


# Isopods Cymothoidae ectoparasites of fish from the Amazon

## Isópodes Cymothoidae ectoparasitos de peixes da Amazônia

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### Abstract

Most freshwater species of Cymothoidae are distributed in South America. They have mainly been recorded in the eastern and western regions of the Amazon River basin. However, in this ecosystem, the biodiversity of this group may be greater if the entire Amazon basin is considered. In this regard, the aim of the present study was to provide an updated list of isopod species of the family Cymothoidae that are found in fish in the Brazilian Amazon region and to report on new fish host occurrences and expanded geographical distributions for cymothoid isopods that parasitize fish in the southwestern Brazilian Amazon region. The parasites found in fish specimens were collected, fixed and identified later. We found eight species of Cymothoidae parasitizing different host fish species in the southwestern Amazon region. However, we found 14 species of Cymothoidae throughout the Brazilian Amazon region. Three additional species are thus reported here, which increases the number of species of Cymothoidae in this region to 17. These additional species are also new records for Brazil. Therefore, this study has contribute to expand the knowledge about the distribution and diversity of Cymothoidae in the Amazon basin.

**Keywords:** Amazon River basin, geographical distribution, Cymothoidae, freshwater fish, diversity.

### Resumo

A maioria das espécies de água doce de Cymothoidae está distribuída na América do Sul e foi registrada principalmente nas regiões Leste e Oeste da bacia do Rio Amazonas. Entretanto, nesse ecossistema, a biodiversidade desse grupo pode ser maior se toda a bacia amazônica for considerada. Nesse sentido, o objetivo do presente estudo foi fornecer uma lista atualizada de espécies de isópodes da família Cymothoidae que são encontrados em peixes na Região Amazônica brasileira e relatar novas ocorrências de peixes hospedeiros, ampliando as distribuições geográficas para isópodes cimotoides que parasitam peixes na região Sudoeste da Amazônia brasileira. Os parasitos encontrados em espécimes de peixes coletados foram analisados e posteriormente identificados. Foram encontradas oito espécies de Cymothoidae parasitando diferentes espécies de peixes hospedeiros na região Sudoeste da Amazônia. No entanto, foram encontradas 14 espécies de Cymothoidae em toda a Região Amazônica brasileira. Três novos relatos de espécies foram observados, o que aumenta o número de espécies de Cymothoidae nessa região para 17. Essas espécies relatadas, também são novos registros para o Brasil. Portanto, este estudo ajudou a expandir o conhecimento sobre a distribuição e diversidade de Cymothoidae na bacia amazônica.

**Palavras-chave:** Bacia do Rio Amazonas, distribuição geográfica, Cymothoidae, peixes de água doce, diversidade.

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## Introduction

The family Cymothoidae comprises around 40 genera and 380 species that have been described. Some species occur in both marine and freshwater environments (Ahyong et al., 2011; Smit et al., 2014). They are obligate parasites, and mostly use fish as their hosts, although some parasitize shrimps (Smit et al., 2014). Unlike other groups of parasites, isopods have a large body (~ 10 to 50 mm). Moreover, these parasites have morphological characteristics specific to parasitic life, such as buccal appendages with setae similar to the robust curved terminal and subterminal spines that serve to attach the parasite to the host tissue as well, and nails modified into powerful claws to attach to the host (Brusca et al., 2001).

Most species of Cymothoidae attach to the integument, fins, tongue, gills and buccal cavity (e.g. those in the genera *Anphira*, *Asotana*, *Braga*, *Cymothoa*, *Livoneca*, *Paracymothoa* and *Telotha*) (Thatcher, 1988; Araujo et al., 2009; Gomiero et al., 2012; Martin et al., 2016; Murrieta-Morey et al., 2016; Oliveira et al., 2017). Other species drill holes in the host integument (e.g. those in the genera *Riggia* and *Artystone*) (Magalhães et al., 2018; Oliveira et al., 2019). The host specificity in those parasites varies according to the genus and may be high (e.g. genera *Cymothoa* and *Mothocya*) or low (e.g. genera *Braga* and *Nerocila*) (Brusca et al., 2001; Tavares-Dias et al., 2014).

The highest diversity of cymothoid isopods is concentrated in the tropics, with well-known distribution in marine environments. However, they have only been poorly studied in freshwater ecosystems (Smit et al., 2014). Most freshwater species (around 13) are distributed in South America, mainly in the Amazon River basin (Thatcher et al., 2003). These species were collected in its eastern region (around 9) and central region (around 6), which concentrate the highest cymothoid diversity (Thatcher, 1993; Magalhães et al., 2018; Oliveira et al., 2017; Esteves-Silva et al., 2020). Furthermore, the northwestern Amazon region is the only area in which the occurrence of *Asotana magnifica* Thatcher, 1988 has been reported, parasitizing the mouth cavity of a specimen of *Serrasalmus* sp. (Thatcher, 1988) (Table 1).

**Table 1.** Cymothoidae species in fish of the Brazilian Amazon.

Parasite species	Host species	IS	Locations	References
<i>Anphira branchialis</i>	<i>Serrasalmus spilopleura</i>	Gill chamber	Solimões River, AM; Ilha de Maracá - RR	Thatcher (1993), Murrieta-Morey et al. 2016
	<i>Pygocentrus nattereri</i>	Gill chamber	Solimões River, AM; Ilha de Maracá - RR	Thatcher (1993), Murrieta-Morey et al. 2016, Vital et al. (2011)
	<i>Serrasalmus altispinis</i>	Gill chamber	Solimões River, AM	Murrieta-Morey et al. (2016)
<i>Vanamea symmetrica</i>	<i>Serrasalmus altispinis</i>	Gill chamber	Solimões River, AM	Murrieta-Morey et al. 2016
	<i>Serrasalmus spilopleura</i>	Mouth cavity	Amazon River, AM	Thatcher (1993)
	<i>Serrasalmus elongatus</i>	Mouth cavity	Amazon River, AM	
<i>Anphira junki</i>	<i>Triportheus albus</i>	Gill chamber	Solimões River, AM	Araújo & Thatcher (2003)
	<i>Triportheus flavus</i>	Gill chamber	Solimões River, AM	
<i>Anphira xinguensis</i>	<i>Ossubtus xinguense</i>	Gill chamber	Xingu River, PA	Thatcher (1995)
	<i>Metynnis lippincottianus</i>	Gill	Xingu River, PA	Magalhães et al. (2018)
	<i>Metynnis hypsauchen</i>	Gill	Xingu River, PA	
	<i>Metynnis altidorsalis</i>	Gill	Xingu River, PA	
<i>Artystone minima</i>	<i>Nannostomus beckfordi</i>	Tegumentar orifice	Upper Rio Negro, AM	Thatcher & Carvalho (1988)
<i>Artystone trysibia</i>	<i>Caquetaia spectabilis</i>	Tegumentar orifice	Jari River, AP	Oliveira et al. (2019)

AM: Amazonas state; AP: Amapá state; RR: Roraima state; PA: Pará state; TO: Tocantins state; MT: Mato Grosso state; NI: Not informed.

