native were parasitized by larval and adult forms of Nematoda, Digenea, Acanthocephala and Cestoidea, while in the hosts of floodplain area only a few Digenea and Nematoda species were found. However, in the gills and intestine of native hosts collected in both environments there were found metacercariae of Digenea in different stages of development. Ectoparasite crustaceans were also found only in

Table 1. Mean weight and total length of Cichlidae species captured at two sites of the Igarapé Fortaleza basin, Amapá State, eastern Amazon, Brazil.

Fish species	Main channel			Floodplain area		
	N	Weight (g)	Length (cm)	N	Weight (g)	Length (cm)
<i>Aequidens</i> sp.	4	71.0 ± 24.4	13.9 ± 1.5	3	37.7 ± 5.7	11.7 ± 0.7
<i>Aequidens tetramerus</i>	33	57.1 ± 18.2	13.5 ± 1.6	59	69.0 ± 27.5	14.5 ± 2.2
<i>Astronotus ocellatus</i>	13	212.0 ± 65.0	20.1 ± 2.6	4	236.3 ± 104.5	21.5 ± 4.8
<i>Chaetobranchius flavescens</i>	14	94.4 ± 62.6	17.0 ± 4.4	-	-	-
<i>Chaetobranchopsis orbicularis</i>	31	105.2 ± 43.9	16.6 ± 3.0	-	-	-
<i>Cichlassoma amazonarum</i>	6	34.6 ± 7.0	10.7 ± 1.0	54	49.2 ± 19.6	12.8 ± 2.2
<i>Cichlassoma bimaculatum</i>	8	59.0 ± 21.1	14.1 ± 2.9	-	-	-
<i>Geophagus brasiliensis</i>	01	76.0 ± 0.0	14.5 ± 0.0	-	-	-
<i>Heros efasciatus</i>	3	64.6 ± 43.9	12.1 ± 4.1	-	-	-
<i>Hypselecara temporalis</i>	1	56.0 ± 0.0	13.2 ± 0.0	-	-	-
<i>Laetacara curviceps</i>	17	55.4 ± 24.3	13.6 ± 2.0	3	18.5 ± 4.0	9.1 ± 1.2
<i>Mesonauta</i> sp.	2	34.0 ± 0.0	12.0 ± 0.5	29	54.6 ± 31.6	12.6 ± 2.2
<i>Mesonauta acora</i>	7	22.0 ± 7.3	10.0 ± 1.4	30	62.1 ± 18.7	13.6 ± 1.5
<i>Mesonauta guyanae</i>	9	19.3 ± 7.7	9.5 ± 2.1	-	-	-
<i>Oreochromis niloticus</i>	37	275.2 ± 51.5	23.2 ± 1.7	181	115.4 ± 77.5	17.2 ± 4.9
<i>Pterophyllum scalare</i>	7	11.1 ± 3.8	8.5 ± 1.1	-	-	-
<i>Satanoperca jurupari</i>	20	41.3 ± 32.8	12.0 ± 4.0	-	-	-

native cichlids of the main channel of this Amazonian ecosystem (Table 3, 4).

Most of the parasites were native species and only four parasites were exotic species (*Cichlidogyrus tilapiae* Paperna, 1960, *P. africana*, *T. nobilis* and *T. centrostrigata*) occurred in fish of this natural environment after 9-10 years of the invasion of *O. niloticus*. These

exotic parasites were found only in invasive *O. niloticus*, except *T. nobilis* that was also transferred to *Aequidens tetramerus* Heckel, 1840, a native cichlid species. Protozoans *Piscinoodinium pillulare* Schäperclaus, 1954 and *I. multifiliis* were also found mainly in natives fish, but both are ectoparasites of unknown origin in Brazil. However, only one native ciliated was found, *Tripartiella tetramerii*, a trichodinid of *A. tetramerus* (Tables 3, 4).

Table 2. Richness of parasite species by taxonomic groups in native host fish and the exotic host fish in the Igarapé Fortaleza basin, Amapá State, eastern Amazon, Brazil.

