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Original Article

# Isopod parasites of *Pygocentrus piraya* (Characiformes: Serrasalmidae) in the lower São Francisco River, Brazil

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## ABSTRACT

Isopods of the suborder Cymothoida include ectoparasite species that cause physical damage and affect the development of the host by feeding on blood and tissues. On fishes, these parasites attach themselves to the skin, fins, gills, and oral cavity using claws on articulated legs. The ability to remain hidden in cavities even after the fish is caught enables isopods to be transported to new areas along with the host, making these parasites potential co-invaders. Understanding the role and environmental impact of parasites is essential, although research on parasitism in the context of biological invasions lags in comparison to general research on such invasions. Previous records indicate only two species of parasitic isopods in the São Francisco River basin. However, the present study reports the first record of two other species (*Braga patagonica* and *Braga nasuta*) on *Pygocentrus piraya* and in the basin itself. This demonstrates a lack of knowledge regarding fish parasites in the region, despite the presence of other parasites. Collaborations with research groups conducting fish sampling in the basin can contribute to expanding knowledge on these parasites and the training of human resources in fish



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parasitology. The present study provides important information on the presence of unidentified parasitic isopods on fishes in the São Francisco River basin, underscoring the need for further studies and expanding the geographic distribution of these parasites, as well as the host list for these isopods.

**KEYWORDS**

*Braga*, Cymothoidae, ectoparasites, Neotropical region, freshwater fishes.

## INTRODUCTION

Isopods of the family Cymothoidae Leach, 1814 correspond to a group of obligate ectoparasitic crustaceans currently represented by 40 genera and 380 species (Smit et al., 2014). These parasites usually occur on marine and freshwater fishes and are associated with the gill cavity (sometimes several specimens simultaneously), mouth, body surface, fins, and even holes in tissues of the host (Thatcher, 2006; Smit et al., 2014). They feed on blood, mucus, and epithelial tissues by attaching to the body of the host with the claws and using parts of the oral apparatus. This behavior can cause physical damage and compromise host health (Thatcher, 2006). In addition, these parasites are protandrous hermaphrodites, in which males become females (Costa and Chellappa, 2010; Eiras et al., 2010; Fadel et al., 2020).

The greatest diversity of Cymothoidae occurs in the tropics, with a well-documented distribution of marine parasites (Searle and Richardson, 1905; Brusca, 1981; Bruce, 1897; Kensley and Schotte, 1989; Silva and Souza-Filho, 2017; Ravichandran et al., 2019; Alves et al., 2019; Purivirojkul and Songsuk, 2020; Ribeiro et al., 2021). However, studies on these parasites in freshwater ecosystems are incipient and usually involve the description of species and new records (Smit et al., 2014; Tavares-Dias et al., 2014; Virgilio et al., 2020). In Brazil, filling gaps in knowledge is a key point for understanding distribution patterns of isopod species in freshwater environments, as the country has the largest hydrographic network in the world and is one of the most important countries in terms of freshwater fish diversity (Dagosta and de Pinna, 2019).

Among freshwater parasitic isopods in Brazil, the genus *Braga* Schioedte and Meinert, 1881 has eight valid species (Thatcher et al. 2009), most of which are associated with the tongue, gills, and body surface of the host. Species of the genus *Braga* are characterized by a symmetrical body, anterior region slightly immersed in pereonite 1, all prehensile pereopods with robust claw-shaped dactyls, a wider than long pleotelson, and multilaminate pleopods 2–5 (Thatcher, 2006; Thatcher et al., 2009). Although this is a well-studied group, gaps in knowledge remain regarding the distribution of this genus in Brazilian watersheds. The aim of the present study is to report, for the first time, the occurrence of two species of *Braga*, *Braga patagonica* Schioedte and Meinert, 1884 and *Braga nasuta* Schioedte and Meinert, 1881, on the freshwater piranha *Pygocentrus piraya* (Cuvier), expanding the geographic distribution of isopods in Brazilian freshwater environments.

