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Review Article

Contracaecum larvae: morphological and morphometric retrospective analysis, biogeography and zoonotic risk in the amazon

Larva de *Contracaecum*: análise retrospectiva morfológica e morfométrica, biogeografia e risco zoonótico na amazônia

Raul Henrique da Silva Pinheiro[1,2]; Adriano Penha Furtado[1,3]; Jeannie Nascimento dos Santos[1,3]; Elane Guerreiro Giese[1,2*]

[1] Programa de Pós-Graduação em Biologia de Agentes Infecciosos e Parasitários, Instituto de Ciências Biológicas, Universidade Federal do Pará - UFPA, Belém, PA, Brasil

[2] Laboratório de Biologia Celular e Helmintologia "Profa Dra Reinalda Marisa Lanfredi", Instituto de Ciências Biológicas, Universidade Federal do Pará - UFPA, Belém, PA, Brasil

[3] Laboratório de Histologia e Embriologia Animal, Instituto da Saúde e Produção Animal, Universidade Federal Rural da Amazônia - UFRA, Belém, PA, Brasil

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Abstract

In Brazil there are several records of parasitic nematodes of fish with zoonotic potential, especially those belonging to the family Anisakidae. This study considers the morphology, morphometry and prevalence of *Contracaecum* in *Astronotus ocellatus*, fish consumed in the Amazon and sold as ornamental and it also performs a retrospective analysis of the diversity of fish with larvae of *Contracaecum*, in studies carried out in Brazil over a period of 90 years. 40 specimens of *A. ocellatus* were necropsied, and the nematodes were collected and fixed in 93 parts 70% ethyl alcohol, 5 parts formaldehyde, and 2 parts glacial acetic acid (AFA) for morphological analysis under light microscopy and scanning electron microscopy. Of the 40 fish collected during this work, 27 were parasitized by *Contracaecum* larvae with a total intensity of 150 larvae. Retrospective analysis of intermediate host diversity for *Contracaecum* larvae resulted in 16 orders, 49 families, 96 genera, 140 species and a hybrid morphotype. In the retrospective study, half of the fish were from freshwater, with the order Perciformes being the most representative, with 16 families, 30 genera and 37 species. In Brazil, the occurrence of larvae of *Contracaecum* in fish was reported in 15 of the 26 states, with Rio de Janeiro presenting the most information regarding fish harboring *Contracaecum* larvae.

Keywords: *Astronotus ocellatus*, fish hygiene, zoonosis, Pará.

Resumo

No Brasil existem vários registros de nematóides parasitos de peixes com potencial zoonótico, especialmente aqueles pertencentes à família Anisakidae. Este estudo considera a morfologia, morfometria e prevalência de *Contracaecum* em *Astronotus ocellatus*, peixe consumido na Amazônia e vendido como ornamental, e também realiza uma análise retrospectiva da ictiofauna parasitada com larvas de *Contracaecum*, em estudos realizados no Brasil, durante um período de 90 anos. 40 espécimes de *A. ocellatus* foram necropsiados, e os nematóides foram coletados e fixados em 93 partes de álcool etílico 70%, 5 partes de formaldeído e 2 partes de ácido acético glacial (AFA) para análise morfológica em microscopia de luz e microscopia eletrônica de varredura. Dos 40 peixes coletados durante este trabalho, 27 estavam parasitados por *Contracaecum*, com intensidade total de 150 larvas. Análises retrospectivas da diversidade de hospedeiros intermediários para larvas de *Contracaecum* resultaram em 16 ordens, 49 famílias, 96 gêneros,140 espécies e um morfotipo híbrido.

***Corresponding author:** Elane Guerreiro Giese. Laboratório de Histologia e Embriologia Animal, Instituto da Saúde e Produção Animal, Universidade Federal Rural da Amazônia – UFRA, Avenida Presidente Tancredo Neves, 2501, Terra Firme, CEP 66077-830, Belém, PA, Brasil.
e-mail: elane.giese@ufra.edu.br

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No estudo retrospectivo, metade dos peixes eram de água doce, sendo a ordem Perciformes a mais representativa, com 16 famílias, 30 gêneros e 37 espécies. No Brasil, a ocorrência de larvas de *Contracaecum* em peixes foi relatada em 15 dos 26 estados, com o Rio de Janeiro apresentando mais informações sobre peixes portadores de larvas de *Contracaecum*.

Palavras-chaves: *Astronotus ocellatus*, higiene do pescado, zoonose, Pará.

Introduction

Astronotus ocellatus (Agassiz, 1831) (Cichliformes: Cichlidae) is a species native to the Amazon basin. Its culture was stimulated in the 1930s by governmental policies aimed at establishing this species in the South and Southeast river basins of the country (FONTENELE & NEPOMUCENO, 1983), due its their economic value (AZEVEDO et al., 2007) and trophic plasticity (FIROUZBAKHSH et al., 2011).

Fish consumption is a good option for healthy eating, but consumption of raw or cold-smoked fish combined with deficient sanitary quality may make fish consumption a public health problem (KNOFF et al., 2013), since Amazonian fish have a large parasitic fauna. In Brazil, there are several records of the Anisakidae and Raphidascarididae families in marine fish, with parasites possessing zoonotic potential (FONTENELLE et al., 2013). Considering the great representativeness of the Anisakidae family in commercially important fish in Brazil, the Ministério da Saúde in 2010 classified the biological risk of Anisakidae infection as belonging to Risk Class 2, since they are parasites with moderate risk and limited risk of transmission (BRASIL, 2010). Infections by Anisakidae larvae result in a combination of two factors: direct action of larvae during tissue invasion and interactions between the host's immune system and the substances released by the parasite or the host's immune response to its presence (UBEIRA et al., 2000).

Although there are many studies related to larvae of the family Anisakidae in marine fish, the occurrence, data on the prevalence and morphology of larvae of this family in freshwater fish are still scarce, when compared to the numbers of freshwater environments and diversity of fish present in these habitats, distributed in the different states of Brazil. The objective of this study is to characterize the morphology, morphometry, biogeography and prevalence of nematoda Anisakidae in *A. ocellatus*, commercialized in the municipality of Santarém, Pará, in the Brazilian Amazon, in addition to gathering and analyzing retrospective data on the Brazilian ichthyofauna that hosts larvae of *Contracaecum* sp.

Materials and Methods

Forty *A. ocellatus* [total length 19-29 (23) cm; weight 175–514 (354) g] specimens were obtained. Fish were captured by artisanal fishermen in Tapajós river in the municipality of Santarém (2°26'22"S: 54°41'55'W'), Pará State (Fig. 1). The fish were transported in an isothermal box to the Laboratório de Histologia e Embriologia Animal, Instituto de Saúde e Produção Animal, Universidade Federal do Rural da Amazônia, City of Belém for necropsy. After biometric analyses, the animals were necropsied for helminths. The digestive tract of each specimen was isolated in a Petri dish containing physiological solution and analyzed using stereomicroscope (LEICA-ES2). The nematode larvae found dead were fixed in AFA solution (93 parts 70% ethyl alcohol, 5 parts formaldehyde, and 2 parts glacial acetic acid), stored at room temperature. For morphological and morphometric analysis ten larvae were dehydrated in an ethanol series, clarified with lactophenol, placed on a microscope slide under a coverslip as a temporary mount, observed using a light microscope, and photographed using a LEICA DM2500 microscope with an imaging capture system. Measurements are shown in micrometers as the mean followed by the range, or as otherwise indicated. Taxonomic classification of nematodes was in accordance with Moravec (1998), Timi et al. (2001), Felizardo et al. (2009), and Fonseca et al. (2016).

For scanning electron microscopy, six larvae were washed in phosphate-buffered saline (pH 7.0), post-fixed in 1% osmium tetroxide, dehydrated to the critical point of CO_2, metalized with gold-palladium, and analyzed with the VEGA 3 LMU/TESCAN scanning electron microscope at the Laboratório de Microscópia Eletrônica de Varredura, Instituto da Saúde e Produção Animal - Universidade Federal Rural da Amazônia - UFRA, state of Pará, Brazil. The ecological indexes of parasitism were used according to Bush et al. (1997) and Bautista-Hernández et al. (2015). A review was made of the occurrence of *Contracaecum* larvae in different hosts present in the Brazilian ichthyofauna by means of databases, and the available results are shown in Table 1.

Results

A total of 150 nematodes were recovered from *A. ocellatus* showing prevalence: 67.5% (27/40), mean intensity: 5.5, mean abundance: 3.7 and amplitude: 1 to 15 nematodes per fish. All specimens collected showed characteristics compatible with third stage larvae of *Contracaecum* sp. (Nematoda: Anisakidae). The parasites were encysted in the intestinal serosa and mesentery. The morphological and morphometric characteristics of the third-stage larvae of *Contracaecum* are presented below.