Table 1. Continued...

Parasite species	Host species	IS	Locations	References
	<i>Geophagus brasiliensis</i>	Tegumentar orifice	Roraima River, RR	Van Name (1936)
<i>Asotona magnifica</i>	<i>Serrasalmus</i> sp.	Mouth cavity	Uraricoera River, RR	Thatcher (1988)
<i>Braga amapaensis</i>	<i>Acestrorhynchus microlepis</i>	Mouth cavity	Upper Araguari River, AP	Thatcher (1996)
	<i>Acestrorhynchus guyanensis</i>	Mouth cavity	Upper Araguari River, AP	
<i>Braga cichlae</i>	<i>Cichla temensis</i>	Mouth cavity	Negro River, AM	Araujo et al. (2009)
<i>Braga fluviatilis</i>	<i>Leporinus friderici</i>	Mouth cavity	Jari River, AP	Oliveira et al. (2017)
	<i>Salminus maxillosus</i>	NI	Xingu River, MT	Lemos de Castro (1959)
	<i>Loricaria anus</i>	NI	Xingu River, MT	
<i>Braga nasuta</i>	<i>Arapaima gigas</i>	Tegument	Fish-farming in Parauapebas, PA	Jesus et al. (2017)
<i>Braga patagonica</i>	<i>Hoplias malabaricus</i>	Gill	Igarapé Fortaleza River, AP	Alcântara & Tavares-Dias (2015)
	<i>Plasgioscion squamosissimus</i>	Mouth cavity; gills	Middle Solimões, AM	Tavares-Dias et al. (2014)
	<i>Pygocentrus nattereri</i>	Mouth cavity; gills	Middle Solimões, AM	
<i>Colossoma macropomum</i>		Mouth cavity; gills	Middle Solimões, AM	
	<i>Serrasalmus</i> sp.	Mouth cavity; gills	Middle Solimões, AM	
	<i>Serrasalmus rhombeus</i>	Mouth cavity; gills	Middle Solimões, AM	
	<i>Mylossoma duriventre</i>	Mouth cavity; gills	Middle Solimões, AM	
	<i>Brycon amazonicus</i>	Mouth cavity; gills	Middle Solimões, AM	
	<i>Chaetobranchopsis orbicularis</i>	Mouth cavity; gills	Middle Solimões, AM	
	<i>Hydrolycus scombreoides</i>	Mouth cavity; gills	Middle Solimões, AM	
<i>Colossoma macropomum</i>		Tegument	Fish-farming in Macapá, AP	Dias et al. (2015)
<i>Chaetobranchus flavescens</i>		Gill	Igarapé Fortaleza River, AP	Tavares-Dias et al. (2018)
<i>Acestrorhynchus falcatus</i>		Gill	Igarapé Fortaleza River, AP	Hoshino et al. (2016)
<i>Colossoma macropomum</i>		Gill	Fish-farming in Macapá, AP	Dias et al. (2015)
	<i>Curimata incompta</i>	Gills and fins	Igarapé Fortaleza River, AP	Neves et al. (2016)
<i>Chaetobranchus flavescens</i>		Gill	Igarapé Fortaleza River, AP	Bittencourt et al. (2014)
<i>Colossoma macropomum</i>		Fins	Jari River, AP	Gonçalves et al. (2018)
	<i>Serrasalmus altispinis</i>	Mouth cavity	Jari River, AP	Oliveira et al. (2017)
	<i>Leporinus fasciatus</i>	Gill	Matapi River, AP	Neves & Tavares-Dias (2019)
<i>Livoneca guianensis</i>	<i>Leporinus friderici</i>	Mouth cavity	Jari River, AP	Oliveira et al. (2017)
<i>Riggia puyensis</i>	<i>Ancistrus</i> sp.	Tegumentar orifice	Xingu River, PA	Magalhães et al. (2018)

AM: Amazonas state; AP: Amapá state; RR: Roraima state; PA: Pará state; TO: Tocantins state; MT: Mato Grosso state; NI: Not informed.

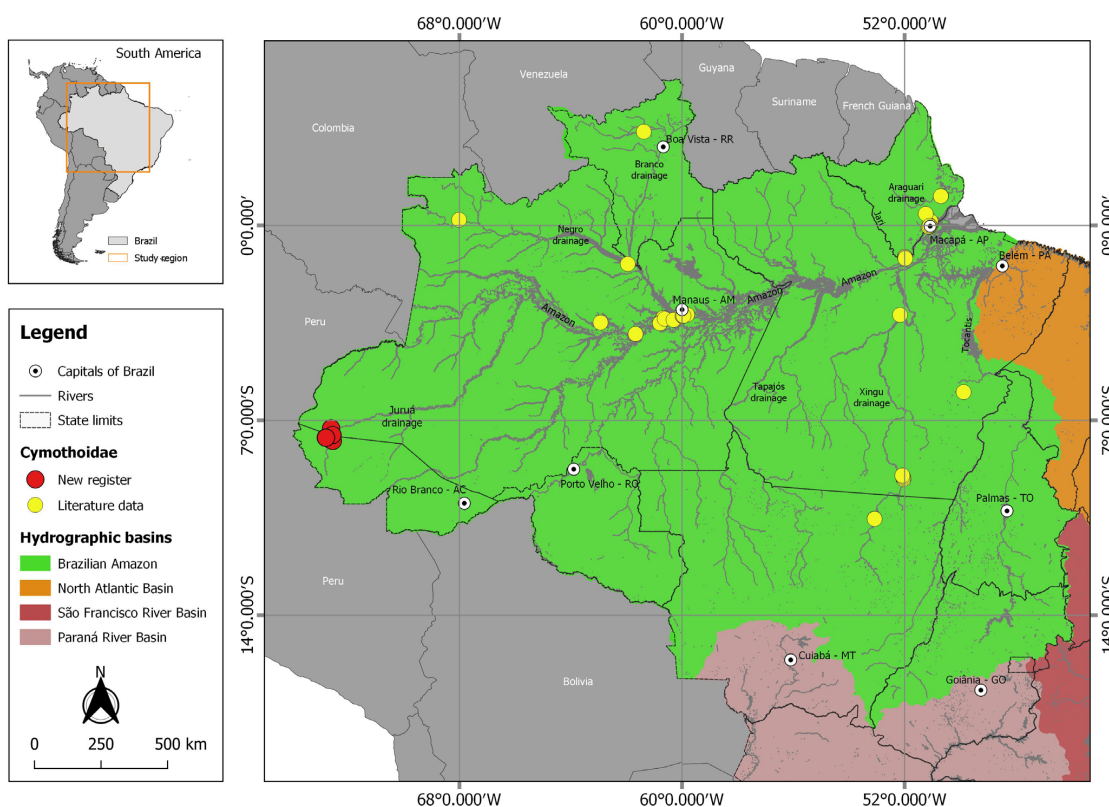
The species of Cymothoidae that parasitize fish in the southwestern Brazilian Amazon region (e.g. the state of Acre) were hitherto unknown. This region shows high heterogeneity of aquatic environments and high fish diversity (Begossi et al., 1999), which are ideal for accommodating great richness of Cymothoidae. Based on this principle, it is important to develop studies that expand the knowledge about the distribution of these ectoparasite crustaceans in this region of the Amazon basin. This will not only contribute information on the biodiversity of the Neotropical region, but also can help prevent fish losses in farming systems, where these organisms are known pests (Tavares-Dias et al., 2015).