## MATERIAL AND METHODS

Parasitized individuals of *P. piraya* were sampled in two environments in the lower São Francisco River (Fig. 1). Sampling in the lotic section was conducted in the main channel of the river (10°13'2.25"S 36°46'1.67"W; 10°10'51.50"S 36°50'37.20"W), with pH 7.64 ± 0.09, electrical conductivity 85.9 ± 0.4 μS $cm^{-1}$, total dissolved solids 56.0 ± 0.01 mg $L^{-1}$, and dissolved oxygen 7.48 ± 0.43 mg $L^{-1}$. The abiotic variables were different in the location corresponding to Lagoa da Marituba (10°18'17.47"S 36°23'43.16"W) and reflected the lentic environment, with slightly acidic pH (6.83 ± 0.05) likely due to the presence of humic acids and the decomposition of organic matter, which may contribute to higher values of electrical conductivity (226.4 ± 0.1 μS $cm^{-1}$) total dissolved solids (114.9 ± 0.1 mg $L^{-1}$) and lower concentrations of dissolved oxygen (2.55 ± 0.05 mg $L^{-1}$).

Fishes were collected between 2022 and 2023, using gill nets set up at dusk and removed at dawn, with

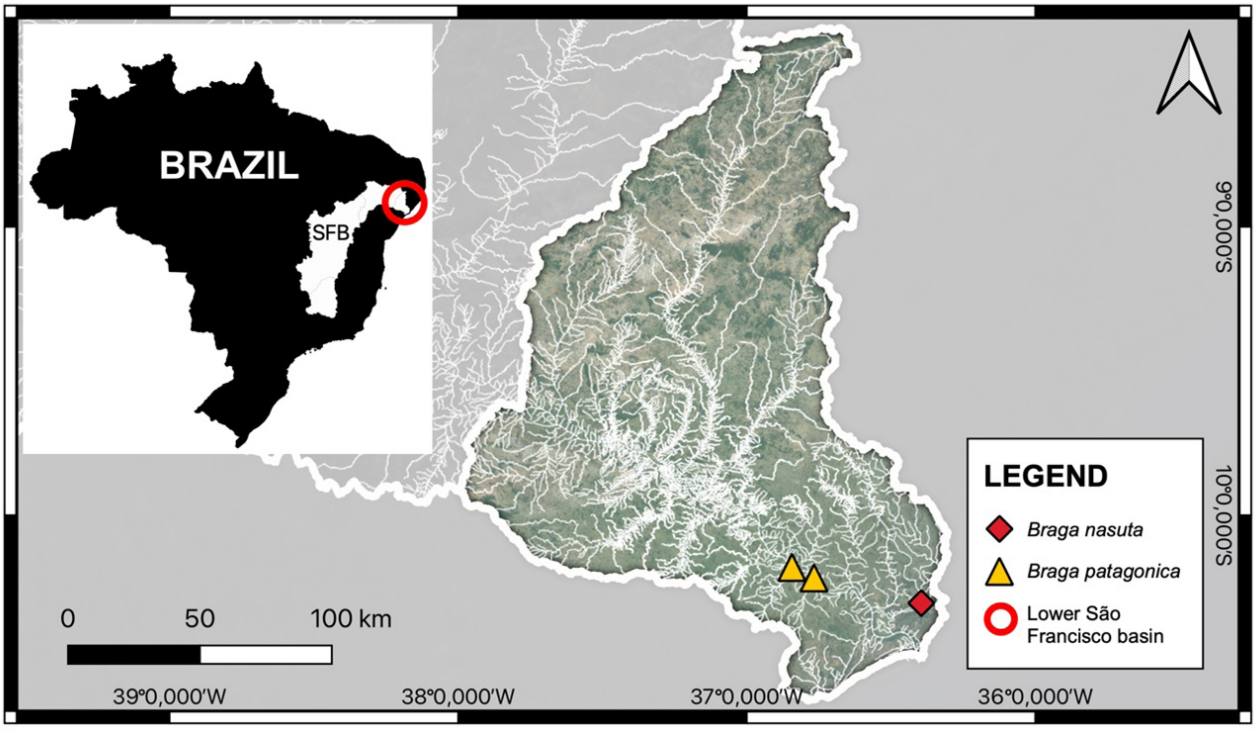


**Figure 1.** Location of the São Francisco River basin (SFB) in Brazil, with details of records of *Braga nasuta* and *Braga patagonica* found parasitizing *Pygocentrus piraya* in the lower portion of the river.

an average deployment time of 14h. The individuals were removed from the net and transported to the laboratory for biometry. Total length (TL), standard length (SL), and body weight (BW) were measured. Ectoparasites were macroscopically located and removed from the hosts using fine-tipped tweezers, placed into Petri dishes, and cleaned with jets of water. Representative specimens of taxa were deposited in the Zoological Collection of Universidade Federal de Sergipe (CZUFS), São Cristóvão, Sergipe, Brazil.