Contracaecum Railliet & Henry, 1912

Contracaecum sp. (third-stage larvae) (Figs. 2 and 3)

(Description based on ten larvae)

Medium-sized nematodes, measuring 14 mm (11−16 mm) in length, maximum width at ventriculus 451 (367−533), opaque-white when alive. Transversely striated cuticle present and more distinct at the extremities of the body, with anterior region interrupted by a short, lateral line (Figures 2a, 3a). Cephalic extremity rounded with a small, ventral cuticular tooth, 4 submedian cephalic papillae surrounding the small, transverse oval oral aperture; three poorly-developed lips (Figures 2b, 3b,c). Excretory pore situated below the ventral cephalic tooth (Figure 3b,c). Oesophageal muscle narrow, measuring 1.7 (1−2mm) × 85 (66−133) (Figure 2a). Ventricle is small, rounded, 86 (66−120) × 80 (60−120); Ventricular appendix is short, 356 (233−460) × 76 (66−93) (Figure 2c). Nerve

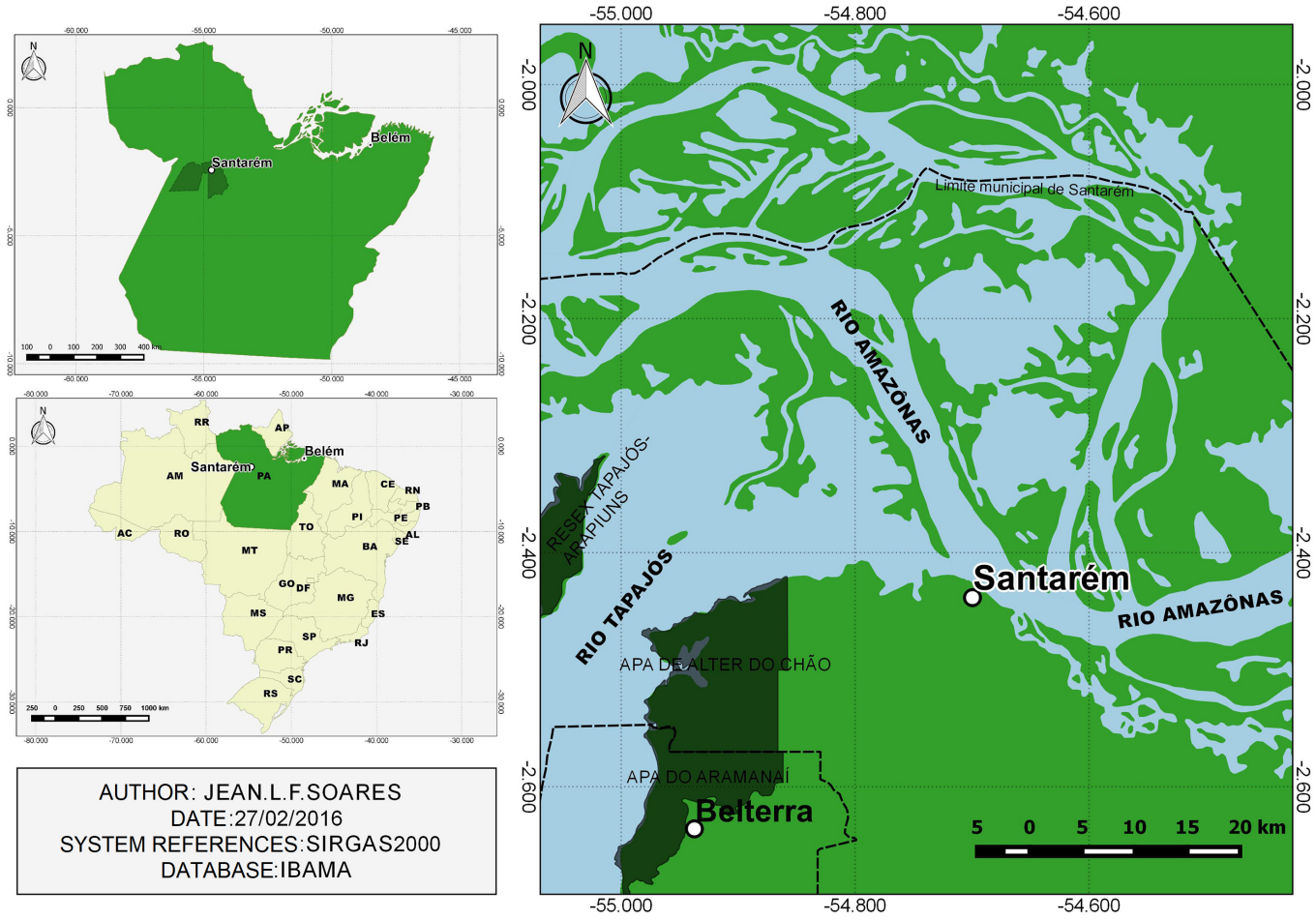

Figure 1. Collection locality of *A. ocellatus* in the Tapajós river, municipality of Santarém, State of Pará, Brazil.

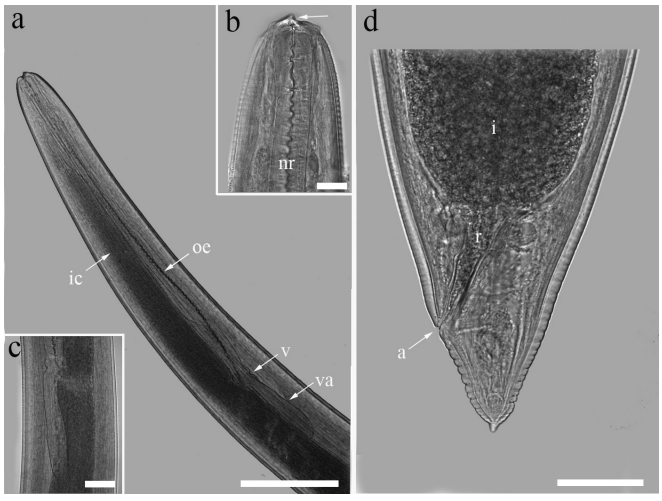

Figure 2. Light microscopy of *Contracaecum* sp. (L3 larvae) parasite of *A. ocellatus*: (a) Lateral view of the cephalic region showing evidence of the oesophagus (oe), intestinal caecum (ic), ventricle (v) and ventricular appendix (va). Bar = 200 µm; (b) Detail of larval tooth (arrow), nerve ring (nr) and cuticle with delicate transversal striations. Bar = 200 µm; (c) Detail of ventricle and ventricular appendix. Bar = 200 µm; (d) Posterior portion, portion of the intestine (i), rectum (r) and (a) anus, the tail without mucron. Bar = 50 µm .

ring positioned at 283 (260–313) from the anterior extremity (Figure 2b). Deirids were observed only by SEM (Figure 3c). Long intestinal caecum, extending anteriorly to the nerve ring, measuring 1.2 (1–1.5mm) × 145 (120–167) (Figure 2a). The length ratio of the caecum and ventricular appendix is 30% (20–40%). Genital primordium is indistinct positioned at 4 (3–5mm) from the anterior extremity. Rectum is a short hyaline tube; 3 small, unicellular rectal glands are present measuring 134 (110–233) (Figure 2d, 3e). Tail is conical, 131 (100–200) in length.

Taxonomic Summary:

Nematoda (Rudolphi, 1808)

Anisakidae Skrjabin & Karokhin, 1945

Contracaecum sp. (L3 Larvae)

Host: *Astronotus ocellatus* (Agassiz, 1831) (Cichliformes: Cichlidae)

Common Name: acará-açu, apairi, oscar, bola de ouro and acará.

Length and mean weight of hosts: 19-29 (23) cm and 175–514 (354) g, respectively.

Infection sites: Encysted in the intestinal serosa and mesentery.

Biome: Amazon - Setting: freshwater

Locality type: River Tapajós, municipality of Santarém, Pará, eastern Brazilian Amazon.

Table 1. Check list of records of third-stage larvae of *Contracaecum* spp. in fishes from Brazil.

Order/ Family/ Host/ Environment[a]	Site of infection[b]	Locality[c]	Reference[d]
Order Cichliformes			
Family Cichlidae			
Astronotus ocellatus (Agassiz, 1831)[FW]	**ME, IN**	RJ, SP, **PA**, AP	**Present study**, Moravec (1998), Azevedo et al. (2007; 2010; 2011), Eiras et al. (2010), Luque et al. (2011), Neves et al. (2013), Tavares-Dias et al. (2014), Bittencourt et al. (2014), Eiras et al. (2016), Tavares-Dias & Neves (2017)
Geophagus brasiliensis (Quoy & Gaimard, 1824)[FW, BW]	BC, ME, LI, IN	RJ, SP, PR, RS	Kohn et al. (1988), Luque & Poulin (2004), Paraguassú et al. (2005), Azevedo et al. (2006, 2011), Eiras et al. (2010), Carvalho et al. (2010), Luque et al. (2011), Bellay et al. (2012), Zago et al. (2013), Rassier et al. (2015), Eiras et al. (2016)
Cichla monoculus (Agassiz, 1831)[FW]	ME	PR	Machado et al. (2000), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Cichla kelberi (Kullander & FerrEiras, 2006)[FW]	CO, IN	PR, SP, RN, MG	Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Yamada & Takemoto (2013), Santos-Clapp & Brasil-Sato (2014), Eiras et al. (2016)
Cichla piquiti (Kullander & FerrEiras, 2006)[FW]	BC, ME	SP, PR, TO	Eiras et al. (2010), Franceschini et al. (2013b), Yamada & Takemoto (2013), Eiras et al. (2016)
Cichla ocellaris (Bloch & Schneider, 1801)[FW, BW]	MU, BC, ME, AC	SP, SE	Martins et al. (2003), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Crenicichla lepidota (Heckel, 1840)[FW]	ST, PE, BC	PR	Kohn et al. (1988), Moravec et al. (1993), Moravec (1998), Vicente & Pinto (1999), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Crenicichla britskii (Kullander, 1982)[FW]	IN	PR	Graça & Machado (2007)
Crenicichla haroldoi (Luengo & Britski, 1974)[FW]	NS	NS	Eiras et al. (2016)
Oreochromis niloticus (Linnaeus, 1758)[e, FW, BW]	IN	PR	Graça & Machado (2007)
Order Perciformes			
Family Sciaenidae			
Menticirrhus americanus (Linnaeus, 1758)[MAR, BW]	IN	RJ	Chaves & Luque (1999), Luque et al. (2011), Eiras et al. (2016)
Micropogonias furnieri (Desmarest, 1823)[MAR, BW]	ME	RJ	Alves & Luque (2001a, b), Luque et al. (2010), Luque et al. (2011), Mattos et al. (2014), Eiras et al. (2016)
Paralonchurus brasiliensis (Steindachner, 1875)[MAR, BW]	ME	RJ	Luque et al. (2003), Luque & Poulin (2004), Luque et al. (2011), Eiras et al. (2016)
Pachyurus bonariensis (Steindachner, 1879)[FW]	ME	RJ, MT	Lacerda et al. (2009), Eiras et al. (2010), Eiras et al. (2016)
Plagioscion squamosissimus (Heckel, 1840)[FW, BW]	ST, PE, MU, ME, E, LI, GO, AC, G, GB, KI	PR, SP, PA	Moravec et al. (1993), Moravec (1998), Vicente & Pinto (1999), Martins et al. (2003), Eiras et al. (2010), Luque et al. (2011), Rodrigues et al. (2015), Eiras et al. (2016)
Plagioscion ternetzi (Boulenger, 1895)[FW]	ME	MT	Luque et al. (2003), Lacerda et al. (2009), Eiras et al. (2010), Eiras et al. (2016)
Macrodon ancylodon (Bloch & Schneider, 1801)[MAR, BW]	IN, ME	MA	Vicente & Fernandes (1978), Vicente et al. (1985), Luque et al. (2011), Eiras et al. (2016)
Cynoscion guatucupa (Cuvier, 1830)[MAR]	ME, AC	RJ	Fontenelle et al. (2013)