Taxon	Native Cichlidae	<i>O. niloticus</i>
Protozoa	4	4
Crustacea	4	0
Monogeneoidea	11	1
Nematoda	6	0
Digenea	7	0
Acanthocephala	4	0
Cestoidea	2	0
Total number of species	38	5

Discussion

In Brazil, more than 40 years after introducing *O. niloticus*, the parasitic fauna of this fish in fish farms consists primarily of species from its place of origin such as *P. africana* (Trichodinidae), *C. tilapiae*, *Cichlidogyrus aegypticus* Ergens, 1981, *Cichlidogyrus cirratus* Paperna, 1964, *Cichlidogyrus halli* Price & Kirk, 1967, *Cichlidogyrus thurstonae* Ergens, 1981, *Cichlidogyrus arthracanthus* Paperna, 1960, *Scutogyrus longicornis* Paperna & Thurston, 1969, *Gyrodactylus cichlidarum* Paperna, 1968 and *Enterogyrus cichlidarum* Paperna, 1963 (Monogeneoidea); besides *Trichodina compacta* Van As & Basson, 1989, *Trichodina magna* Van As & Basson, 1989 (Trichodinidae) and *Lamproglana monodi* Capart, 1944 (Copepoda), parasites originally described as species of cichlids from Africa, Taiwan and the Philippines, as well as *Clinostomum complanatum* Rudolphi, 1814, *Diplostomum* sp. (Digenea), *Argulus spinulosus* Silva, 1980 (Branchiura), *Dolops carvalhoi* Lemos de Castro, 1949 (Branchiura) and *Ergasilus* sp. (Copepoda) acquired from species of Brazilian ichthyofauna (PANTOJA et al., 2012).

In its place of origin, the Nile River delta (Egypt), *O. niloticus* has been parasitized by the following species of helminthes: *C. tilapiae*, *C. aegypticus*, *C. cirratus*, *C. halli*, *C. thurstonae*, *C. arthracanthus*, *S. longicornis*, *G. cichlidarum* and *E. cichlidarum*, *Paracamallanus cyathopharynx* Baylis, 1923 (Nematoda), *Orientocreadium batrochoides* Tubangul, 1931 (Digenea), *Polyonchobotrium* sp. (Cestoidea), *Acanthosentis tilapiae* Baylis, 1948 (Acanthocephala), *I. multifiliis*, *T. centrostrigata*, *T. rectinucinata* and *Chilodonella hexastica* Kiernik, 1909 (Ciliophora), *L. monodi*, *Ergasilus sarsi* Capart, 1944 (Copepoda) and *Lernaea cyprinacea* Linnaeus, 1758 (Copepoda) (EL-SEIFY et al., 2011; EISSA et al., 2011; SOLIMAN; IBRAHIM, 2012). Therefore, with the introduction of *O. niloticus* in Brazilian fish farms, there was a loss of its species of endohelminthes and crustaceans, which were then replaced by the common species of native ichthyofauna. However, such results in fish farms may not be representative of conditions in natural Brazilian ecosystems that may be invaded by *O. niloticus*.

In the Igarapé Fortaleza basin, the parasites of *O. niloticus* were *C. tilapiae*, *T. centrostrigata*, *P. africana*, *T. centrostrigata* and *T. nobilis*, which are then the species from biotic unit of this host fish (Galli's symbiota concept), besides *I. multifiliis*, a ciliated with worldwide distribution. However, such exotic parasites have shown little immediate consequence for the native cichlids, since only once *A. tetramerus* acquired *T. nobilis*. The low acquisition of exotic parasites by the rich ichthyofauna of native cichlids is due to the introduction of these parasites in a community of hosts with great diversity of native ectoparasites, especially species of monogeneoideans, metacercariae of digeneans in different stages, protozoans *I. multifiliis*, *P. pillulare* and *T. tetramerii*, thus resulting in