Isopods were identified through morphological comparisons obtained from the scientific literature (Thatcher, 1995; 2006; Tavares-Dias et al., 2014; Narciso et al., 2019) combined with observations of the body, morphological attributes of the appendages, and other taxonomic structures. The specimens were then illustrated using a mixed technique with colored pencils, colored brush pens, and India ink, based on Alves et al. (2022). The figure boards were assembled and treated using the Paint and GIMP version 2.10.34 software.

Ecological descriptors of isopod parasites were calculated based on Bush et al. (1997): prevalence (P), intensity (I), mean intensity (Im), and mean abundance (Am).

## SYSTEMATICS

Nine individuals of *P. piraya* were collected, three of which were parasitized. Five were collected at 10°13'2.25"S 36°46'1.67"W, one of which was parasitized; two were collected at 10°10'51.50"S 36°50'37.20"W, one of which was parasitized; two were collected at 10°18'17.47"S 36°23'43.16"W, and one was parasitized. The parasitized fish measured 20.5 cm (± 2.12) in length and weighed 171g (± 113.71). The isopods were identified as belonging to the genus *Braga* Schioedte and Meinert, 1881. The diagnoses of the genus and species are as follows:

**Order Isopoda Latreille, 1816**

**Suborder Cymothoida Wägele, 1989**

**Superfamily Cymothooidea Leach, 1814**

**Family Cymothoidae Leach, 1814**

**Genus *Braga* Schioedte and Meinert, 1881**

*Diagnosis* (male and female): Body longer than wide, symmetrical. Cephalon not immersed in pereonite 1; forehead obtuse; antennal bases well

separated. Pereonite 1 larger than pereonite 7; compact coxal plates, not extending posteriorly to the respective pereonites. Relatively long pereopods with 7th pair longer than others, all ending in stout prehensile, claw-shaped dactyls. Mandible subrectangular, without cutting or incisor process. Pleon slightly immersed in pereonite 7; pleonites usually with lateral projections; pleopods multilaminate – pleopod 1 bilaminate, 2 quadrilaminate, 3–5 trilaminate. Pleotelson keelless shield-shaped; uropods short with endopods shorter than exopods.

### *Braga patagonica* Schioedte and Meinert, 1884
(Fig. 2)

*Material examined*. 2 females and 2 males (catalogue number: CZUFS CRU-00373).

*Supplementary description*. Females (Fig. 2A): oval body; light milky color. Cephalon triangular, anterior long and rounded; scattered and discrete chromatophores; relatively small eyes. Antennule with 7 articles and antenna with 8 articles (Fig. 2D, E). Pereon broad, being longest and widest at pereonite 5. Pleon narrow. Pleotelson prominent, wider than long. Pleopod 1 bilaminate, 2 quadrilaminate, 3–5 trilaminate; exopod longer than endopod. Uropod shorter than pleotelson.

Males (Fig. 2B, C). Smaller than females. Milky brownish coloration, with chromatophores forming patterned dotted dark brown pigmentation arranged at lateral and posterior ends of pereonites and in central strip extending from anterior to posterior region. Head with well-developed eyes. Antennule with 7 articles. Antenna bases well separated, with