[a]abbreviations: Host species are given followed by their predominant habitat (MAR = marine, FW = freshwater or BW = brackish water); [b]abbreviations: Site of the infection; when possibe these are grouped (AC = abdominal cavity; BC = body cavity; CO = coelom; G = Guts; GI = gills; GO = gonods; GB = gall baldder; H = heart; HC = hepatic capsule; IN = intestine; IC = intestinal cecum; LI = liver; ME = mesenteries; Mu = muscle; SB = swimming bladder; PC = pyloric caeca; PE = peritôneo; ST = stomach; SV = spiral valve; KI = Kidney; GS = gastric serosa; NS = not specified); [c]localities are given in alphabetical order of Brazilian states (AM = Amazonas, AP = Amapá, BA = Bahia, MA = Maranhão, MG = Minas Gerais, MS = Mato Grosso do Sul, MT = Mato Grosso, PA = Pará, PR = Paraná, RJ = Rio de Janeiro, RN = Rio Grande do Norte, RS = Rio Grande do Sul, SP = São Paulo, SE = Sergipe, and TO = Tocantins); [d]records bibliographical by host in chronological sequence; [e]exotic species; [f]localização geografica descrita como Northeast littoral of Brazil; [g]Patinga hybrid, which is the result of interspecific hybridisation between a female (F1) of *Piaractus mesopotamicus* and male (M1) of *Piaractus brachypomus,* both commonly cultured fish in Brazil; [h]syn *Acestrorhampus macrolepis*; [i]syn *Brycon microlepis*; [j]syn *Prochilodus scrofa*; [l]syn *Paulicea luetkeni.*

Table 1. Continued...

Order/ Family/ Host/ Environment[a]	Site of infection[b]	Locality[c]	Reference[d]
Cynoscion striatus (Cuvier, 1829)[MAR]	NS	NS	Eiras et al. (2016)
Cynoscion sp.[MAR]	NS	NS	Eiras et al. (2016)
Family Carangidae			
Caranx hippos (Linnaeus, 1766)[MAR, BW]	ME	RJ	Luque & Poulin (2004), Luque et al. (2011), Eiras et al. (2016)
Caranx latus (Agassiz, 1831)[MAR, FW, BW]	ME	RJ	Luque & Poulin (2004), Luque et al. (2011), Eiras et al. (2016)
Oligoplites palometa (Cuvier, 1832)[MAR, FW, BW]	GI	RJ	Takemoto et al. (1996), Luque & Poulin (2004), Luque et al. (2011)
Oligoplites saliens (Bloch, 1793)[MAR, BW]	GI	RJ	Takemoto et al. (1996), Luque & Poulin (2004), Luque et al. (2011)
Oligoplites saurus (Bloch & Schneider, 1801)[MAR, BW]	GI	RJ	Takemoto et al. (1996), Luque & Poulin (2004), Luque et al. (2011)
Trachurus lathami (Nichols, 1920)[MAR]	ME	RJ	Luque & Poulin (2004), Luque et al. (2011)
Selene setapinnis (Mitchill, 1815)[MAR, BW]	ME	RJ	Luque & Poulin (2004), Cordeiro & Luque (2004), Luque et al. (2011)
Parona signata (Jenyns, 1841)[MAR]	ME	NS	Luque et al (2011), Eiras et al. (2016)
Family Scombridae			
Scomber japonicus (Houttuyn, 1782)[MAR]	IC, IN, ME, PC, SB	RJ	Rego & Santos (1983), Vicente et al. (1985), Alves et al. (2003), Luque et al. (2011)
Euthynnus alletteratus (Rafinesque, 1810)[MAR, BW]	ME	RJ	Luque & Poulin (2004), Alves & Luque (2006), Luque et al (2011), Eiras et al. (2016)
Sarda sarda (Bloch, 1793)[MAR, BW]	ME	RJ	Alves & Luque (2006), Luque et al. (2011)
Scomberomorus cavalla (Cuvier, 1829)[MAR]	ME	RJ	Dias et al. (2011), Luque et al. (2011)
Scomberomorus brasiliensis (Collette, Russo & Zavala-Camin, 1978)[MAR]	ME	RJ	Luque & Poulin (2004), Luque et al. (2011)
Family Sparidae			
Pagrus pagrus (Linnaeus, 1758)[MAR]	MU, LI, ME, HC	RJ	São Clemente et al. (1994), Barros (1994), Paraguassú et al. (2002), Saad & Luque (2009), Luque et al. (2011), Soares et al. (2014), Mattos et al. (2014), Eiras et al. (2016)
Archosargus rhomboidalis (Linnaeus, 1758)[MAR, BW]	NS	RJ	Luque & Poulin (2004)
Family Pomatomidae			
Pomatomus saltatrix (Linnaeus, 1766)[MAR, BW]	ME, ST, LI, IC, GO, KI, IN, HC, GS	RJ	Rego et al. (1983), Vicente et al. (1985), Luque & Chaves (1999), Luque et al. (2011), Mattos et al. (2014), Eiras et al. (2016)
Family Mullidae			
Mullus argentinae (Hubbs & Marini, 1933)[MAR]	ME	RJ	Luque et al. (2002), Luque & Poulin (2004), Luque et al. (2011), Eiras et al. (2016)
Family Priacanthidae			
Priacanthus arenatus (Cuvier, 1829)[MAR]	ME	RJ	Tavares et al. (2001), Luque et al. (2011), Eiras et al. (2016)
Family Gerreidae			
Diapterus rhombeus (Cuvier, 1829)[MAR, BW]	ME	RJ	Luque & Poulin (2004), Luque et al. (2011), Eiras et al. (2016)

[a]abbreviations: Host species are given followed by their predominant habitat (MAR = marine, FW = freshwater or BW = brackish water); [b]abbreviations: Site of the infection; when possibe these are grouped (AC = abdominal cavity; BC = body cavity; CO = coelom; G = Guts; GI = gills; GO = gonods; GB = gall baldder; H = heart; HC = hepatic capsule; IN = intestine; IC = intestinal cecum; LI = liver; ME = mesenteries; Mu = muscle; SB = swimming bladder; PC = pyloric caeca; PE = peritôneo; ST = stomach; SV = spiral valve; KI = Kidney; GS = gastric serosa; NS = not specified); [c]localities are given in alphabetical order of Brazilian states (AM = Amazonas, AP = Amapá, BA = Bahia, MA = Maranhão, MG = Minas Gerais, MS = Mato Grosso do Sul, MT = Mato Grosso, PA = Pará, PR = Paraná, RJ = Rio de Janeiro, RN = Rio Grande do Norte, RS = Rio Grande do Sul, SP = São Paulo, SE = Sergipe, and TO = Tocantins); [d]records bibliographical by host in chronological sequence; [e]exotic species; [f]localização geografica descrita como Northeast littoral of Brazil; [g]Patinga hybrid, which is the result of interspecific hybridisation between a female (F1) of *Piaractus mesopotamicus* and male (M1) of *Piaractus brachypomus,* both commonly cultured fish in Brazil; [h]syn *Acestrorhampus macrolepis*; [i]syn *Brycon microlepis*; [j]syn *Prochilodus scrofa*; [l]syn *Paulicea luetkeni.*

Table 1. Continued...