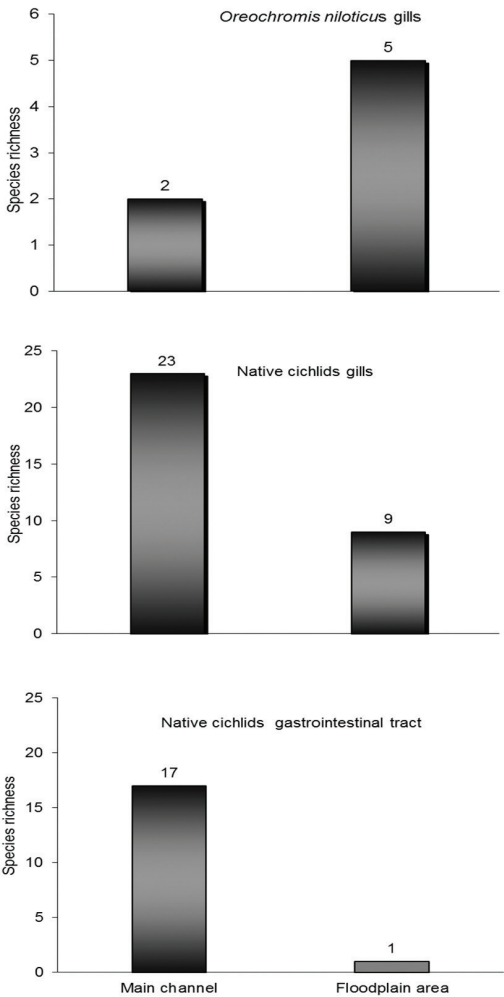


Figure 2. Richness of parasite species according to the local of infection and collection sites of Cichlidae species in the Igarapé Fortaleza basin, Amapá State, eastern Amazon, Brazil.

Table 3. Parasite species of native and exotic Cichlidae in floodplain area from the Igarapé Fortaleza basin, Amapá State, eastern Amazon, Brazil.

Parasite species	P (%)	MI	Host fish
Trichodinidae			
<i>Paratrichodina africana</i>	29.5	8333.4	<i>Oreochromis niloticus</i>
<i>Paratrichodina africana</i> and <i>Trichodina nobilis</i>	45.9	11358.7	<i>Oreochromis niloticus</i>
<i>Paratrichodina africana</i> and <i>Trichodina centrostrigata</i>	100	18422.8	<i>Oreochromis niloticus</i>
<i>Tripartiella tetramerii</i> and <i>Trichodina nobilis</i>	10.2	5974.8	<i>Aequidens tetramerus</i>
Dinoflagellida			
<i>Piscinoodinium pillulare</i>	14.8	422.2	<i>Cichlassoma amazonarum</i>
	10.0	352.6	<i>Mesonauta acora</i>
Ciliophora			
<i>Ichthyophthirius multifiliis</i>	70.7	31040.4	<i>Oreochromis niloticus</i>
	100	64607.3	<i>Astronotus ocellatus</i>
	100	8303.3	<i>Mesonauta acora</i>
	100	18619.0	<i>Mesonauta</i> sp.
	100	17600.3	<i>Laetacara curviceps</i>
	98.1	36453.9	<i>Cichlassoma amazonarum</i>
	100	22493.3	<i>Aequidens tetramerus</i>
	100	5026.3	<i>Aequidens</i> sp.
Monogeneoidea			
<i>Cichlidogyrus tilapiae</i>	3.3	0.11	<i>Oreochromis niloticus</i>
<i>Gussevia asota</i>	100	19.5	<i>Astronotus ocellatus</i>
<i>Sciadicleithrum joanae</i>	26.7	6.5	<i>Mesonauta acora</i>
	6.9	2.5	<i>Mesonauta</i> sp.
<i>Gussevia disparoides</i>	16.7	1.8	<i>Cichlassoma amazonarum</i>
Nematoda			
<i>Procamallanus</i> sp.	3.4	7.0	<i>Mesonauta</i> sp.
	1.8	1.0	<i>Cichlassoma amazonarum</i>
Digenea			
<i>Posthodiplostomum</i> sp. (metacercariae)	10.3	2.3	<i>Mesonauta</i> sp.
	35.2	3.6	<i>Cichlassoma amazonarum</i>
	66.7	1.0	<i>Laetacara curviceps</i>
	75.0	27.0	<i>Astronotus ocellatus</i>
	53.3	6.7	<i>Mesonauta acora</i>

P: Prevalence, MI: Mean intensity.

shortage of available niche for newcomer ectoparasites. Furthermore, *P. africana*, the most frequent trichodinids in *O. niloticus*, has parasite specificity. For native parasites, it was also difficult to colonize *O. niloticus*, because none of these parasites infected this invasive host so far. Thus, while the parasitic fauna of this invasive was formed exclusively by ectoparasites, in native host the infections were caused by ectoparasites and endoparasites, but with higher richness of endohelminthic species, mainly in the main channel where the highest diversity of native fish species occurred.