Therefore, the aim of this study was to provide an updated list of isopod species of the family Cymothoidae that are found in fish in the Brazilian Amazon region and to report on new fish host occurrences and expanded geographical distributions for cymothoid isopods that parasitize fish in the southwestern Brazilian Amazon region.

## Material and Methods

### Collection sites

The fish were caught in the Juruá (7°40'34.1" S; 72°39'39.5" W), Crôa (7°71'48.30" S; 72°53'34.98" W), and Môa rivers (7°37'18" S; 72°47'47" W), all located in the municipality of Cruzeiro do Sul, state of Acre, and Paranã river (7°17'13" S 72°36'49" W) in the municipality of Guajara, in state of Amazonas, Brazil. This was done under a permit from the Brazilian Institute for the Environment and Renewable Natural Resources (no. 59642-2/2019) (Figure 1).



**Figure 1.** Location of occurrence places of Cymothoidae species occurrence sites throughout the Brazilian Amazon.

### Sampling

The fish specimens were caught using gillnets of 80 m in length and 3.0 m in height, with meshes of 1.5 cm, 2.5 cm, 3.5 cm and 5.5 cm between opposite nodes. The nets were installed in the early afternoon and were kept there for 12 hours with fish collections every two hours. The two nets used each had a mesh size of 12 mm, height of 2 m and opening size of 12 m. The nets were launched ten times per collector at each collection point. A beach trawl was also used, measuring 9 m in length and 2.4 m in height, with 13 mm mesh on the wings.

Each fish was initially identified in the field and its mouth, nostrils, operculum, gills, and integument were examined macroscopically to check for the presence of isopod parasites. The fish were then stored in water-filled boxes with an oxygenator and were transported to the laboratory, where they were examined for parasites using a stereomicroscope. After this, the fish were fixed in 10% formalin and were identified in accordance with the specialized literature (Silvano, 2001; Buckup et al., 2007; Queiroz, 2010). The parasites found were fixed in 70% alcohol, sent to the laboratory at Embrapa Amapá and identified in accordance with the specialized literature, as listed in Table 1.

### Database review

A review was conducted in the SciELO, ISI, Scopus, Science Direct, Zoological Records, CAB Abstracts Archive, and Google Scholar databases, in order to describe the distribution of Cymothoidae species in the Brazilian Amazon region (Table 1). The geographical coordinates of each study were ascertained using Google Earth and were used to generate a geographical distribution map of the family Cymothoidae in the Brazilian Amazon region, using the QGIS software, version 3.12.2.

### Results

We collected a total of 2551 fish specimens, belonging to five orders, 23 families and 83 species. Out of the total number of fish collected, only 15 individuals (0.4%) in 10 species (12%) were parasitized by Cymothoidae (Tables 2 and 3).

**Table 2.** Fish species collected in rivers of the southwestern Amazon, Brazil.

Order/Family/Species	Môa River	Paraná River	Juruá River	Crôa River
<b>Characiformes</b>	00	0	0	0
<b>Acestrorhynchidae</b>	0	0	0	0
<i>Acestrorhynchus cf. falcatus</i> (Bloch, 1794)	0	8	6	2
<i>Acestrorhynchus falcistrostris</i> (Cuvier, 1819)	4	0	2	0
<i>Acestrorhynchus heterolepis</i> (Cope, 1878)	7	0	0	0
<i>Acestrorhynchus cf. microlepis</i> (Schomburgk, 1841)	3	0	0	0
<i>Acestrorhynchus</i> sp.	8	23	0	2
<b>Anostomidae</b>	0	0	0	0
<i>Leporinus jamesi</i> (Garman, 1929)	2	2	2	3
<i>Pseudanos cf. gracilis</i> (Kner, 1858)	0	0	0	0
<i>Rhytiodus cf. argenteofuscus</i> (Kner, 1858)	2	0	0	0
<i>Rhytiodus microlepis</i> (Kner, 1859)	0	0	0	1
<b>Characidae</b>	0	0	0	0
<i>Brachychalcinus parnaibae</i> (Reis, 1989)	0	0	0	0
<i>Brachychalcinus retrospina</i> Boulenger, 1892	4	0	0	8
<i>Charax cf. pauciradiatus</i> (Günther, 1864)	7	2	2	2
<i>Moenkhausia cf. jamesi</i> (Eigenmann, 1908)	0	0	1	0
<i>Roeboides myersii</i> (Gill, 1870)	8	0	3	2
<i>Tetragonopterus argenteus</i> Cuvier, 1816	7	0	0	0
<b>Curimatidae</b>	0	0	0	0
<i>Curimatella meyeri</i> (Steindachner, 1882)	6	27	5	2

Table 2. Continued...