Order/ Family/ Host/ Environment[a]	Site of infection[b]	Locality[c]	Reference[d]
Family Trichiuridae			
Trichiurus lepturus (Linnaeus, 1758)[MAR, BW]	CO, ME, HC	RJ	Barros & Amato (1993), Silva et al. (2000), Luque et al. (2011), Mattos et al. (2014)
Family Centropomidae			
Centropomus undecimalis (Bloch, 1792)[MAR, BW, FW]	ME	RJ, SP	Luque & Poulin (2004), Azevedo et al. (2011), Luque et al. (2011), Eiras et al. (2016)
Family Serranidae			
Cephalopholis fulva (Linnaeus, 1758)[MAR]	ME	RJ	Luque & Poulin (2004), Luque et al. (2011), Eiras et al. (2016)
Family Stromateidae			
Peprilus paru (Linnaeus, 1758)[MAR, BW]	NS	RJ	Luque & Poulin (2004), Luque et al. (2011)
Family Percophidae			
Percophis brasiliensis (Quoy & Gaimard, 1825)[MAR]	ME	RJ	Luque & Poulin (2004), Luque et al. (2011)
Family Gempylidae			
Thyrsitops lepidopoides (Cuvier, 1832)[MAR]	NS	RJ	Domingues & Alves (2015)
Family Lutjanidae			
Lutjanus purpureus (Poey, 1866)[MAR]	NS	[f]	Barros & Cavalcanti (1998)
Lutjanus synagris (Linnaeus, 1758)[MAR]	MU	RJ	Silva & São Clemente (2001)
Family Coryphaenidae			
Coryphaena hippurus (Linnaeus, 1758)[MAR, BW]	MU	RJ	Silva & São Clemente (2001)
Ordem Characiformes			
Family Characidae			
Astyanax fasciatus (Cuvier, 1819)[FW]	ST, BC, ME, AC, LI, IN	SP, MG	Kloss (1966), Vicente et al. (1985), Moravec (1998), Madi & Silva (2005), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016), Vieira-Menezes et al. (2017)
Astyanax altiparanae (Garutti & Britski, 2000)[FW]	ME, IN, BC, ME, IN	PR, SP	Lizama et al. (2008), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Abdallah et al. (2012), Camargo et al. (2016a), Eiras et al. (2016)
Astyanax bockmanni (Vari & Castro, 2007)[FW]	IN	SP	Camargo et al. (2016b)
Astyanax bimaculatus (Linnaeus, 1758)[FW]	ST, BC, ME	SP	Kloss (1966), Vicente et al. (1985), Moravec (1998), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Astyanax schubarti (Britski, 1964)[FW]	ST, BC, ME	SP	Kloss (1966), Vicente et al. (1985), Moravec (1998), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Galeocharax humeralis (Valenciennes, 1834)[FW]	ST, PE, BC	PR	Moravec et al. (1993), Moravec (1998), Vicente & Pinto (1999), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Galeocharax knerii (Steindachner, 1879)[FW]	ST, PE, BC	PR	Vicente et al. (1985), Moravec et al. (1993), Moravec (1998), Vicente & Pinto (1999), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Hemibrycon surinamensis (Géry, 1962)[FW]	IN	AP	Hoshino et al. (2014)
Psellogrammus kennedyi (Eigenmann, 1903)[FW]	NS	PR	Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Tetragonopterus argenteus (Cuvier, 1816)[FW]	NS	NS	Luque et al. (2011), Eiras et al. (2016)

[a]abbreviations: Host species are given followed by their predominant habitat (MAR = marine, FW = freshwater or BW = brackish water); [b]abbreviations: Site of the infection; when possibe these are grouped (AC = abdominal cavity; BC = body cavity; CO = coelom; G = Guts; GI = gills; GO = gonods; GB = gall baldder; H = heart; HC = hepatic capsule; IN = intestine; IC = intestinal cecum; LI = liver; ME = mesenteries; Mu = muscle; SB = swimming bladder; PC = pyloric caeca; PE = peritôneo; ST = stomach; SV = spiral valve; KI = Kidney; GS = gastric serosa; NS = not specified); [c]localities are given in alphabetical order of Brazilian states (AM = Amazonas, AP = Amapá, BA = Bahia, MA = Maranhão, MG = Minas Gerais, MS = Mato Grosso do Sul, MT = Mato Grosso, PA = Pará, PR = Paraná, RJ = Rio de Janeiro, RN = Rio Grande do Norte, RS = Rio Grande do Sul, SP = São Paulo, SE = Sergipe, and TO = Tocantins); [d]records bibliographical by host in chronological sequence; [e]exotic species; [f]localização geografica descrita como Northeast littoral of Brazil; [g]Patinga hybrid, which is the result of interspecific hybridisation between a female (F1) of *Piaractus mesopotamicus* and male (M1) of *Piaractus brachypomus,* both commonly cultured fish in Brazil; [h]syn *Acestrorhampus macrolepis*; [i]syn *Brycon microlepis*; [j]syn *Prochilodus scrofa*; [l]syn *Paulicea luetkeni.*

Table 1. Continued...

Order/ Family/ Host/ Environment[a]	Site of infection[b]	Locality[c]	Reference[d]
Markiana geayi (Pellegrin, 1909)[FW]	NS	NS	Eiras et al. (2016)
Moenkhausia sanctaefilomenae (Steindachner, 1907)[FW]	NS	NS	Eiras et al. (2016)
Oligosarcus macrolepis (Steindachner, 1877)[h, FW]	ST, PE, BC	PR	Kohn et al. (1988), Vicente and Pinto (1999), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Oligosarcus paranensis (Menezes & Géry, 1983)[FW]	BC	NS	Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Oligosarcus sp.[FW]	BC	SP	Travassos et al. (1928), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Family Serrasalmidae			
Metynnis lippincottianus (Cope, 1870)[FW]	IN	PR, AP	Moreira et al. (2009), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Yamada et al. (2012), Hoshino & Tavares-Dias (2014), Eiras et al. (2016)
Metynnis hypsauchen (Müller & Troschel, 1844)[FW]	AC	AP	Oliveira et al. (2015)
Serrasalmus marginatus (Valenciennes, 1837)[FW]	ME, ST, IC	MT, MS, PR	Barros et al. (2006), Vicentin et al. (2011), Luque et al. (2011), Eiras et al. (2016), Casali & Takemoto (2016)
Serrasalmus maculatus (Kner, 1858)[FW]	ME	PR	Casali & Takemoto (2016)
Serrasalmus altuvei (Ramírez, 1965)[FW]	AM		Leão et al. (1991), Eiras et al. (2010), Luque et al. (2011)
Pygocentrus nattereri (Kner, 1858)[FW]	BC, SB ME, LI, ST, IC	MT, PA, MS	Barros et al. (2006), Barros et al. (2010), Luque et al. (2011), Benigno et al. (2012), Vicentin et al. (2013), Eiras et al. (2016)
Pygocentrus cariba (Humboldt, 1821)[FW]	BC	NS	Luque et al. (2011)
Piaractus brachypomus (Cuvier, 1818)[FW]	IN, PC, AC	AP	Oliveira and Tavares-Dias (2016)
Piaractus mesopotamicus (Holmberg, 1887)[FW]	ME, BC	SP	Franceschini et al. (2013a)
Patinga "Hybrid"[g, FW]	ME, BC	SP	Franceschini et al. (2013a)
Family Anostomidae			
Leporinus octofasciatus (Steindachner, 1915)[FW]	NS	SP	Madi & Silva (2005), Eiras et al. (2010)
Leporinus friderici (Bloch, 1794)[FW]	G, ME, IN	PR, AP	Guidelli et al. (2006), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Guidelli et al. (2011), Eiras et al. (2016), Oliveira et al. (2017), Yamada et al. (2017)
Leporinus elongatus (Valenciennes, 1850)[FW]	G, ME, IN	PR	Takemoto et al. (2009), Eiras et al. (2010), Guidelli et al. (2011), Luque et al. (2011)
Leporinus obtusidens (Valenciennes, 1837)[FW]	G, ME, IN	PR	Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Guidelli et al. (2011)
Leporinus lacustris (Amaral Campos, 1945)[FW]	BC, ME, G, ME, IN	SP, PR	Vicente et al. (1985), Moravec (1998), Guidelli et al. (2006), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Guidelli et al. (2011), Eiras et al. (2016)
Leporinus copelandii (Steindachner, 1875)[FW]	IN, BC	SP	Vicente et al. (1985), Moravec (1998), Eiras et al. (2010), Luque et al. (2011)
Leporellus vittatus (Valenciennes, 1850)[FW]	IN, BC	SP, PR	Vicente et al. (1985), Moravec (1998), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011)

[a]abbreviations: Host species are given followed by their predominant habitat (MAR = marine, FW = freshwater or BW = brackish water); [b]abbreviations: Site of the infection; when possibe these are grouped (AC = abdominal cavity; BC = body cavity; CO = coelom; G = Guts; GI = gills; GO = gonods; GB = gall baldder; H = heart; HC = hepatic capsule; IN = intestine; IC = intestinal cecum; LI = liver; ME = mesenteries; Mu = muscle; SB = swimming bladder; PC = pyloric caeca; PE = peritôneo; ST = stomach; SV = spiral valve; KI = Kidney; GS = gastric serosa; NS = not specified); [c]localities are given in alphabetical order of Brazilian states (AM = Amazonas, AP = Amapá, BA = Bahia, MA = Maranhão, MG = Minas Gerais, MS = Mato Grosso do Sul, MT = Mato Grosso, PA = Pará, PR = Paraná, RJ = Rio de Janeiro, RN = Rio Grande do Norte, RS = Rio Grande do Sul, SP = São Paulo, SE = Sergipe, and TO = Tocantins); [d]records bibliographical by host in chronological sequence; [e]exotic species; [f]localização geografica descrita como Northeast littoral of Brazil; [g]Patinga hybrid, which is the result of interspecific hybridisation between a female (F1) of *Piaractus mesopotamicus* and male (M1) of *Piaractus brachypomus,* both commonly cultured fish in Brazil; [h]syn *Acestrorhampus macrolepis*; [i]syn *Brycon microlepis*; [j]syn *Prochilodus scrofa*; [l]syn *Paulicea luetkeni.*

Table 1. Continued...