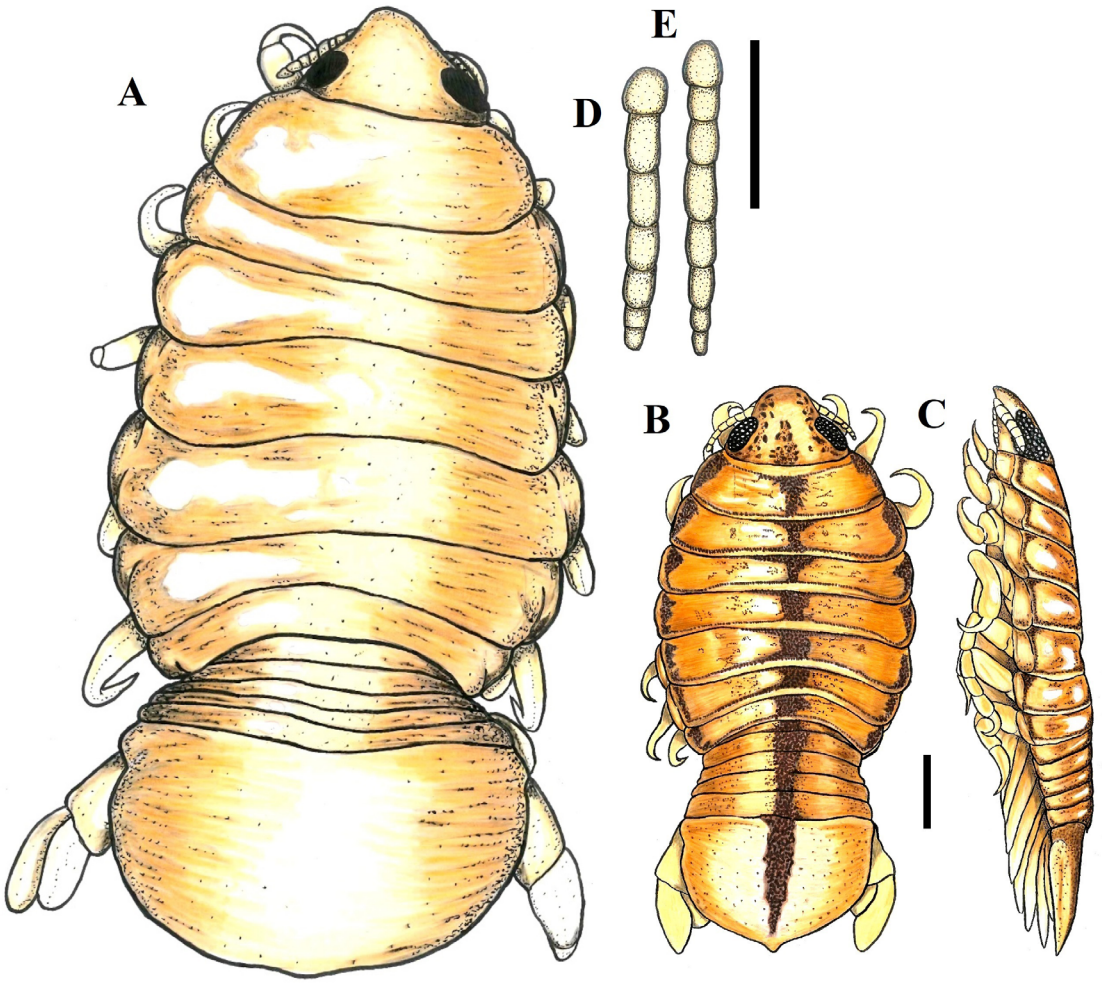


**Figure 2.** *Braga patagonica* (CZUFS CRU-00373) detected on *Pygocentrus piraya*. **A**, Female habitus in dorsal view; **B**, **C**, male, habitus in dorsal and lateral views, respectively, scale: 1 mm; **D**, **E**, antennule and antenna, respectively, scale: 0.5 mm.

8 articles. Seen from side, body practically straight, with subtle depression in pereonite 5.

*Host/site of infection*. *Pygocentrus piraya*, body surface.

*Place of registration*. Main channel of the São Francisco River between the municipalities of Porto Real do Colégio (state of Alagoas) and Propriá (state of Sergipe).

*Ecological descriptors*. P = 22.22%; Im = 2.00; Am = 0.44 ± 1.01

### *Braga nasuta* Schioedte and Meinert, 1881
(Fig. 3)

*Material examined*. One male collected (catalogue number: CZUFS CRU-00374).