Order/Family/Species	Môa River	Paraná River	Juruá River	Crôa River
<i>Cyphocharax cf. festivus</i> Vari, 1992	57	111	3	0
<i>Cyphocharax cf. platanus</i> (Günther, 1880)	0	0	0	0
<i>Potamorhina cf. latior</i> (Spix & Agassiz, 1829)	5	0	34	0
<i>Psectrogaster amazonica</i> Eigenmann & Eigenmann, 1889	0	0	0	3
<b>Cynodontidae</b>	0	0	0	0
<i>Cynodon gibbus</i> (Agassiz, 1829)	0	2	0	0
<b>Erythrinidae</b>	0	0	0	0
<i>Erythrinus erythrinus</i> (Bloch & Schneider, 1801)	0	1	0	0
<i>Hoplias malabaricus</i> (Bloch, 1794)	19	38	26	7
<b>Hemiodontidae</b>	0	0	0	0
<i>Anodus elongatus</i> Agassiz, 1829	5	0	0	3
<b>Prochilodontidae</b>	0	0	0	0
<i>Prochilodus nigricans</i> Spix & Agassiz, 1829	50	14	22	31
<b>Serrasalminidae</b>	0	0	0	0
<i>Metynnis luna</i> Cope, 1878	0	0	57	0
<i>Myloplus cf. arnoldi</i> Ahl, 1936	0	14	0	0
<i>Myloplus cf. rubripinnis</i> (Müller & Troschel, 1844)	16	0	0	0
<i>Pygocentrus nattereri</i> Kner, 1858	0	2	2	13
<i>Serrasalmus rhombeus</i> (Linnaeus, 1766)	0	0	0	0
<b>Triporthidae</b>	0	0	0	0
<i>Triporthes albus</i> Cope, 1872	14	0	0	0
<i>Triporthes angulatus</i> (Spix & Agassiz, 1829)	4	2	12	10
<b>Clupeiformes</b>	0	0	0	0
<b>Pristigasteridae</b>	0	0	0	0
<i>Pellona flavipinnis</i> (Valenciennes, 1837)	1	0	0	0
<b>Gymnotiformes</b>	0	0	0	0
<b>Gymnotidae</b>	0	0	0	0
<i>Electrophorus electricus</i> (Linnaeus, 1766)	0	0	0	2
<b>Rhamphichthyidae</b>	0	0	0	0
<i>Rhamphichthys marmoratus</i> Castelnau, 1855	1	1	0	1
<b>Cichliformes</b>	0	0	0	0
<b>Cichlidae</b>	0	0	0	0
<i>Biotodoma cupido</i> (Heckel, 1840)	0	7	0	6
<i>Biotodoma cf. wavrini</i> (Gosse, 1963)	0	0	0	0
<i>Chaetobranchius flavescens</i> Heckel, 1840	16	0	49	81
<i>Cichla nigromaculata</i> Jardine & Schomburgk, 1843	9	0	2	6
<i>Crenicichla semicincta</i> Steindachner, 1892	11	0	0	0

Table 2. Continued...

Order/Family/Species	Môa River	Paraná River	Juruá River	Crôa River
<i>Heros cf. severus</i> Heckel, 1840	0	2	0	0
<i>Laetacara</i> sp.	2	4	0	0
<i>Satanoperca cf. jurupari</i> Heckel, 1840	0	0	0	0
<b>Scinidae</b>	0	0	0	0
<i>Plagioscion squamosissimus</i> Heckel, 1840	1	0	0	0
<b>Siluriformes</b>	0	0	0	0
<b>Asprendinidae</b>	0	0	0	0
<i>Bunocephalus coracoideus</i> Cope, 1874	0	3	0	0
<b>Auchenipteridae</b>	0	0	0	0
<i>Ageneiosus inermis</i> (Linnaeus, 1766)	3	4	0	1
<i>Auchenipterichthys</i> sp.	15	3	0	0
<i>Auchenipterichthys thoracatus</i> (Kner, 1858)	59	1	0	0
<i>Centromochlus</i> sp.	0	0	0	0
<i>Trachelyopterus cf. galeatus</i> (Linnaeus, 1766)	0	2	0	0
<i>Trachelyopterus</i> sp.	0	185	1	14
<b>Callichthyidae</b>	0	0	0	0
<i>Brochis multiradiatus</i> (Orcés V., 1960)	5	0	13	2
<i>Megalechis cf. thoracata</i> (Valenciennes, 1840)	0	1	29	0
<b>Doradidae</b>	0	0	0	0
<i>Agamyxis pectinifrons</i> (Cope, 1870)	0	53	0	0
<i>Amblydoras affinis</i> (Kner, 1855)	0	12	0	0
<i>Anadoras cf. weddellii</i> (Castelnau, 1855)	0	0	0	3
<i>Nemadoras cf. cristinae</i> Sabaj Pérez, Arce H., Sousa & Birindelli, 2014	16	0	0	0
<i>Nemadoras cf. humeralis</i> (Kner, 1855)	30	1	0	4
<i>Opsodoras boulengeri</i> (Steindachner, 1915)	18	1	0	0
<i>Ossancora asterophysa</i> Birindelli & Sabaj Pérez, 2011	13	733	45	8
<i>Oxydoras niger</i> (Valenciennes, 1821)	0	0	0	0
<i>Platydoras cf. armatulus</i> (Valenciennes, 1840)	2	8	0	0
<i>Platydoras costatus</i> (Linnaeus, 1758)	0	0	0	0
<i>Pterodoras granulosus</i> (Valenciennes, 1821)	0	0	0	0
<i>Trachydoras</i> sp.	2	3	0	5
<i>Tenellus ternetzi</i> (Eigenmann, 1925)	21	0	0	0
<i>Tenellus trimaculatus</i> (Boulenger, 1898)	7	0	6	0
<b>Loricariidae</b>	0	0	0	0
<i>Aphanotorulus cf. unicolor</i> (Steindachner, 1908)	0	0	0	0
<i>Calophysus macropterus</i> (Lichtenstein, 1819)	3	0	0	0
<i>Hypoptopoma cf. steindachneri</i> Boulenger, 1895	2	0	0	0



Table 2. Continued...

Order/Family/Species	Môa River	Paraná River	Juruá River	Crôa River
<i>Loricaria cataphracta</i> Linnaeus, 1758	6	0	0	0
<i>Loricaria</i> sp.	40	0	0	0
<i>Loricariichthys</i> sp.	95	5	21	0
<i>Peckoltia</i> cf. <i>vittata</i> (Steindachner, 1881)	0	0	0	0
<i>Spatuloricaria</i> sp.	0	0	0	0
<i>Squaliforma</i> cf. <i>squalina</i> (Jardine, 1841)	1	0	0	0
<i>Sturisoma</i> cf. <i>lyra</i> (Regan, 1904)	10	0	0	0
<i>Sturisoma</i> cf. <i>tenuirostris</i> (Steindachner, 1910)	2	0	0	0
<i>Sturisoma</i> sp.	2	0	0	0
<b>Pimelodidae</b>	0	0	0	0
<i>Hemisorubim</i> sp.	0	3	0	0
<i>Hypophthalmus edentatus</i> Spix & Agassiz, 1829	0	0	0	0
<i>Pimelodella</i> cf. <i>humeralis</i> Slobodian, Akama & Dutra, 2017	0	0	2	1
<i>Pimelodina flavipinnis</i> Steindachner, 1876	0	0	1	0
<i>Pimelodus blochii</i> Valenciennes, 1840	8	0	5	3
<i>Pinirampus pirinampu</i> (Spix & Agassiz, 1829)	2	0	1	0
<i>Sorubim lima</i> (Bloch & Schneider, 1801)	1	0	0	5
<b>Tetraodontiformes</b>	0	0	0	0
<b>Tetraodontidae</b>	0	0	0	0
<i>Colomesus asellus</i> (Müller & Troschel, 1849)	37	0	1	0

We collected a total of 15 specimens of Cymothoidae, belonging to eight species: *Artystone bolivianensis* Thatcher & Schindler, 1999; *Artystone trysibia* Schioedte, 1866; *Braga fluviatilis* Richardson, 1911; *Paracymothoa parva* Taberner, 1976; *Braga* sp. Schioedte & Meinert, 1881; *Braga patagonica* Schiödt & Meinert, 1884; *Braga brachmanni* Stadler, 1972; and *Livoneca guianensis* Van Name, 1925. All the parasites were recorded for the first time in these host fish species. *Artystone bolivianensis*, *B. brachmanni* and *P. parva* were recorded for the first time parasitizing fish in Brazil (Table 3).