Order/ Family/ Host/ Environment[a]	Site of infection[b]	Locality[c]	Reference[d]
Schizodon nasutus (Kner, 1858)[FW]	IN, BC	SP	Vicente et al. (1985), Moravec (1998), Eiras et al. (2010), Luque et al. (2011)
Family Erythrinidae			
Hoplias malabaricus (Bloch, 1794)[FW]	PE, G, CC, SM, BC, IN, LI, ST, ME, MU, IC, GO, AC, IC	RJ, PR, SP, MT, PA, AP, MA, RS	Fábio (1982), Vicente et al. (1985), Weiblen & Brandão (1992), Moravec et al. (1993), Moravec (1998), Vicente & Pinto (1999), Martins et al. (2003), Barros et al. (2004), Madi & Silva (2005), Martins et al. (2005), Paraguassú & Luque (2007), Barros et al. (2007), Justino & Barros (2008), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Benigno et al. (2012), Alcântara & Tavares-Dias (2015), Gonçalves et al. (2016), Eiras et al. (2016), Rodrigues et al. (2017), Carvalho et al. (2017)
Hoplerythrinus unitaeniatus (Spix & Agassiz, 1829)[FW]	ME, LI, GO, ST, IN, IC	PA, AP	Martins et al. (2005), Eiras et al. (2010), Benigno et al. (2012), Alcântara & Tavares-Dias (2015), Eiras et al. (2016), Gonçalves et al. (2016)
Family Acestrorhynchidae			
Acestrorhynchus lacustris (Lütken, 1875)[FW]	H, GO, AC, SB, LI, E, S, IN	AM, PR, SP	Carvalho et al. (2003), Takemoto et al. (2009), Luque et al. (2011), Abdallah et al. (2012), Camargo et al. (2015), Leite et al. (2017), Pedro et al. (2016), Eiras et al. (2016)
Acestrorhynchus falcatus (Bloch, 1794)[FW]	IN, LI	AP	Hoshino et al. (2016)
Acestrorhynchus falcirostris (Cuvier, 1819)[FW]	IN, LI	AP	Hoshino et al. (2016)
Family Bryconidae			
Salminus hilarii (Valenciennes, 1850)[FW]	ME	SP	Madi & Silva (2005), Eiras et al. (2010), Luque et al. (2011)
Salminus brasiliensis (Cuvier, 1816)[FW]	BC, ME, IN	SP, PR	Vicente et al. (1985), Moravec (1998), Eiras et al. (2010), Luque et al. (2011), Mesquita et al. (2012), Karling et al. (2013a), Eiras et al. (2016)
Brycon hilarii (Valenciennes, 1850)[i, FW]	ME, LI	MT	Saraiva et al. (2006), Barros et al. (2006), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Brycon amazonicus (Spix & Agassiz, 1829)[FW]	ME	AM	Ribeiro et al. (2016)
Brycon melanopterus (Cope, 1872)[FW]	ME	AM	Ribeiro et al. (2016)
Family Cynodontidae			
Rhaphiodon vulpinus (Spix & Agassiz, 1829)[FW]	ME	PR, MS	Moravec et al. (1993), Moravec (1998), Vicente & Pinto (1999), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Karling et al. (2013b), Eiras et al. (2016)
Family Triportheidae			
Triportheus angulatus (Spix & Agassiz, 1829)[FW]	IN	AP, SP	Abdallah et al. (2012), Oliveira et al. (2016)
Family Curimatidae			
Cyphocharax modestus (Fernández-Yépez, 1948)[FW]	LI	SP	Abdallah et al. (2012), Eiras et al. (2016)
Cyphocharax nagelii (Steindachner, 1881)[FW]	IN, ST	SP	Abdallah et al. (2012), Vieira et al. (2013), Eiras et al. (2016)

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Table 1. Continued...

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Curimata sp.[FW]	BC	SP	Vicente et al. (1985), Moravec (1998), Eiras et al. (2010), Luque et al. (2011)
Family Prochilodontidae			
Prochilodus lineatus (Valenciennes, 1837)[j, FW]	IN, CA, PE, ST	SP, PR	Vicente et al. (1985), Moravec et al. (1993), Moravec (1998), Vicente & Pinto (1999), Eiras et al. (2010), Eiras et al. (2016)
Ordem Siluriformes			
Family Pimelodidae			
Hemisorubim platyrhynchos (Valenciennes, 1840)[FW]	ME	PR	Guidelli et al. (2003), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Pseudoplatystoma fasciatum (Linnaeus, 1766)[FW]	ME, MU	MT	Eiras & Rego (1989), Barros et al. (2006), Barros et al. (2009), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Pseudoplatystoma corruscans (Spix & Agassiz, 1829)[FW]	ME	PR, MT	Moravec et al. (1993), Machado et al. (1994), Machado et al. (1996), Moravec (1998), Vicente & Pinto (1999), Barros et al. (2006), Campos et al. (2008), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Brachyplatystoma filamentosum (Lichtenstein, 1819)[FW, BW]	ME, E, LI, GO, AC, GU, GB, KI	PA	Rodrigues et al. (2015)
Brachyplatystoma rousseauxii (Castelnau, 1855)[FW]	ME, E, LI, GO, AC, GU, GB, KI	PA	Rodrigues et al. (2015)
Pinirampus pirinampu (Spix & Agassiz, 1829)[FW]	ME	MT	Barros et al. (2006), Luque et al. (2011), Eiras et al. (2016)
Zungaro zungaro (Humboldt, 1821)[l, FW]	ME	MT	Barros et al. (2006), Luque et al. (2011), Eiras et al. (2016)
Iheringichthys labrosus (Lütken, 1874)[FW]	IN	PR	Moreira et al. (2005), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Pimelodus maculatus (Lacepède, 1803)[FW]	ME	PR	Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011)
Pimelodus ortmanni (Haseman, 1911)[FW]	ST, PE, BC	PR	Kohn et al. (1988), Vicente & Pinto (1999), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Pimelodus pohli (Ribeiro & Lucena, 2006)[FW]	CO	MG	Sabas & Brasil-Sato (2014), Eiras et al. (2016)
Bergiaria sp.[FW]	ST, PE, BC	PR	Kohn et al. (1988), Vicente & Pinto (1999), Eiras et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Family Auchenipteridae			
Trachelyopterus striatulus (Steindachner, 1877)[FW]	LI	RJ	Azevedo et al. (2011), Luque et al. (2011)
Trachelyopterus galeatus (Linnaeus, 1766)[FW]	IN	AP	Pantoja et al. (2016)
Trachelyopterus coriaceus (Valenciennes, 1840)[FW]	IN	AP	Pantoja et al. (2016)
Auchenipterus osteomystax (Miranda Ribeiro, 1918) [FW]	NS	NS	Eiras et al. (2016)

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Table 1. Continued...

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Ageneiosus inermis (Linnaeus, 1766)[FW]	NS	NS	Eiras et al. (2010), Luque et al. (2011)
Ageneiosus ucayalensis Castelnau, 1855[FW]	IN, CA	AP	Ferreira & Tavares-Dias (2017)
Family Heptapteridae			
Rhamdia quelen (Quoy & Gaimard, 1824)[FW]	ME, ST, IN, LI	SP, RS	Kohn et al. (1989), Madi & Silva (2005), Eiras et al. (2010), Azevedo et al. (2011), Luque et al. (2011), Dias et al. (2016), Eiras et al. (2016)
Pimelodella lateristriga (Lichtenstein, 1823)[FW]	NS	SP	Travassos et al. (1928), Eiras et al. (2010), Luque et al. (2011)
Family Doradidae			
Oxydoras niger (Valenciennes, 1821)[FW]	ME, ST, LI, GO, AC, G, GB, KI	PA	Rodrigues et al. (2015)
Family Ariidae			
Genidens barbus (Lacepède, 1803)[MAR, BW]	ME	RJ	Tavares & Luque (2004), Luque & Poulin (2004), Luque et al. (2011), Eiras et al. (2016)
Family Loricariidae			
Loricariichthys castaneus (Castelnau, 1855)[FW]	ME	SP	Azevedo et al. (2011), Luque et al. (2011), Eiras et al. (2016)
Ordem Carcharhiniformes			
Family Carcharhinidae			
Carcharhinus brachyurus (Günther, 1870)[MAR]	SV	RS	Knoff et al. (2001), Luque et al. (2011), Eiras et al. (2016)
Carcharhinus signatus (Poey, 1868)[MAR]	SV, ST	PR	Knoff et al. (2001), Luque et al. (2011), Eiras et al. (2016)
Family Triakidae			
Galeorhinus galeus (Linnaeus, 1758)[MAR]	SV	RS	Knoff et al. (2001), Luque et al. (2011), Eiras et al. (2016)
Mustelus canis (Mitchill, 1815)[MAR, BW]	SV, ST	RS	Knoff et al. (2001), Luque et al. (2011)
Mustelus schmitti (Springer, 1939)[MAR]	SV	RS	Knoff et al. (2001), Luque et al. (2011)
Family Scyliorhinidae			
Scyliorhinus haeckelii (Miranda Ribeiro, 1907)[MAR]	SV, ST	PR	Knoff et al. (2001), Luque et al. (2011)
Family Sphyrnidae			
Sphyrna zygaena (Linnaeus, 1758)[MAR, BW]	SV, ST	RS	Knoff et al. (2001), Luque et al. (2011)
Ordem Tetraodontiformes			
Family Balistidae			
Balistes capriscus (Gmelin, 1789)[MAR]	ME	RJ	Luque & Poulin (2004), Alves et al. (2005), Luque et al. (2011), Eiras et al. (2016)
Balistes vetula (Linnaeus, 1758)[MAR]	ME	RJ	Luque & Poulin (2004), Alves et al. (2005), Luque et al. (2011), Eiras et al. (2016)
Family Monacanthidae			
Aluterus monoceros (Linnaeus, 1758)[MAR]	LI, ME	RJ	Luque & Poulin (2004), Dias et al. (2010), Luque et al. (2011), Eiras et al. (2016)
Ordem Clupeiformes			
Family Clupeidae			
Harengula clupeola (Cuvier, 1829)[MAR]	NS	BA	Guimarães & Cristofaro (1974)