*Supplementary description*. Male: Yellowish coloration with chromatophores forming a patterned dotted dark pigmentation in distinct longitudinal bands along the body (Fig. 3A). Laterally, body curved, with concave shape (Fig. 3B); compact coxal plates not extending beyond pereonites. Cephalon anteriorly truncated, with well-developed eyes. Antennule with 7 articles. Antennal bases well separated, with 8 articles

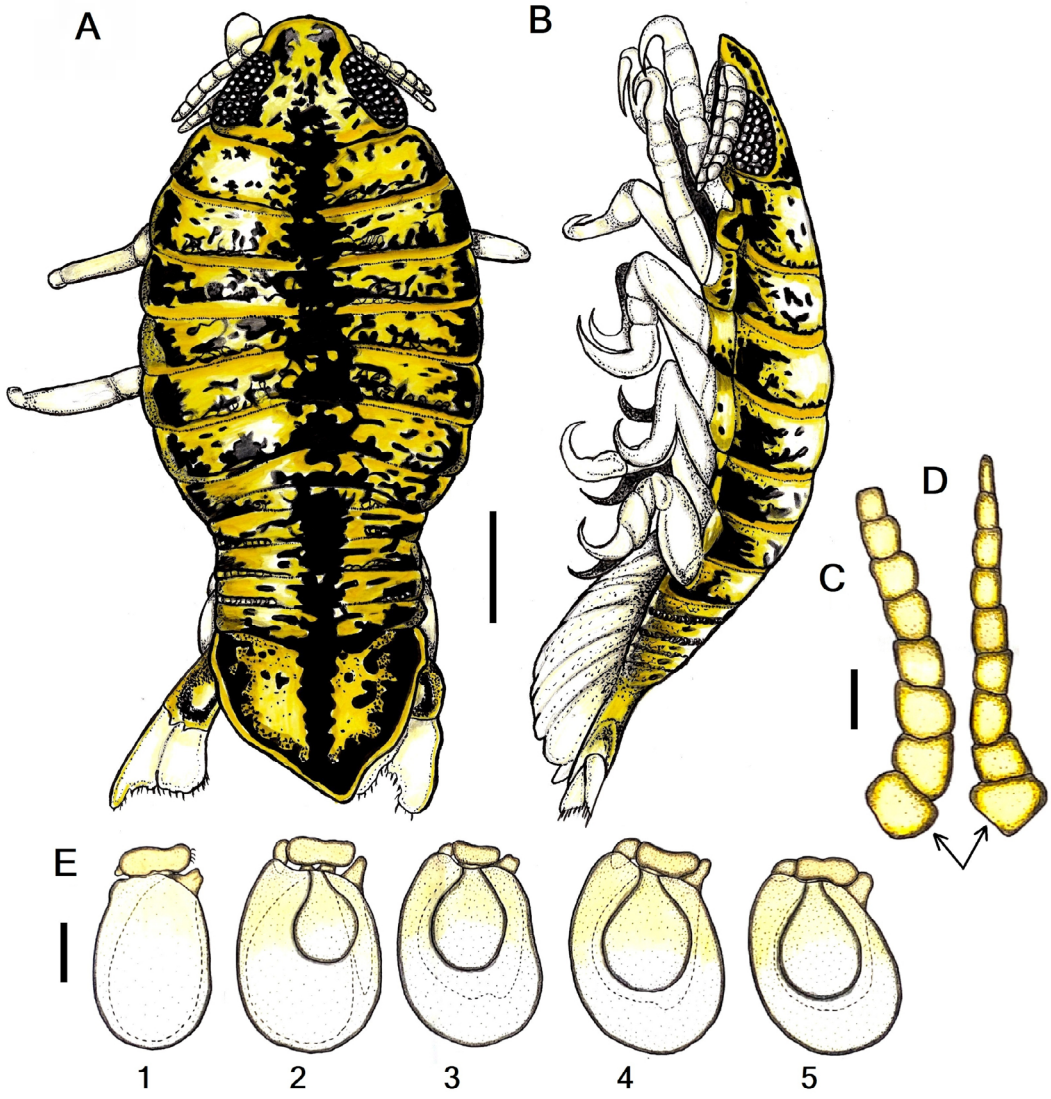


**Figure 3.** *Braga nasuta* (CZUFS CRU-00374) detected on *Pygocentrus piraya*; **A**, **B**, Male, habitus in dorsal and lateral views, respectively, scale: 1 mm; **C**, **D**, antennule and antenna, respectively, arrows point to the basal article, scale: 0.5 mm; **E**, pleopods 1–5 (2–5 are multilaminate), scale: 0.5 mm.