The parasite species with rich fauna generally occur in a few species of hosts fish, since they are experts, while the parasites in poor fauna are mostly general species (KENNEDY; POJMANSKA, 1996; POULIN, 1997), but this relation does not occur in fish that have suffered frequent translocations to the same environment (POULIN, 1997). In the Igarapé Fortaleza basin, the community of parasites in *O. niloticus* was dominated by species of gills opportunistic ciliates.

Species of native cichlids were also parasitized by protozoa (*I. multifiliis*, *P. pillulare* and *T. tetramerii*) but its parasitic fauna

was dominated mainly by a rich diversity of Monogeneoidea, adults and larvae of Nematoda, Digenea, Cestoidea and Acanthocephala, indicating that they are intermediate or paratenic hosts of endohelminthic species in the area of this study. On the other hand, *O. niloticus*, in its original site this host accumulates in the gills eight species of monogeneoideans and four species of helminthic endoparasites. In an artificial lake in Maringá, Southern Brazil, *O. niloticus* was parasitized by *C. sclerosus*, *C. longicornis*, *Cichlidogyrus* sp.; besides larvae of *Contracaecum* sp. and Cestoidea, endohelminth that also parasitized *Geophagus brasiliensis* Quoy & Gaimard, 1824 and *Crenicichla britskii* Kullander, 1982, species of cichlids of ichthyofauna of Brazil (GRAÇA; MACHADO, 2007). For this tilapia introduced into the Guarapiranga Reservoir, southeastern Brazil, the parasitic fauna is constituted only by *Cichlidogyrus* sp., *Trichodina* sp., *I. multifiliis*, *Cryptobia* sp. and *Henneguya* sp. (RANZANI-PAIVA et al., 2005). The parasite fauna of native cichlid *Vieja maculicauda* Regan, 1905 in the Panama Canal is rich in species of Monogeneoidea, Trematoda, Nematoda and Acanthocephala. However, the helminth fauna of the invasive

Table 4. Parasite species of native and exotic Cichlidae in the main channel from the Igarapé Fortaleza basin, Amapá State, eastern Amazon, Brazil.

Parasite species	P (%)	MI	Host fish
Trichodinidae			
<i>Paratrichodina africana</i>	100	2019.4	<i>Oreochromis niloticus</i>
Dinoflagellida			
<i>Piscinoodinium pillulare</i>	57.1	324.5	<i>Pterophyllum scalare</i>
	14.3	758.0	<i>Chaetobranchus flavescens</i>
	14.3	160.0	<i>Mesonauta acora</i>
	64.5	5254.0	<i>Chaetobranchopsis orbicularis</i>
	55.0	1347.7	<i>Satanoperca jurupari</i>
	12.5	320.0	<i>Cichlassoma bimaculatum</i>
Ciliophora			
<i>Ichthyophthirius multifiliis</i>	100	16142.2	<i>Oreochromis niloticus</i>
	100	7105.0	<i>Geophagus brasiliensis</i>
	100	3330.1	<i>Pterophyllum scalare</i>
	76.9	8554.2	<i>Astronotus ocellatus</i>
	100	40866.7	<i>Heros efasciatus</i>
	100	45562.2	<i>Chaetobranchus flavescens</i>
	100	13458.4	<i>Mesonauta acora</i>
	100	10875.0	<i>Mesonauta</i> sp.
	55.5	2034.0	<i>Mesonauta guyanae</i>
	100	20541.3	<i>Chaetobranchopsis orbicularis</i>
	100	8229.7	<i>Cichlassoma amazonarum</i>
	100	51512.1	<i>Cichlassoma bimaculatum</i>
	100	22614.6	<i>Aequidens tetramerus</i>
	100	1568.0	<i>Aequidens</i> sp.
	100	5935.4	<i>Laetacara curviceps</i>
	80.0	10508.6	<i>Satanoperca jurupari</i>
	100	1305.0	<i>Hypselecara temporalis</i>
Branchiura			
<i>Dolops longicauda</i>	6.4	1.0	<i>Chaetobranchopsis orbicularis</i>
	6.0	2.0	<i>Aequidens tetramerus</i>
<i>Argulus multicolor</i>	7.7	1.0	<i>Astronotus ocellatus</i>
Copepoda			
<i>Ergasilus</i> sp.	28.6	3.5	<i>Aequidens</i> sp.
Isopoda			
<i>Braga patagonica</i>	7.1	1.0	<i>Chaetobranchus flavescens</i>
Monogenoidea			
<i>Gussevia asota</i>	92.3	63.1	<i>Astronotus ocellatus</i>
<i>Gussevia disparoides</i>	100	37.3	<i>Heros efasciatus</i>
	66.7	4.0	<i>Cichlassoma amazonarum</i>
	82.3	14.1	<i>Laetacara curviceps</i>
<i>Sciadicleithrum joanae</i>	85.7	25.7	<i>Mesonauta acora</i>
<i>Sciadicleithrum geophagi</i>	58.1	12.8	<i>Chaetobranchopsis orbicularis</i>
<i>Gussevia disparoides</i> and <i>Gussevia alioides</i>	78.8	19.4	<i>Aequidens tetramerus</i>
<i>Gussevia elephas</i> and <i>Gussevia spirallocirra</i>	78.6	5.2	<i>Chaetobranchus flavescens</i>
<i>Gussevia arilla</i>	62.5	2.8	<i>Cichlassoma bimaculatum</i>
<i>Gussevia spirallocirra</i>	100	23.2	<i>Aequidens</i> sp.
<i>Sciadicleithrum satanoperca</i>	40.0	5.4	<i>Satanoperca jurupari</i>
<i>Sciadicleithrum iphthimum</i>	100	13.4	<i>Pterophyllum scalare</i>
<i>Urocleidoides</i> sp.	33.3	1.3	<i>Mesonauta guyanae</i>
Nematoda			
<i>Ichthyouris</i> sp.	85.7	6.7	<i>Pterophyllum scalare</i>
	33.3	4.0	<i>Heros efasciatus</i>