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Brevoortia aurea (Spix & Agassiz, 1829)[MAR]	ME	RJ	Luque & Poulin (2004), Luque et al. (2011), Eiras et al. (2016)
Ordem Scorpaeniformes			
Family Dactylopteridae			
Dactylopterus volitans (Linnaeus, 1758)[MAR, BW]	ME	RJ	Luque & Poulin (2004), Cordeiro & Luque (2005), Luque et al. (2011), Eiras et al. (2016)
Ordem Gymnotiformes			
Family Gymnotidae			
Gymnotus carapo (Linnaeus, 1758)[FW]	ST, ME, IN	SP, RJ	Moravec (1998), Takemoto et al. (2009), Eiras et al. (2010), Luque et al. (2011), Azevedo et al. (2011), Eiras et al. (2016)
Gymnotus sp. [FW]	ME	MS	Isaac et al. (2004), Eiras et al. (2016), Ventura et al. (2016, 2018)
Ordem Gadiformes			
Family Phycidae			
Urophycis mystacea (Miranda Ribeiro, 1903)[MAR]	ME	RJ	Luque et al. (2011)
Urophycis brasiliensis (Kaup, 1858)[MAR]	ME	RJ	Alves et al. (2004), Luque et al. (2011)
Ordem Lophiiformes			
Family Lophiidae			
Lophius gastrophysus (Miranda Ribeiro, 1915)[MAR]	ME	RJ	Saad et al. (2012), Eiras et al. (2016)
Ordem Ophidiiformes			
Family Ophidiidae			
Genypterus brasiliensis (Regan, 1903)[MAR]	ME	RJ	Alves et al. (2002), Knoff et al. (2007), Luque et al. (2011), Mattos et al. (2014)
Genypterus blacodes (Forster, 1801)[MAR]	NS	NS	Eiras et al. (2016)
Ordem Pleuronectiformes			
Family Paralichthyidae			
Paralichthys isosceles (Jordan, 1891)[MAR]	ME, IN	RJ	Luque & Poulin (2004), Felizardo et al. (2009), Luque et al. (2011), Alarcos et al. (2016), Eiras et al. (2016)
Paralichthys patagonicus (Jordan, 1889)[MAR]	MU, ST, IN, AC	RJ	Fonseca et al. (2016)
Xystreurys rasile (Jordan, 1891)[MAR]	ST, IN, AC	RJ	Fonseca et al. (2016)
Ordem Rajiformes			
Family Rajidae			
Dipturus trachyderma (Krefft & Stehmann, 1975)[MAR]	SV, ST	PR	Knoff et al. (2001), Luque et al. (2011), Eiras et al. (2016)
Ordem Hexanchiformes			
Family Hexanchidae			
Heptranchias perlo (Bonnaterre, 1788)[MAR]	SV	PR	Knoff et al. (2001), Luque et al. (2011), Eiras et al. (2016)
Hexanchus griseus (Bonnaterre, 1788)[MAR]	SV	PR	Knoff et al. (2001), Luque et al. (2011), Eiras et al. (2016)
Ordem Squatiniformes			
Family Squatinidae			
Squatina sp. [MAR]	SV	RJ	Knoff et al. (2001), Luque et al. (2011)

[a]abbreviations: Host species are given followed by their predominant habitat (MAR = marine, FW = freshwater or BW = brackish water); [b]abbreviations: Site of the infection; when possibe these are grouped (AC = abdominal cavity; BC = body cavity; CO = coelom; G = Guts; GI = gills; GO = gonods; GB = gall baldder; H = heart; HC = hepatic capsule; IN = intestine; IC = intestinal cecum; LI = liver; ME = mesenteries; Mu = muscle; SB = swimming bladder; PC = pyloric caeca; PE = peritôneo; ST = stomach; SV = spiral valve; KI = Kidney; GS = gastric serosa; NS = not specified); [c]localities are given in alphabetical order of Brazilian states (AM = Amazonas, AP = Amapá, BA = Bahia, MA = Maranhão, MG = Minas Gerais, MS = Mato Grosso do Sul, MT = Mato Grosso, PA = Pará, PR = Paraná, RJ = Rio de Janeiro, RN = Rio Grande do Norte, RS = Rio Grande do Sul, SP = São Paulo, SE = Sergipe, and TO = Tocantins); [d]records bibliographical by host in chronological sequence; [e]exotic species; [f]localização geografica descrita como Northeast littoral of Brazil; [g]Patinga hybrid, which is the result of interspecific hybridisation between a female (F1) of *Piaractus mesopotamicus* and male (M1) of *Piaractus brachypomus,* both commonly cultured fish in Brazil; [h]syn *Acestrorhampus macrolepis*; [i]syn *Brycon microlepis*; [j]syn *Prochilodus scrofa*; [l]syn *Paulicea luetkeni.*

The biogeographical study of fish species presents in the Brazilian ichthyofauna that are reported as intermediate hosts of *Contracaecum* larvae are presented in a retrospective study obtained in articles published in Brazil between 1928 and 2018. This study identified 16 Orders (Cichliformes, Perciformes, Characiformes, Siluriformes, Tetraodontiformes, Carcharhiniformes, Clupeiformes, Scorpaeniformes, Gymnotiformes, Gadiformes, Lophiiformes, Ophidiiformes, Pleuronectiformes, Rajiformes, Hexanchiformes, Squatiniformes); 49 families; 96 genera, 140 species and morphotypeg "Patinga" hybrid, which is the result of interspecific hybridisation between a female (F1) of *Piaractus mesopotamicus* and male (M1) of *Piaractus brachypomus*, all distributed in three aquatic habitats (Fig. 4). Freshwater fish was the most prevalent, with 56% of the fish of this environment parasitized by *Contracaecum* larvae, followed by marine fish (25%) and estuarine fish (19%).

The fish of the order Perciformes were the most representative in number of families, while the order Characiformes showed the greatest richness of species that are intermediate hosts of *Contracaecum* larvae. The order Cichliformes although it showed low diversity in providing hosts, demonstrated its importance by including genera of great economic value to the Amazon region such as *Astronotus*, *Cichla*, *Crenicichla* and *Geophagus*. In relation to the diversity of hosts and available information, the State of Rio de Janeiro appears first in the number of fishes recorded as having larvae of Anisakidae, followed respectively by the states of Paraná and São Paulo; additionally, these larvae are distributed in another 12 Brazilians states. Among the species with the highest number of scientific records of parasitism by larvae of *Contracaecum* the piscivorous species, *Hoplias malabaricus* is the one most cited, besides the species *Geophagus brasiliensis* and *A. ocellatus,* the species used in this study, with the mesentery and intestinal serosa being the main sites of infection of this parasite with 52% and 27% respectively (Table 1 and 2).

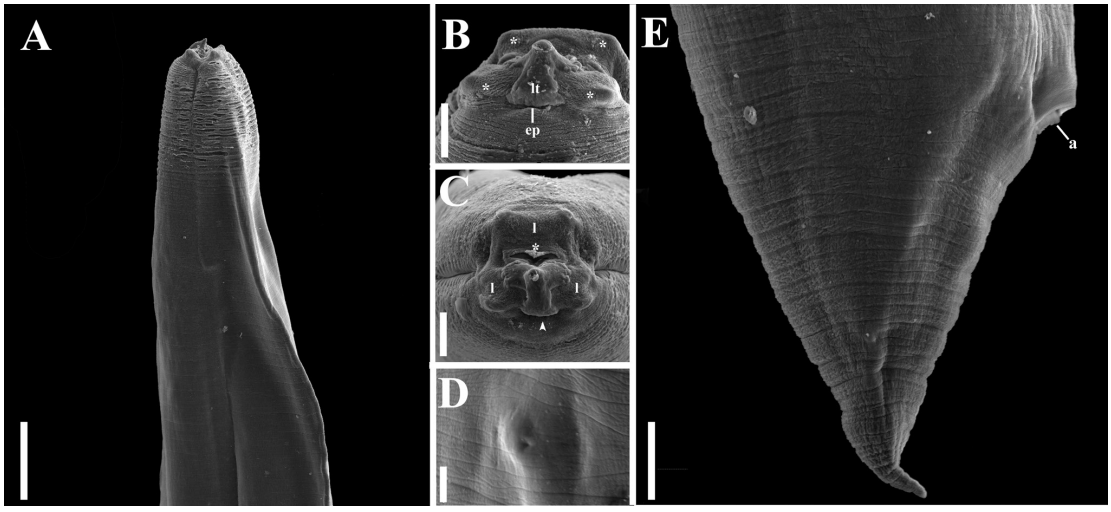

Figure 3. Scanning electron micrographs of *Contracaecum* sp. (L3 larvae) parasite of *A. ocellatus:* (A) Cephalic region showing evidence cuticle with transversal striations and larval tooth. Bar = 20 µm; (B) Side view of cephalic region with papillae (*), larval tooth (lt) and excretory pore (ep). Bar = 20 µm. (C) Frontal view of the oral opening with three lips (l), mouth opening, larval tooth and excretory pore (arrow head). (D) Detail of deirid. Bar = 20 µm. (E) Posterior portion, (a) anus, the tail without mucron. Bar = 20 µm.