(Fig. 3C, D). Pereopods ending in prehensile dactyls (hooks); some chromatophores also found on some pereopods; pereopod 7 with shorter dactyl than others. Pleotelson triangular, ending in small point. Pleopods short (Fig. 3E), rounded. Pleopod 1 bilaminate, 2 quadrilaminate, 3–5 trilaminate; uropod extending beyond apex of pleotelson, with exopod slightly longer than endopod. Male appendix flattened, tapering; small lateral and near medial peduncular lobes on all pleopods; anterior accessory gill lamellae present on pleopods 2–5.

*Host/site of infection*. *Pygocentrus piraya*, body surface.

*Place of registration*. Lagoa da Marituba, municipality of Penedo (state of Alagoas).

*Ecological descriptors*. P = 11.1%; Im = 1.00; Am = 0.11 ± 0.33.

## DISCUSSION

The studied specimens of *B. patagonica* and *B. nasuta* had similar morphologies to specimens reported by Thatcher (1995; 2006), Tavares-Dias et al. (2014), and Narciso et al. (2019). Although pigmentation is not a taxonomic characteristic, the difference in pigmentation between males and females is notable. According to Trilles (1991), this difference in pigmentation is related to the habitat occupied by isopods. Specimens that parasitize the buccal or branchial cavity, preferably occupied by females, are whitish or weakly pigmented. In contrast, species that parasitize the surface of the host, preferentially occupied by males, have more intense or stronger pigmentation.

The findings of the present study expand the distribution of the genus *Braga* and contribute to biogeographical knowledge of the species. The ability to parasitize species from different taxonomic groups attests to the low specificity, as past records indicate parasitized fishes from different families of Characiformes, Siluriformes, Cichliformes, and Osteoglossiformes, such as *Arapaima gigas* (Schinz) (Tab. 1). This fact seems very opportune because of the great diversity of fishes in the Neotropical region (Dagosta and de Pinna, 2019), which may be directly associated with the wide geographical distribution of the parasites.

Isopods of the suborder Cymothoida are ectoparasites that can cause physical harm and affect the development of the host, feeding on blood and tissues when attached to the integument, fins, gills, and oral cavity by claws at the ends of their articulated legs (Izdebska and Rolbiecki, 2010). Owing to their fixation method and the possibility of remaining hidden (e.g., oral and gill cavities) even after the fish has been caught, these parasites can be transported to new areas along with the host. In the context of biological invasions, this is an important factor to consider, as they can be co-invaders and benefit from the lack of host specificity to continue their cycle in other species in the receiving river basin (Lymbery et al., 2014). Poulin (2017) stated that research on parasitism in the context of biological invasions is not keeping pace with research on biological invasions in general and it is crucial to reverse this situation, as understanding the role and environmental impact of parasites is fundamental.

Previous studies have indicated the presence of only two species of isopods in the São Francisco River basin: *Braga fluviatilis* Richardson, 1911 on *P. piraya* and *Amphira branchialis* Thatcher, 1993 on the serrasalmid *Pygocentrus nattereri* Kner (Santos, 2008; Vital et al., 2011). However, *B. patagonica* and *B. nasuta* have not previously been reported, even in large studies. Although parasitic intensity was low, the presence of adult females of *B. patagonica* with a developed marsupium on *P. piraya* suggests that this fish is a suitable host for parasitism. Thus, the information presented in this study corresponds to the first record of these isopods on *P. piraya* and for the São Francisco River basin. This indicates that there is still a lack of knowledge regarding the study of fish parasites in the river basin, as previous records show the occurrence of other parasites (e.g., Nematoda, Cestoidea, and Eupentasomida) (Santos et al., 2009; Santos-Clapp et al., 2022; Duarte et al., 2022). Collaborations between research groups that carry out sampling of fishes throughout the basin can contribute to the expansion of knowledge on these organisms as well as the training of human resources in fish parasitology.