P: Prevalence, MI: Mean intensity.

Table 4. Continued...

Parasite species	P (%)	MI	Host fish
	15.0	10.3	<i>Satanoperca jurupari</i>
	44.4	35.3	<i>Mesonauta guyanae</i>
<i>Ichthyouris</i> sp.1, <i>Ichthyouris</i> sp.2, <i>Procamallanus</i> sp. and <i>Pseudoproleptus</i> sp.	71.4	16.2	<i>Mesonauta acora</i>
<i>Procamallanus</i> sp.	50.0	2.7	<i>Cichlassoma amazonarum</i>
<i>Pseudoproleptus</i> sp.	51.5	8.7	<i>Aequidens tetramerus</i>
	76.5	25.8	<i>Laetacara curviceps</i>
Anisakidae gen. sp. (larvae)	9.1	13.0	<i>Aequidens tetramerus</i>
	10.0	5.0	<i>Laetacara curviceps</i>
<i>Contracaecum</i> sp.	38.5	2.4	<i>Astronotus ocellatus</i>
Cestoidea			
Proteocephalidea gen. sp. (plerocercoid)	12.1	1.0	<i>Aequidens tetramerus</i>
	5.0	1.0	<i>Laetacara curviceps</i>
<i>Proteocephalus gibsoni</i>	23.1	7.0	<i>Astronotus ocellatus</i>
Digenea			
Digenea gen. sp.	14.3	4.0	<i>Pterophyllum scalare</i>
	93.9	53.2	<i>Aequidens tetramerus</i>
Cladorchiidae gen. sp. (metacercariae)	100	5.0	<i>Heros efasciatus</i>
Acanthostomidae gen. sp. and <i>Posthodiplostomum</i> sp. (metacercariae)	92.3	38.8	<i>Astronotus ocellatus</i>
Acanthostomidae gen. sp. and <i>Thometrema</i> sp. (metacercariae)	57.1	42.0	<i>Aequidens</i> sp.
Cladorchiidae gen. sp. and <i>Posthodiplostomum</i> sp. (metacercariae)	100	26.0	<i>Mesonauta acora</i>
	57.1	23.8	<i>Mesonauta acora</i>
	83.3	8.6	<i>Cichlassoma amazonarum</i>
<i>Clinostomum marginatum</i>	9.6	8.7	<i>Chaetobranchopsis orbicularis</i>
	7.7	2.0	<i>Astronotus ocellatus</i>
<i>Thometrema</i> sp.	30.7	6.2	<i>Astronotus ocellatus</i>
Derogenidae gen. sp. (metacercariae)	20.0	3.3	<i>Satanoperca jurupari</i>
<i>Posthodiplostomum</i> sp. (metacercariae)	100	11.0	<i>Mesonauta</i> sp.
	41.9	70.3	<i>Chaetobranchopsis orbicularis</i>
Acanthocephala			
<i>Gorytocephalus spectabilis</i>	33.3	5.0	<i>Heros efasciatus</i>
	28.6	7.0	<i>Mesonauta acora</i>
	12.1	2.5	<i>Aequidens tetramerus</i>
	10.0	44.0	<i>Satanoperca jurupari</i>
<i>Echinorhynchus paranensis</i> and <i>Gorytocephalus spectabilis</i>	50.0	31.1	<i>Chaetobranchus flavescens</i>
<i>Echinorhynchus paranensis</i> and <i>Neoechinorhynchus pterodoriidis</i>	77.4	22.8	<i>Chaetobranchopsis orbicularis</i>