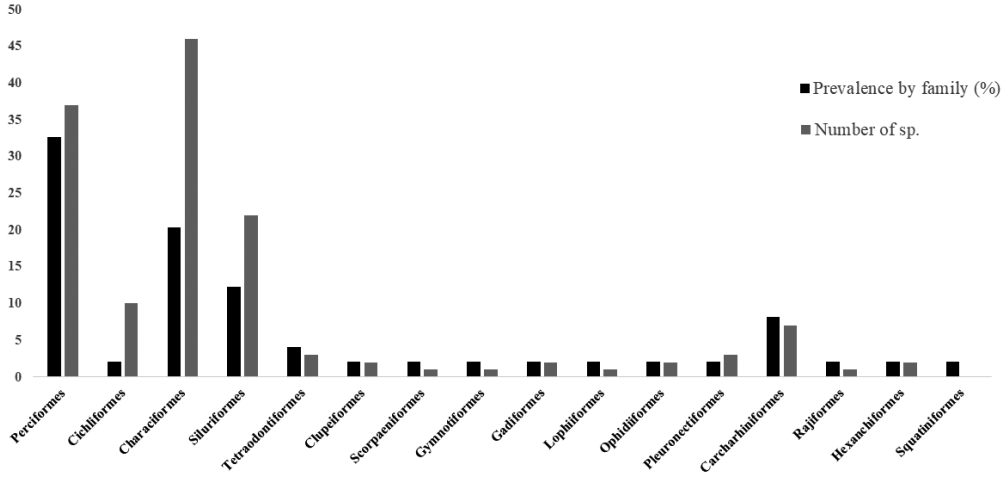

Figure 4. Distribution and prevalence of families by orders and diversity of fish that are hosts of *Contracaecum* larvae in Brazil.

Table 2. Morphological and morphometric comparison of third-stage larvae of *Contracaecum* sp. collected from *Astronotus ocellatus* commercialized in the state of Pará.

Character	Third stage larvae the *Contracaecum* spp.				
Hosts larvae	*Astronotus ocellatus*	Type 1 *Galeocharax humeralis; Rhaphiodon vulpinus*	Type 2 *Rhaphiodon vulpinus; Prochilodus lineatus*[c]	*Hoplias malabaricus; Hoplerythinus unitaeniatus*	*Paralichthys isosceles*
Locality	**Santarém–Pará**	**Paraná**	**Paraná**	**Maranhão**	**Rio de Janeiro**
Environment	**Freshwater**	**Freshwater**	**Freshwater**	**Freshwater**	**Marine**
Prevalence	**67.5%**	–	–	**100% and 80%**	**3.3%**
Length[a]	**11-16**	3.89-4.80	15.70-25.70	12-34.50	4.88-5.06
Width	**367-533**	150-313	449-843	320-710	90-220[d]
Nervous ring	**260-313**	205-225	313-381	180-370	140-180
Esophagus[L, ab]	**1-2**	537-693	1.97-2.11	1.87-2.61	640-700
Esophagus[W]	**66-133**	–	–	60-120	30-90
Intestinal cecum[L, ab]	**1-1.5**	310-476	1.50-1.58	1.20-2.15	280-330
Intestinal cecum[W,b]	**120-167**	–	–	160-280	–
Ventriculus[L,b]	**66-120**	24-33	63	60-120	–
Ventriculus[W,b]	**60-120**	33-36	81	60-120	40-100
Ventricular appendix[L,b]	**233-460**	510-721	462-503	400-720	420-500
Ventricular appendix[W,b]	**66-93**	–	–	60-150	–
Genital primordium[a]	**3-5**	–	–	–	–
Rectum	**110-233**	–	–	–	–
Tail	**100-200**	78-126	95	100-220	140-170
Mucron	**Absent**	–	–	Absent	Absent
Reference	From this study	Moravec et al. (1993)	Moravec et al. (1993)	Martins et al. (2005)	Felizardo et al. (2009)

Character	Third stage larvae the *Contracaecum* spp.					
Hosts larvae	*Lophius gastrophysus*	*Cynoscion guatucupa*	*Pygocentrus nattereri*	*Paralichthys patagonicus*	*Xystreurys rasile*	*Astyanax fasciatus*
Type locality	**Rio de Janeiro**	**Rio de Janeiro**	**Mato Grosso do Sul**	**Rio de Janeiro**	**Rio de Janeiro**	**Minas Gerais**
Environment	**Marine**	**Marine**	**Freshwater**	**Marine**	**Marine**	**Freshwater**
Prevalence	**8.3%**	**6.6%**	**61.84%**	**8.3%**	**13.3%**	**58.11%**
Length[a]	4.14	2.9-4.25	15.11-27.25	3.05-4.80	3.25-4.30	2.75-4.55
Width	90	110-150	617-798	140-190	140-160	93-197
Nervous ring	60	170-180	160-280	160-170	160-170	144-220
Esophagus[L, ab]	200	430-550	1.7-2.93	600-650	550-600	201-309
Esophagus[W, b]	–	–	–	250-280	250-260	15-42
Intestinal cecum[L, ab]	100	200-310	1.42-2.74	260-300	270-290	227-482
Intestinal cecum[W, b]	–	–	–	–	–	
Ventriculus[L, b]	20	50-75	114-243	20-40	40-70	41-83
Ventriculus[W, b]	30	30-65	76-169	30-35	30-40	11-32
Ventricular appendix[L, b]	360	400-470	400-770	440-460	440-450	367-682
Ventricular appendix[W, b]	–	–	–	130-160	130-150	–
Genital primordium[a]	–	–	–	–	–	–
Rectum	–	–	–	–	–	–
Tail	120	80-110	140-260	110-140	110-130	74-130
Mucron	–	Absent	Absent	Absent	Absnet	Absent
	Saad et al. (2012)	Fontenelle et al. (2013)	Vicentin et al. (2013)	Fonseca et al. (2016)	Fonseca et al. (2016)	Vieira-Menezes et al. (2017)

[a]Measurements in micrometers unless indicated; The parameter number of buds is given in amplitude; [b]Abbreviations: L = length, W = width; [c]Other hosts cited by Moravec, Kohn, Fernandes 1993: *Pseudoplatystoma corruscans*; *Galeocharax humeralis*; *Rhaphiodon vulpinus*; *Hoplias malabaricus*; *Plagioscion squamosissimus*; *Crenicichla lepidota*; [d]Measurement of the width withdrawn in the middle of the body.

Discussion

The nematode found parasitizing the intestine and mesentery of *A. ocellatus* of the municipality of Santarém, state of Pará has characteristics similar to the *Contracaecum* genus, including an oesophagus with small ventricle, ventricular appendix, caecum that extends anteriorly to the nerve ring, an excretory pore opening at the head end slightly posterior to the larval tooth at the base of the ventral lip, oval and transversal buccal opening, surrounded by three lips. According to Moravec (1998), Timi et al. (2001), Felizardo et al. (2009) and Fonseca et al. (2016) these are important characteristics for diagnosing nematodes in the Anisakidae (Skrjabin & Karokhin, 1945) included *Contracaecum* (Railliet & Henry, 1912).

The *Contracaecum* larvae parasites of *A. ocellatus* present morphological and morphometric similarities with the other described larvae parasitizing different hosts in Brazil; however, we do not consider it appropriate to morphologically and morphometrically the classify larvae found in this work as morphotype I, II as suggested by Moravec et al. (1993). We corroborate Moravec (1998), Moravec et al. (2016) in affirming that the systematics of *Contracaecum* fish parasites have been based on the morphology of the adult; while systematics of the larvae remains undeveloped, which makes it impossible to attribute more specific taxonomic levels to the larval forms. Morphological and morphometric data on the third-stage larvae *Contracaecum* parasite of *A. ocellatus* of the municipality of Santarém are compared to the morphometric data of larvae harvested from different hosts in Brazil in Table 2.

Although this is the first record of the prevalence, morphology and morphometry of *Contracaecum* larvae in the municipality of Santarém, state of Pará in *A. ocellatus,* a fish of ornamental and food importance in the region, other authors such as Moravec (1998), Azevedo et al. (2007; 2010; 2011) and Luque et al. (2011) have already reported the occurrence of this genus parasitizing *A. ocellatus* introduced in different localities of Brazil.