Among the eight species of Cymothoidae collected, four were found in the Paraná River, two in the Moa River, one in the Juruá River and one in the Crôa River. *Braga fluviatilis* and *L. guianensis* were observed to parasitize the highest number of hosts, such that *L. guianensis* occurred in all four rivers. The mean intensity of the species of Cymothoidae were similar to each other, i.e. one parasite per fish (Table 3).

Out of the 15 individuals of Cymothoidae collected, ten were females (73.3%). The highest prevalence of specimens were recorded for *B. fluviatilis* (three specimens) and *L. guianensis* (three specimens). Most of these isopods were found in the fish integument and mouth cavity. However, *P. parva* and *Braga* sp. occurred in the anal cavity of the hosts and *B. patagonica* in the gills (Table 3).

We found a total of 34 host fish species for these species of Cymothoidae in the Brazilian Amazon region. Eight species of these isopods were found in fish in the state of Amazonas, five in the state of Amapá, four in the state of Pará, two in the state of Roraima and one in the state of Mato Grosso. Across the Brazilian Amazon region, the isopod *B. patagonica* showed the widest geographical distribution and largest number of host species (Table 1).



**Table 3.** Cymothoidae species and fish of the Amazon River basin, in states of Amazonas and Acre, northern Brazil.

Hosts	Parasites	Locality	Sex of parasites	IS	EF/PF	MA	MI	TNP
<i>Auchenipterichthys thoracatus</i>	<i>Braga fluviatilis</i>	Môa River, AC	M	Tegument	22/1	0.045	1	1
<i>Biotodoma wavrini</i>	<i>Artystone bolivianensis</i>	Paraná River, AM	F	Tegumentar orifice	2/1	0.500	1	1
<i>Brachyhalcinus retrospina</i>	<i>Braga fluviatilis</i>	Môa River, AC	M	Mouth cavity	10/1	0.100	1	1
<i>Brachyhalcinus retrospina</i>	<i>Paracymothoa parva</i>	Môa River, AC	F	Anus	10/1	0.100	1	1
<i>Curimatella meyeri</i>	<i>Braga</i> sp.	Môa River, AC	F	Anus	67/1	0.015	1	1
<i>Laetacara</i> sp.	<i>Artystone trysibia</i>	Paraná River, AM	F, F	Anus and tegumentar orifice	2/2	1.000	1	2
<i>Leporinus jamesi</i>	<i>Livoneca guianensis</i>	Paraná River, AM	F	Mouth cavity	2/1	0.500	1	1
<i>Leporinus jamesi</i>	<i>Braga fluviatilis</i>	Môa River, AC	M	Mouth cavity	2/1	0.500	1	1
<i>Pimelodella</i> cf. <i>humeralis</i>	<i>Livoneca guianensis</i>	Juruá River, AC	F	Mouth cavity	22/1	0.045	1	1
<i>Pimelodella</i> cf. <i>humeralis</i>	<i>Braga patagonica</i>	Paraná River, AM	F	Gill	2/1	0.500	1	1
<i>Rhytidodus microlepis</i>	<i>Livoneca guianensis</i>	Crôa River, AC	F	Tegument	1/1	1.000	1	1
<i>Sturisoma lyra</i>	<i>Braga brachmanni</i>	Môa River, AC	F, M	Mouth and tegument	1/2	1.000	1	2
<i>Tonellus ternetzi</i>	<i>Livoneca guianensis</i>	Môa River, AC	F	Mouth cavity	8/1	0.125	1	1

AM: Amazonas state, AC: Acre state. IS: infestation site, MA: mean abundance, MI: mean infestation, EF: examined fish, PF: parasitized fish, P: prevalence, MI: mean intensity, MA: mean abundance, TNP: total number of parasites.

## Discussion

Parasites of the family Cymothoidae are distributed throughout the Amazon River basin, in which the largest numbers of species have been reported in the central and eastern regions of this basin, where these cymothoids parasitize a great diversity of hosts belonging to the families Acestrorhynchidae, Anostomidae, Arapaimidae, Bryconidae, Curimatidae, Cynodontidae, Triportheidae, Serrasalminidae, Loricariidae, Pimelodidae, Lebiasinidae, Cichlidae, Erythrinidae and Sciaenidae (Table 1). Our results from the southwestern Amazon region, together with data from the central and eastern Amazon regions, depict an area with great richness of species of Cymothoidae, totaling 17 species recorded in fish in the Brazilian Amazon region.

This richness of cymothoid species in the Neotropical region was expected, especially in the Amazon basin (Smit et al., 2014). This ecosystem is home to a great diversity of fish, which enables occurrences of species of Cymothoidae in different aquatic environments, such as rivers, lakes and flooded forests (Winemiller et al., 2016). Recently, Tavares-Dias et al. (2015) listed eight species of freshwater Isopoda throughout Brazil. Our study, which included both bibliographic review and data collection, recorded 17 species of Cymothoidae in the Brazilian Amazon region alone. This demonstrates the importance of the Amazon region for biodiversity in the Neotropical region. However, it is essential to note that the biogeographical status of freshwater cymothoids may still be underestimated (Smit et al., 2014) because of the extensive area of the Amazon region. Many areas of this region have never been studied to assess the fauna of this group of parasites.

In the present study, not all the fish species acted as hosts for these cymothoids. The species parasitized generally have low abundance, since out of the 84 fish species analyzed, only 10 were parasitized by cymothoids, with low values for mean abundance and intensity. Immunological, behavioral, environmental and genetic characteristics may explain this complex parasite-host interaction (Poulin, 2013; Aneesh et al., 2013; Tavares-Dias et al., 2015)

and act as important factors in the selection of a host fish. Recently, it was observed that the defenses of some fish species are important for preventing colonization by cymothoids. These defenses include the ability of the host to remove the parasite using its mouth or through rapid movements with its body. In some cases, fish can eat these isopods, thereby eliminating the risk of parasitism (Alberto et al., 2009). Another factor that can influence the degree of infestation is the short period for which this parasite can survive freely in the environment. Free living requires a large energy investment, to search for a host fish, and the time that this takes can lead these parasites to death (Leonardos & Trilles, 2003).