P: Prevalence, MI: Mean intensity.

O. niloticus consisted of Trematoda and native Nematoda and three Monogenoidea species of its place of origin, out of which only *Cichlidogyrus dossoui* Douellou, 1993 was acquired by *V. maculicauda* (ROCHE et al., 2010). Therefore, this parasite fauna in *O. niloticus* was higher than that in the present study, which shows that during the early establishment of *O. niloticus* in the Igarapé Fortaleza basin the small number of parasite species is one of the factors favoring their rapid demographic growth and population explosion in this new environment.

Monogenoideans are parasites with direct life cycle and resistant to elimination when translocated (PÉREZ-PONCE DE LEÓN et al., 2000). Thus, species of the genus *Cichlidogyrus* translocated with *O. niloticus* colonized species of endemic cichlids of Mexico (JIMÉNEZ-GARCÍA et al., 2001) and Panama (ROCHE et al., 2010), due to its relative parasite specificity. In contrast, *C. tilapiae*, the only species of helminth

parasitizing this invasive fish in the region of this study, was not competent to invade any of the 16 species of native cichlids, fish ecologically similar. However, in Brazilian fish farms, *O. niloticus* has been parasitized by *C. tilapiae* and by *C. sclerosus*, besides other species still unidentified (PANTOJA et al., 2012), possibly the *C. longicornis*. Thus, the results of this fish introduction in Brazilian fish farms do not reflect what occurs in the natural environment; it indicates loss of monogenoideans species with the translocation of this tilapia from other regions of Brazil to the studied area. Therefore, the acquisition and transmission of exotic parasites depend on a complex set of factors, including biological aspects of host and parasite, host-parasite interaction and scale-space (JIMÉNEZ-GARCÍA et al., 2001; ROCHE et al., 2010; GENDRON et al., 2012; PATERSON et al., 2012).

The colonization of exotic hosts by native parasites is a process that can take a long time (KENNEDY; POJMANSKA 1996)

or be slow (GENDRON et al., 2012), caused by variations in the host-parasite system to species of investigated fish. Invasive fish need some time to acquire generalist helminthic parasites of native ichthyofauna (KENNEDY; POJMANSKA, 1996; PATERSON et al., 2012), especially endohelminthes. Thus, in the Igarapé Fortaleza basin, due to the recent history of invasion of *O. niloticus* (less than a decade), there was not enough time to acquire common helminth species to their native competitors, which had a rich fauna species of endohelminthes, parasites of complex life cycle involving fish communities and also invertebrates (PÉREZ-PONCE DE LEÓN et al., 2000; PATERSON et al., 2012).

Invasive fish are poor in species of helminthes (GUÉGAN; KENNEDY, 1993; KENNEDY; POJMANSKA 1996; GENDRON et al., 2012; PATERSON et al., 2012), mainly fish that have in their fauna specialist endohelminthes, because these fish are not susceptible to invasion by species of specialist parasites of native fish. Pérez-Ponce de León et al. (2000) found only a single species of endohelminth (Nematoda) parasitizing *O. niloticus* introduced on the Lake Pátzcuaro (Mexico), while for the same host of lakes of the Panama Canal, Roche et al. (2010) reported four species of Digenea and four species of Nematoda. Therefore, more time is necessary for this invasive tilapia being colonized by species of endohelminthes common to the local ichthyofauna of this study; however, the period is difficult to estimate.