Astronotus ocellatus from the Tapajós river in Santarém-PA presented a prevalence of 67.5% of infection, and a total infection intensity of 150 larvae of *Contracaecum* encysted in the intestinal serosa and mesentery. Azevedo et al. (2007; 2010; 2011) reported the occurrence of *Contracaecum* larvae parasitizing *A. ocellatus* introduced in the Rio Guandu in the State of Rio de Janeiro, with a prevalence of 2.8%. Latini & Petrere (2004) and Azevedo et al. (2007) state that introduction of exotic fish into new habitats may cause changes in the composition of the local fish fauna to the point of altering the ecological flow, modifying reproduction, growth and development in local species, reducing the abundance of young individuals and parental cross-breeding, all leading to a reduction in the genetic and population biodiversity of some species. These factors influence the parasitic microbiota of native fish, introducing parasites previously not found in these habitats.

For the northern region of Brazil, there are few reports of the occurrence of *Contracaecum* larvae in commercially important fish, especially the Cichlidae family, since the family is very diverse in the Amazonian biome. For *A. ocellatus* in the northern region, only the works of Neves et al. (2013), Tavares-Dias et al. (2014), Bittencourt et al. (2014) and Tavares-Dias & Neves (2017) have reported the occurrence and prevalence of parasitism by *Contracaecum* larvae in the states of Amapá and Amazonas, but the prevalence of *A. ocellatus* infection observed in this study stands out when compared to other states of northern Brazil. Table 3 presents the studies that reported the occurrence and prevalence of *Contracaecum* larvae in the Amazonian biome in the last 10 years.

In this study the level of parasitic infection of *A. ocellatus* (67.5%) by *Contracaecum* sp. was high, while other authors reported parasitism by *Contracaecum* sp. in different hosts in the Brazilian Amazon region. Salgado (2011) showed a prevalence of 17.5% of *Contracaecum* sp. in *Cichla* spp. commercialized in southeastern Pará; Benigno et al. (2012), analysed *Hoplerythrinus unitaeniatus* (Spix & Agassiz, 1829), *Hoplias malabaricus* (Bloch, 1794) and *Pygocentrus nattereri* Kner, 1858, species consumed on the island of Marajó and reported a prevalence of 34.31%, 41.35% and 58.42% by *Contracaecum* larvae, in addition to the occurrence of coinfection with other nematodes. Rodrigues et al. (2015) reported *Contracaecum* larvae in 5 different species of fish from the northeast of Pará, with prevalence of 60% in the municipality of Colares and 40% in Vigia municipality, both in the State of Pará.

Of the 26 Brazilian States and the federal district, the occurrence of *Contracaecum* larvae was recorded in 15 states. Although the highest prevalence of occurrence is in the studies of freshwater fish, the State of Rio de Janeiro appears first in the number of records in the literature for of Anisakidae larvae, primarily in marine fish. Pavanelli et al. (2013), warn about parasite diversity in fish, reporting that less than 25% of the Brazilian ichthyofauna have been studied in order to learn about their parasitic fauna, with the Amazon region and Paraná basin the important areas in generating of research into parasites of aquatic organisms, while other regions of Brazil remain as a vast field to be explored.

This work contributes new quantitative data on infections by *Contracaecum* larvae, informing the population of the occurrence of this parasite in 16 orders, 49 family, 96 genera, 140 species and Patinga hybrid of fish, with the ichthyofauna of the freshwater environment being the ones most cited as intermediate hosts for this genus. According to Pavanelli et al. (2015), the genus *Contracaecum* has a wide geographic distribution and has been observed in wild fish and in culture systems, having been found parasitizing more than 70 species of fish in almost all regions of the country. For Agostinho et al. (2005) in Brazil, the number of fish in continental aquatic ecosystems is still imprecise and difficult to estimate, especially because of the number of unregulated watersheds, infrastructure required for sampling, dispersal information or often difficult to access, and the need for taxonomic revision for several groups.

Hoplias malabaricus, *Geophagus brasiliensis* and *Astronotus ocellatus,* the species used in herein are generally carnivorous (FROESE & PAULY, 2018). *H. malabaricus* and *A. ocellatus* are preferentially piscivorous as adults, but feed on plankton, crustaceans, insects and seeds as juveniles (SANTOS et al., 2006; FROESE & PAULY, 2018). Micro-crustaceans are the first intermediate hosts and fish act as second intermediate hosts or as paratenic hosts of *Contracaecum* larvae, while piscivorous birds are the definitive hosts (MOREIRA et al., 2009; MORAVEC, 2009).

The species of the orders Perciformes and Characiformes were the most cited as intermediate hosts of *Contracaecum* larvae.

Table 3. Prevalence and comparison of larvae of *Contracaecum* sp. the parasite *Astronotus ocellatus* is commercialized in the state of Pará and compared to larvae of *Contracaecum* spp. larvae of parasites of different hosts of northern Brazil registered in the last 10 years.

Host	Locality	Prevalence (%)	Reference
Astronotus ocellatus	**Pará**	**67.5**	**From this study**
	Amapá	53	Neves et al. (2013)
	Amazon	25	Tavares-Dias et al. (2014)
	Amapá	38.5	Bittencourt et al. (2014)
	Amapá	24.2	Tavares-Dias & Neves (2017)
Hoplias malabaricus	Pará	43	Benigno et al. (2012)
	Amapá	51.5; 33.3; 6.1[a]	Alcântara & Tavares-Dias (2015)
	Amapá	69.7; 70.67[b]	Gonçalves et al. (2016)
	Amapá	83.3; 10; 10; 3.3[c]	Oliveira et al. (2018)
Hoplerythrinus unitaeniatus	Pará	35	Benigno et al. (2012)
	Amapá	63.3; 20[d]	Alcântara & Tavares-Dias (2015)
	Amapá	76.75; 74.4[b]	Gonçalves et al (2016)
	Amapá	90; 3.3[e]	Oliveira et al. (2018)
Pygocentrus nattereri	Pará	59	Benigno et al. (2012)
	Amapá	53.3	Brito-Junior & Tavares-Dias (2018)
Metynnis lippincottianus	Amapá	68.7	Hoshino and Tavares-Dias (2014)
Hemibrycon surinamensis	Amapá	15.1	Hoshino et al. (2014)
Plagioscion squamosissimus	Pará	70	Rodrigues et al. (2015)
Brachyplatystoma filamentosum	Pará	68.18	Rodrigues et al. (2015)
Brachyplatystoma rousseauxii	Pará	90	Rodrigues et al. (2015)
Oxydoras niger	Pará	10	Rodrigues et al. (2015)
Metynnis hypsauchen	Amapá	3.3	Oliveira et al. (2015)
Piaractus brachypomus	Amapá	32.3; 14.7; 5.9[f]	Oliveira & Tavares-Dias (2016)
Acestrorhynchus falcatus	Amapá	93.4	Hoshino et al. (2016)
Acestrorhynchus falcirostris	Amapá	81.8	Hoshino et al. (2016)
Triportheus angulatus	Amapá	3.3	Oliveira et al. (2016)
Trachelyopterus coriaceus	Amapá	17.1	Pantoja et al. (2016)
Trachelyopterus galeatus	Amapá	13.5	Pantoja et al. (2016)
Brycon amazonicus	Amazonas	10; 16.13[g]	Ribeiro et al. (2016)
Brycon melanopterus	Amazonas	60	Ribeiro et al. (2016)
Cichla monoculus	Amazonas	7.89	Santana et al. (2017)
Gymnotus carapo	Amapá	60	Brito-Junior & Tavares-Dias (2018)
Astyanax abramis	Amapá	33.3	Brito-Junior & Tavares-Dias (2018)
***Astyanax* sp.**	Amapá	40	Brito-Junior & Tavares-Dias (2018)

[a]Prevalence by site of infection intestine, caecum and liver respectively; [b]Seasonal variation of parasitism prevalence according to the dry season and rainy season respectively; [c]Prevalence by site of infection mesentery, cecum, live and intestine; [d]Prevalence by site of infection intestine and caecum respectively; [e]Prevalence by site f infection mesentery and intestine; [f]Prevalence by site of infection intestine, pyloric cecum and abdominal cavity respectively; [g]Prevalence of the parasitisms of *Contracaecum* sp. of *Brycon amazonicus* collected in Rio Negro and Solimões respectively.

Takemoto & Lizama (2010) noted the low host specificity for nematodes, especially in the larval stage. Parasitism in these two orders, in addition to the order Cichliformes, is important because they harbor that are widely consumed in the northern region, such as apaiari (*A. ocellatus*), tucunaré (*Cichla* spp.), pescada branca (*Plagioscion squamosissimus*), pescada (*Macrodon ancylodon*), lambarí (*Astyanax* spp.), Piau (*Leporinus* spp.), as well as fish of high importance for the Brazilian aquaculture sector, such as pacu (*Piaractus mesopotamicus*), pirapitinga (*Piaractus brachypomus*), matrinxã (*Brycon* spp.), Curimbata (*Prochilodus* spp.), and other species, which are commercialized as ornamental fish or are important elements in the ecological flow of Amazonian aquatic environments, even though they are not consumed by the Brazilian population, especially in the northern region.

Conclusions

The morphological, morphometric, biogeographic and prevalence data of the *Contracaecum* larvae provided here are important because they reinforce *A. ocellatus* as the intermediate host of this nematode. In addition to the aquariophilic value of *A. ocellatus* that is important to the Amazonian region as a source of foreign exchange, this fish is part of the food base for riverside populations, and is also consumed by other animals that live on the

banks of the Tapajós river, and are therefore potential intermediate or definitive hosts of this parasite, either by completing the cycle or by increasing its geographical distribution.

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