*Artystone bolivianensis*, *B. brachmanni* and *P. parva* are new species records for the Amazon and Brazil. *Artystone bolivianensis* was previously described parasitizing *Otocinclus vestitus* Cope, 1872, in Santa Cruz de la Sierra, Bolivia (Thatcher & Schindler, 1999). *Braga brachmanni* was previously described parasitizing *Ancistrus cirrhosus* Valenciennes, 1836, in Argentina (Stadler, 1972). *Paracymothoa parva* was previously described parasitizing *Hyphessobrycon callistus* (synonym of *Hyphessobrycon eques* Steindachner, 1882) (Taberner, 1977) and subsequently parasitizing *Metynnix maculatus* Kner, 1858 (Taberner, 1977), also in Argentina.

New reports on Cymothoidae in the Amazon region can be expected, given the high diversity of environments and host fish in this region (Hata et al., 2017; Tavares-Dias et al., 2015). In this context, when research is conducted in areas where few studies had previously been conducted, new reports of known species are expected for that region, in addition to species not yet described.

The data from the present study expanded the geographical distribution of *B. patagonica* to the southwestern part of the Brazilian Amazon region. *Braga patagonica* has wide geographical distribution, occurring in different tributaries of the Amazon River basin (e.g. the middle Solimões River, Amazon River, Jari River and Matapi River). This species parasitizes a variety of hosts belonging to the families Acestrorhynchidae, Anostomidae, Bryconidae, Curimatidae, Cynodontidae, Serrasalminidae, Cichlidae, Erythrinidae and Sciaenidae (Table 1). The generalist nature of this species of Cymothoidae demonstrates its low parasitic specificity (Tavares-Dias et al., 2014, 2015).

In general, in the Amazon region, genera of Cymothoidae such as *Anphira* and *Vanamea* have been found infesting the gill cavities of hosts, while *Artystone* and *Riggia* have been found inside holes formed by the parasite in the tegument of the fish, mostly in the pelvic region of these hosts (Table 1). However, *Braga* species can be found in several places in the host, such as the mouth and gill cavities, and integument surface. The ways in which the parasite becomes attached to the host fish can influence the specificity of species of Cymothoidae regarding their host choice (Hata et al., 2017). Cymothoids parasitizing the external surfaces of their hosts, such as the gill and mouth cavities, are more generalist, and can become attached to many fish species (Bruce, 1986; Hadfield et al., 2015). This was observed in the present study, in which species of the genera *Braga* and *Livoneca* were seen to infest the integument, gills and mouth cavities in many fish species.

Encapsulation in the host integument as the means of attachment is characteristic of *Artystone* and *Riggia* (Thatcher et al., 2003; Junoy, 2016; Oliveira et al., 2019) and can be considered to be a host-parasite specific characteristic (Tsai & Dai 1999; Yamano et al., 2011; Hata et al., 2017). Data in the literature show that species are generalists, parasitizing fish species of the families Anostomidae, Ariidae, Characidae, Cichlidae, Heptapteridae, Loricariidae and Pimelodidae (Junoy, 2016). However, in the Brazilian Amazon region, the *Artystone* species that was observed can be considered to be a specialist because it was found parasitizing only Cichlidae fish (Oliveira et al., 2019). Studies on integrative, comparative and molecular biology may be the approach that should be followed in order to understand these complex interactions.

*Artystone trysibia*, *Braga* sp. and *P. parva* were found in the anal cavity of their hosts (Table 2). Among the cymothoids reported in Brazil, only *Riggia acuticaudata* Thatcher, Lopes & Froehlich, 2002 was found parasitizing the anal cavity of its host, a specimen of *Ancistrus* sp. (Oda et al., 2015). Therefore, the present study suggests that because the anal cavity is an opening and these parasites have the habit of living in cavities, this site becomes an important place of refuge and the parasites may use excreted food waste in their diet.

In conclusion, through this study, the occurrence and distribution of Cymothoidae in the Brazilian Amazon are expanded, with new records of host fish and infestation sites. Therefore, this study contributes towards future studies on the diversity, distribution and specificity of cymothoids in the Amazon region, which is the most biodiverse region on the planet.