Trichodinidae are predominantly opportunistic protozoans that have broad geographic distribution and generally parasitize the skin of their native and exotic hosts. Overall, the most specialized species parasitize gills of certain groups of hosts, and when they are translocated, remain with their hosts of origin (VAN AS; BASSON, 1987). *Paratrichodina africana* is a parasite of gills of *O. niloticus*, but rarely of skin (KAZUBSKI; EL-TANTAWY, 1986), is it strongly associated with *Oreochromis* hosts. *Trichodina centrostrigata* from gills, skin and fins of species of *Oreochromis mossambicus* Peters, 1852, *Pseudocrenilabrus philander* Weber, 1897, *Tilapia rendalli* Boulenger, 1897, *Tilapia sparrmanii* Smith, 1840 (Cichlidae) and *Cyprinus carpio* Linnaeus, 1758 from Africa (BASSON et al., 1983); subsequently, it has been found parasitizing *O. niloticus* in Africa (EL-TANTAWY; KAZUBSKI, 1986), Philippines (BONDAD-REANTASO; ARTHUR, 1989) and now in Brazil, due to its translocation. Thus, this species seems to be more specific to the Cichlidae species (BONDAD-REANTASO; ARTHUR, 1989).

Trichodina nobilis originally described to Cyprinidae is associated with skin and gills of fish species of this family, but it has the skin as a preferential habitat (BASSON; VAN AS, 1994; MARTINS et al., 2012). Thus, it has been reported that this trichodinid parasites the skin, gills and fins of different Cichlidae species (BASSON; VAN AS, 1994), skin of Poeciliidae (MARTINS et al., 2012), as well as gills of *O. niloticus* of Nile River (EL-SEIFY et al., 2011) and also the Amazon estuary in Northern Brazil. Van As and Basson (1987) reported that the species of *Tripartiella* can vary the degree of specificity, because some species are restricted to the gills of particular genus or even to a single host. In fact, it is observed in the studies of Vulpe (2002), Mohilal and Hemananda (2012), and Mitra et al. (2012) that *Tripartiella obtusa* Ergens & Lom, 1970, *Tripartiella copiosa* Lom, 1959 and *Tripartiella bulbosa* Lom, 1959 are often associated with species of Cyprinidae of genera *Cirrhinus*, *Labeo*, *Catla* and *Cyprinus*. Furthermore,

T. tetramerii was parasite only of *A. tetramerus*, a native cichlid in region of this study.

Trichodinidae ciliates can be considered the most common parasites in fish of different environments. In gills of *O. niloticus* of the Igarapé Fortaleza basin, it was found higher levels of infections caused by *P. africana* when associated with *T. centrostrigata* or *T. nobilis*. Similarly, in the gills of *A. tetramerus* the parasitism by *T. tetramerii* (native) was associated to infection by *T. nobilis*, but levels of infection were lower compared to exotic trichodinids in gills of *O. niloticus*. However, for the same tilapia species from the Brazilian reservoir, the levels of infection by *Trichodina* sp. caused by low temperature of the region (RANZANI-PAIVA et al., 2005) were lower than that in this study. In poor environmental conditions of intensive culture and high stocking density (VAN AS; BASSON, 1987; TAVARES-DIAS et al., 2001; JERÔNIMO et al., 2012) or even in a natural environment (RANZANI-PAIVA et al., 2005), the intensity of these ciliates can increase rapidly. Because its reproduction is favored by excess organic matter (TAVARES-DIAS et al., 2001; JERÔNIMO et al., 2012; MARTINS et al., 2012), especially at high temperatures, as it was the case of this study.