## References

- Ahyong ST, Lowry JK, Alonso M, Bamber RN, Boxshall GA, Castro P, et al. Subphylum Crustacea Brünnich, 1772. In: Zhang, ZQ. Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness. 1st ed. Magnolia Press. *Zootaxa* 2011; 318(1): 165-191. <http://dx.doi.org/10.11646/zootaxa.3148.1.33>.
- Alberto RMF, Maciel PC, Araujo PB. Infestation by the freshwater cymothoid *Artystone trysibia* Schioedte (Crustacea, Isopoda): parasite and host behaviour. *J Nat Hist* 2009; 43(1-2): 47-56. <http://dx.doi.org/10.1080/00222930802409912>.
- Alcântara NM, Tavares-Dias M. Estrutura da comunidade de parasitos em dois Erythrinidae do sistema do Rio Amazonas (Brasil). *Rev Bras Parasitol Vet* 2015; 24(2): 183-190. <http://dx.doi.org/10.1590/S1984-29612015039>. PMID:26083690.
- Aneesh PT, Sudha K, Arshad K, Anilkumar G, Trilles JP. Seasonal fluctuation of the prevalence of cymothoids representing the genus *Nerocila* (Crustacea, Isopoda), parasitizing commercially exploited marine fishes from the Malabar Coast, India. *Acta Parasitol* 2013; 58(1): 80-90. <http://dx.doi.org/10.2478/s11686-013-0112-3>. PMID:23377916.
- Araujo CSO, Barros MC, Gomes ALS, Varella AMB, Viana GDM, Silva NPD, et al. Parasitas de populações naturais e artificiais de tucunaré (*Cichla* spp.). *Rev Bras Parasitol Vet* 2009; 18(1): 34-38. <http://dx.doi.org/10.4322/rbpv.01801006>. PMID:19500458.
- Araujo CS, Thatcher VE. *Anphira junki* n. sp. (Isopoda, Cymothoidae) a gill chamber parasite of *Triporthus albus* and *T. flavus* (Pisces) in the Brazilian Amazon. *Amazoniana* 2003; 17(3-4): 283-290.
- Begossi A, Silvano RAM, do Amaral BD, Oyakawa OT. Uses of fish and game by inhabitants of an extractive reserve (Upper Juruá, Acre, Brazil). *Environ Dev Sustain* 1999; 1(1): 73-93. <http://dx.doi.org/10.1023/A:1010075315060>.
- Bittencourt LS, Pinheiro DA, Cárdenas MQ, Fernandes BM, Tavares-Dias M. Parasites of native Cichlidae populations and invasive *Oreochromis niloticus* (Linnaeus, 1758) in tributary of Amazonas River (Brazil). *Rev Bras Parasitol Vet* 2014; 23(1): 44-54. <http://dx.doi.org/10.1590/S1984-29612014006>. PMID:24728360.
- Bruce NL. Revision of the isopod crustacean genus *Mothocya* Costa, in Hope, 1851 (Cymothoidae: Flabellifera), parasitic on marine fishes. *J Nat Hist* 1986; 20(5): 1089-1192. <http://dx.doi.org/10.1080/00222938600770781>.
- Brusca RC, Coelho V, Taiti S. A guide to the coastal isopods of California. *Epi Info* [online]. 2001 [cited 2020 May 10]. Available from: <http://tolweb.org/notes>
- Buckup PA, Menezes NA, Ghazzi MAS. *Catálogo das espécies de peixes de água doce do Brasil*. Rio de Janeiro: Museu Nacional; 2007.
- Dias MKR, Neves LR, Marinho RGB, Tavares-Dias M. Parasitic infections in tambaqui from eight fish farms in Northern Brazil. *Arq Bras Med Vet Zootec* 2015; 67(4): 1070-1076. <http://dx.doi.org/10.1590/1678-4162-7592>.
- Esteves-Silva PH, Oliveira MSB, Gentil-Vasconcelos HC, Costa-Campos CE, Tavares-Dias M. New records of hosts for *Excorallana longicornis* and *Nerocila acuminata* (Crustacea: Isopoda) in brackish fish from the coast of the State of Amapá (Brazil), with an update on the geographic distribution of *Nerocila acuminata*. *J Parasit Dis* 2020; 44(2): 420-428. <http://dx.doi.org/10.1007/s12639-020-01192-x>. PMID:32508417.
- Gomiero LM, Souza UP, Braga FMDS. Condition factor of *Astyanax intermedium* Eigenmann, 1908 (OSTEICHTHYES, CHARACIDAE) parasitised by *Paracymothoa astyanaxi* Lemos de Castro, 1955 (CRUSTACEA, CYMOTHOIDAE) in the Grande River, Serra do Mar State Park - Santa Virgínia Unit, São Paulo, Brazil. *Braz J Biol* 2012; 72(2): 379-388. <http://dx.doi.org/10.1590/S1519-69842012000200020>. PMID:22735147.
- Gonçalves BB, Oliveira MSB, Borges WF, Santos GG, Tavares-Dias M. Diversity of metazoan parasites in *Colossoma macropomum* (Serrasalmidae) from the lower Jari River, a tributary of the Amazonas River in Brazil. *Acta Amaz* 2018; 48(3): 211-216. <http://dx.doi.org/10.1590/1809-4392201704371>.
- Hadfield KA, Bruce NL, Smit NJ. Review of *Mothocya* Costa, in Hope, 1851 (Crustacea: Isopoda: Cymothoidae) from southern Africa, with the description of a new species. *Afr Zool* 2015; 50(2): 147-163. <http://dx.doi.org/10.1080/15627020.2015.1043943>.
- Hata H, Sogabe A, Tada S, Nishimoto R, Nakano R, Kohya N, et al. Molecular phylogeny of obligate fish parasites of the family Cymothoidae (Isopoda, Crustacea): evolution of the attachment mode to host fish and the habitat shift from saline water to freshwater. *Mar Biol* 2017; 164(5): 105. <http://dx.doi.org/10.1007/s00227-017-3138-5>.
- Hoshino MDFG, Neves LR, Tavares-Dias M. Parasite communities of the predatory fish, *Acestrorhynchus falcatus* and *Acestrorhynchus falcirostris*, living in sympatry in Brazilian Amazon. *Rev Bras Parasitol Vet* 2016; 25(2): 207-216. <http://dx.doi.org/10.1590/S1984-29612016038>. PMID:27334822.
- Jesus EC, Cardoso L, Ferreira TH, Martins ML, Rodrigues MDN. *Braga nasuta* (Cymothoidae): an ectoparasite of the Giant Amazonian fish *Arapaima gigas* (Osteoglossidae) fingerlings cultured in the Amazon region in Northern Brazil. *Acta Sci Biol Sci* 2017; 39(4): 507-511. <http://dx.doi.org/10.4025/actascibiols.v39i4.35080>.
- Junoy J. Parasitism of the isopod *Artystone trysibia* in the fish *Chaetostoma dermorhynchum* from the Tena River (Amazonian region, Ecuador). *Acta Trop* 2016; 153: 36-45. <http://dx.doi.org/10.1016/j.actatropica.2015.10.006>. PMID:26466983.

- Lemos de Castro A. Sobre as espécies sul-americanas do gênero *Braga* Schioedte et Meinert, 1881 (Isopoda: cymothoidae). *Arch Mus Nac Rio de Janeiro* 1959; 59(1): 69-77.
- Leonardos I, Trilles JP. Host-parasite relationships: occurrence and effect of the parasitic isopod *Mothocya epimerica* on sand smelt *Atherina boyeri* in the Mesolongi and Etolikon Lagoons (W. Greece). *Dis Aquat Organ* 2003; 54(3): 243-251. <http://dx.doi.org/10.3354/dao054243>. PMID:12803388.
- Magalhães C, Robles R, Souza-Carvalho EA, Carvalho FL, Malta JCO, Mantelatto FL. Annotated checklist of parasitic and decapod crustaceans from the middle and lower Xingu (Amazon Basin) above and below the Belo Monte dam complex, Pará State, Brazil. *Proc Acad Nat Sci Philadelphia* 2018; 166(1): 1-34. <http://dx.doi.org/10.1635/053.166.0105>.
- Martin MB, Bruce NL, Nowak BF. Review of the fish-parasitic genus *Cymothoa* Fabricius, 1793 (Crustacea: Isopoda: Cymothoidae) from Australia. *Zootaxa* 2016; 4119(1): 1-72. <http://dx.doi.org/10.11646/zootaxa.4119.1.1>. PMID:27395199.
- Murrieta-Morey GA, Santana HP, Malta JC. As espécies de Isopoda (Crustacea: Cymothoidea) parasitas de *Serrasalmus altispinis* Merckx, Jégu & Santos, 2000 (Characiformes: Serrasalminidae) coletadas em lagos de várzea da Amazônia, Brasil. *Folia Amaz* 2016; 25(2): 145-151. <http://dx.doi.org/10.24841/fa.v25i2.398>.
- Neves LR, Braga ECR, Tavares-Dias M. Diversity of parasites in *Curimata incompta* (Curimatidae), a host from Amazon river system in Brazil. *J Parasit Dis* 2016; 40(4): 1296-1300. <http://dx.doi.org/10.1007/s12639-015-0674-0>. PMID:27876934.
- Neves LR, Tavares-Dias M. Low levels of crustacean parasite infestation in fish species from the Matapi River in the state of Amapá, Brazil. *Rev Bras Parasitol Vet* 2019; 28(3): 493-498. <http://dx.doi.org/10.1590/s1984-29612019006>. PMID:31188939.
- Oda FH, Da Graça RJ, Tencatt LFC, Tavares LER, Froehlich O, Takemoto RM. The poorly known *Riggia acuticaudata* (Crustacea: Isopoda) parasitizing *Ancistrus* sp. (Siluriformes: Loricariidae) from the Paraguay River basin, Brazil, with comments on its reproductive biology. *Comp Parasitol* 2015; 82(1): 25-28. <http://dx.doi.org/10.1654/4738.1>.
- Oliveira MSB, Corrêa LL, Ferreira DO, Neves LR, Tavares-Dias M. Records of new localities and hosts for crustacean parasites in fish from the eastern Amazon in northern Brazil. *J Parasit Dis* 2017; 41(2): 565-570. <http://dx.doi.org/10.1007/s12639-016-0852-8>. PMID:28615880.
- Oliveira MSB, Esteves-Silva PH, Andrade MC, Tavares-Dias M. First report of *Artystone trysibia* (Isopoda: Cymothoidae) in *Caquetaia spectabilis* (Cichliformes: Cichlidae). *Rev Bras Parasitol Vet* 2019; 28(4): 735-738. <http://dx.doi.org/10.1590/s1984-29612019030>. PMID:31215608.
- Poulin P. Parasite manipulation of host personality and behavioural syndromes. *J Exp Biol* 2013; 216(1): 18-26. <http://dx.doi.org/10.1242/jeb.073353>. PMID:23225863.
- Queiroz LJ. *Peixes do rio Madeira*. São Paulo: Dialetto; 2010.
- Silvano RAM. *Peixes do Alto Rio Juruá (Amazonas, Brasil)*. São Paulo: EdUSP; 2001.
- Smit NJ, Bruce NL, Hadfield KA. Global diversity of fish parasitic isopod crustaceans of the family Cymothoidae. *Int J Parasitol Parasites Wildl* 2014; 3(2): 188-197. <http://dx.doi.org/10.1016/j.ijppaw.2014.03.004>. PMID:25180163.
- Stadler T. *Braga bachmanni*, nuevo ectoparasito de *Ancistrus cirrosus* (Crustacea, Cymothoidae) en peces Loricariidae. *Neotropica* 1972; 18(57): 141-145.
- Taberner R. *Nebula maculatus* gen. nov. sp. nov. (Crustacea, Isopoda, Cymothoidae) ectoparasito de *Metynnis maculatus* (Kner, 1860) Berg, 1897 (Pisces, Characidae). *Physis B* 1977; 35(91): 163-169.
- Tavares-Dias M, Araújo CSO, Barros MS, Viana GM. New hosts and distribution records of *Braga patagonica*, a parasite Cymothoidae of fishes from the Amazon. *Braz J Aquat Sci Tech* 2014; 18(1): 91-97. <http://dx.doi.org/10.14210/bjast.v18n1.p91-97>.
- Tavares-Dias M, Dias-Júnior MBF, Florentino AC, Silva LMA, Cunha ACD. Distribution pattern of crustacean ectoparasites of freshwater fish from Brazil. *Rev Bras Parasitol Vet* 2015; 24(2): 136-147. <http://dx.doi.org/10.1590/S1984-29612015036>. PMID:26154954.
- Tavares-Dias M, Gonçalves RA, Oliveira MSB, Neves LR. Parasites community in *Chaetobranchius flavescens* Heckel, 1840, (Cichliformes: Cichlidae) from the Eastern Amazon, Brazil. *Bol Inst Pesca* 2018; 44(1): 10-16. <http://dx.doi.org/10.20950/1678-2305.2018.262>.
- Thatcher VE, Carvalho ML. *Artystone minima* n. sp. (Isopoda, Cymothoidae) a body cavity parasite of the pencil fish (*Nannostomus beckfordi* Guenther) from the Brazilian Amazon. *Amazoniana* 1988; 10(3): 255-265.
- Thatcher VE, Lopes LPDC, Froehlich O. *Riggia cryptocularis* sp. nov. (Isopoda, Cymothoidae) from the body cavity of a freshwater fish of Mato Grosso do Sul State, Brazil. *Rev Bras Zool* 2003; 20(2): 285-289. <http://dx.doi.org/10.1590/S0101-81752003000200019>.
- Thatcher VE. *Asotana magnifica* n. sp. (Isopoda, Cymothoidae) an unusual parasite (commensal?) of the buccal cavities of piranhas (*Serrasalmus* sp.) from Roraima, Brazil. *Amazoniana* 1988; 10(3): 239-248.

Thatcher VE. *Anphira branchialis* gen. et sp. nov. (Crustacea, Isopoda, Cymothoidae) um parasita da cavidade branquial de piranhas (*Serrasalmus* spp.) na Amazônia Brasileira. *Acta Amazon* 1993; 23(2-3): 297-307. <http://dx.doi.org/10.1590/1809-43921993233307>.

Thatcher VE. *Anphira xinguensis* sp. nov. (Isopoda, Cymothoidae) a gill chamber parasite of an Amazonian serrasalmid fish, *Ossobius xinguense* Jégu, 1992. *Amazoniana* 1995; 13(3-4): 293-303.

Thatcher VE. *Braga amapaensis* n. sp. (Isopoda: Cymothoidae) a mouth cavity parasite of the Amazonian fish, *Acestrorhynchus guyanensis* Menezes, with a redefinition of the genus *Braga*. *Amazoniana* 1996; 14(1-2): 121-129.

Thatcher VE, Schindler I. *Artystone bolivianensis* n. sp. (Isopoda, Cymothoidae) from a loriciid catfish of the Bolivian Amazon. *Amazoniana* 1999; 15(3-4): 183-191.

Tsai ML, Dai CF. *Ichthyoxenus fushanensis*, new species (Isopoda: Cymothoidae), parasite of the fresh-water fish *Varicorhinus barbatulus* from northern Taiwan. *J Crustac Biol* 1999; 19(4): 917-923. <http://dx.doi.org/10.2307/1549311>.

van Name WG. Names and general distribution of the American land and freshwater Isopoda. *Bull Am Mus Nat Hist* 1936; 71(1): 23-31.

Vital JF, Varella AMB, Porto DB, Malta JCO. Sazonalidade da fauna de metazoários de *Pygocentrus nattereri* (Kner, 1858) no lago Piranha (Amazonas, Brasil) e a avaliação de seu potencial como indicadora da saúde do ambiente. *Biota Neotrop* 2011; 11(1): 199-204. <http://dx.doi.org/10.1590/S1676-06032011000100021>.

Winemiller KO, McIntyre PB, Castello L, Fluet-Chouinard E, Giarrizzo T, Nam S, et al. Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science* 2016; 351(6269): 128-129. <http://dx.doi.org/10.1126/science.aac7082>. PMID:26744397.

Yamano H, Yamauchi T, Hosoya K. A new host record of *Ichthyoxenus amurensis* (Crustacea: Isopoda: Cymothoidae) from the Amur bitterling *Rhodeus sericeus* (Cypriniformes: Cyprinidae). *Limnology* 2011; 12(1): 103-106. <http://dx.doi.org/10.1007/s10201-010-0325-1>.