Monogenoidea species were not found in *O. niloticus* of the main channel of the Igarapé Fortaleza. On the other hand, in this invasive fish of floodplain area, the low levels of gill infection by *C. tilapia* were associated with high parasitism by opportunistic protozoa (*I. multifiliis*, *P. africana*, *T. centrostrigata* and *T. nobilis*), parasites known for their strong influence on low environmental quality (TAVARES-DIAS et al., 2001; JERÔNIMO et al., 2012). Possibly, *C. tilapia* has suffered pressure in this new environment and also by habitat competition (in gills) with the ciliates species. In this same region, for this tilapia from fish farms, it was reported high levels of infection caused by *C. tilapia* associated with low parasitism by *Trichodina* sp. (probably *T. centrostrigata*), *P. africana* and *I. multifiliis* (PANTOJA et al., 2012), indicating that infections caused by ciliates were secondary. Fish with acute and subacute infection become more susceptible (TAVARES-DIAS et al., 2001) to infections by opportunistic species of protozoa showed in this study. In gills of *O. niloticus* from reservoir, the levels of infections by *Cichlidogyrus* sp. were also low due to the occurrence in some months of the year (RANZANI-PAIVA et al., 2005). Sanchez-Ramirez et al. (2004) reported that in *O. niloticus* kept experimentally in polluted environment, the abundance of *C. sclerosus* decreased, but the infection was chronic. Therefore, *C. tilapia* may be sensitive to environmental eutrophication and may have seasonal infection pattern, this is why it was not found parasitizing this invasive fish in the main channel of the natural investigated ecosystem.

The differences in parasitism between fish of the main channel and floodplain area should be due to the highest diversity of native hosts in the main channel, location with low occupancy by invasive *O. niloticus*. The low acquisition of exotic parasites by the rich fauna of native cichlids species was expected, since our recent studies (PANTOJA et al., 2012) indicated a reduced fauna of exotic parasites in farmed *O. niloticus* in Brazil. However, it was unexpected non colonization in *O. niloticus* by parasite species common to native ichthyofauna, since this exotic fish is in this region for almost a decade. Further studies are needed on the factors that have limited the richness of the community of

parasites in *O. niloticus* and influenced the colonization period in this host to understand the mechanisms of recruitment controlling parasites in introduced fish and the influence on the parasitic fauna of other species of native ichthyofauna.

This was the first report on *T. nobilis* (Trichodinidae) for *A. tetramerus* and *O. niloticus*; *T. centrostrigata* (Trichodinidae) for *O. niloticus*; *P. pillulare* (Dinoflagellida) for *Cichlassoma amazonarum*, *Mesonauta acora*, *Pterophyllum scalare*, *Chaetobranchopsis orbicularis*, *Satanoperca jurupari*, *Cichlassoma bimaculatum* and *Chaetobranchius flavescens*; *I. multifiliis* (Ciliophora) for *M. acora*, *Laetacara curviceps*, *C. amazonarum*, *A. tetramerus*, *G. brasiliensis*, *P. scalare*, *Heros efasciatus*, *C. flavescens*, *Mesonauta guayanae*, *C. orbicularis*, *C. bimaculatum*, *S. jurupari* and *Hypselecara temporalis*; *Sciadicleithrum joanae* (Monogeneoidea) for *M. acora*; *Gussevicia disparoides* (Monogeneoidea) for *C. amazonarum*, *A. tetramerus*, *L. curviceps* and *H. efasciatus*; *G. alioides* (Monogeneoidea) for *A. tetramerus*; *Gussevicia elephas* (Monogeneoidea) for *C. flavescens*; *Gussevicia spirallocirra* (Monogeneoidea) for *C. flavescens*; *Gussevicia arilla* (Monogeneoidea) for *C. bimaculatum*; *Sciadicleithrum satanoperca* (Monogeneoidea) for *S. jurupari*; *Urocleidoides* sp. (Monogeneoidea) for *M. guayanae*; *Posthodiplostomum* sp. (Diplostomidae) for *C. amazonarum*, *M. acora* and *C. orbicularis*; *Dolops longicauda* (Branchiura) for *A. tetramerus* and *C. orbicularis*; *Braga patagonica* (Isopoda) for *C. flavescens*; *Proteocephalus gibsoni* (Proteocephalidae) for *Astronotus ocellatus*; *Clinostomum marginatum* (Clinostomidae) for *C. flavescens* and *A. ocellatus*; *Gorytocephalus spectabilis* (Neoechinorhynchidae) for *H. efasciatus*, *M. acora*, *A. tetramerus*, *S. jurupari* and *C. flavescens*, and *Echinorhynchus paranensis* (Echinorhynchinae) for *C. flavescens* and *C. orbicularis*.

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