**Table 1.** Occurrence records of *Braga patagonica* and *Braga nasuta* in Brazilian hydrographic basins.

| Parasite | Host | Order/Family | Hydrographic basin | Reference |
|---|---|---|---|---|
| *Braga patagonica* | *Pygocentrus nattereri* Kner | Characiformes/Serrasalmidae | Tocantins basin | Carvalho et al. (2004) |
| | *Colossoma macropomum* (Cuvier) | Characiformes/Serrasalmidae | Amazon, High São Francisco, Paraná and Southeast Atlantic basins | Luque et al. (2013) |
| | *Hoplias malabaricus* (Bloch) | Characiformes/Erythrinidae | | |
| | *Salminus hilarii* (Valenciennes) | Characiformes/Erythrinidae | | |
| | *Colossoma macropomum* | Characiformes/Serrasalmidae | Amazon basin | Tavares-Dias et al. (2014) |
| | *Pygogentrus nattereri* | Characiformes/Serrasalmidae | | |
| | *Mylossoma duriventre* (Cuvier) | Characiformes/Serrasalmidae | | |
| | *Serrasalmus rhombeus* (Linnaeus) | Characiformes/Serrasalmidae | | |
| | *Brycon amazonicus* (Spix and Agassiz) | Characiformes/Bryconidae | | |
| | *Hydrolycus scomberoides* (Cuvier) | Characiformes/Cynodontidae | | |
| | *Chaetobranchopsis orbicularis* (Steindachner) | Cichliformes/Cichlidae | | |
| | *Oreochromis niloticus* (Linnaeus) | Cichliformes/Cichlidae | Amazon basin | Bittencourt et al. (2014) |
| | *Colossoma macropomum* | Characiformes/Serrasalmidae | Pisciculture | Dias et al. (2015) |
| | *Peprilus paru* (Linnaeus) | Scombriformes/Stromateidae | Amazon basin | das Chagas et al. (2015) |
| | *Acestrorhynchus falcatus* (Bloch) | Characiformes/ Acestrorhynchidae | Amazon basin | Hoshino et al. (2016) |
| | *Curimata incompta* Vari | Characiformes/Curimatidae | Amazon basin | Neves et al. (2016) |
| | *Odontesthes bonariensis* (Valenciennes) | Atheriniformes/Atherinopsidae | Guaíba, Mirim-São Gonçalo and Southeast Atlantic basins | Huanto (2017) |
| | *Serrasalmus altispinis* Merckx, Jégu and Santos | Characiformes/Serrasalmidae | Amazon basin | Oliveira et al. (2017) |
| | *Chaetobranchus flavescens* Heckel | Cichliformes/Cichlidae | Amazon basin | Tavares-Dias et al. (2018) |
| | *Pellona castelnaeana* Valenciennes | Clupeiformes/Pristigateridae | Amazon basin | Souza (2018) |
| | *Pygocentrus nattereri* (Kner) | Characiformes/Serrasalmidae | Amazon basin | Souza et al. (2018) |
| | *Serrasalmus elongatus* (Kner) | Characiformes/Serrasalmidae | | |
| | *Brycon amazonicus* (Spix and Agassiz) | Characiformes/Bryconidae | | |
| | *Triportheus albus* Cope | Characiformes/Triportheidae | | |
| | *Mylesinus* sp. | Characiformes/Serrasalmidae | | |
| | *Colossoma macropomum* | Characiformes/Serrasalmidae | Amazon basin | Gonçalves et al. (2018) |
| | *Leporinus fasciatus* (Bloch) | Characiformes/Anostomidae | Amazon basin | Neves and Tavares-Dias (2019) |
| | *Propimelodus eigenmanni* (Van der Stigchel) | Siluriformes/Pimelodidae | | |
| | *Phractocephalus hemioliopterus* Bloch and Schneider | Siluriformes/Pimelodidae | Amazon basin | Oliveira et al. (2019) |
| | *Pimelodella humeralis* Slobodian, Akama and Dutra | Siluriformes/Heptapteridae | Amazon basin | Virgilio et al. (2020) |
| | *Hoplias malabaricus* | Characiformes/Erythrinidae | Western Northeast Atlantic Basin | Ribeiro and Mugnai (2020) |
| | *Serrasalmus* sp. | Characiformes/Serrasalmidae | | |
| *Braga nasuta* | *Hypostomus* sp. | Siluriformes/Loricariidae | Amazon High São Francisco Paraná and Southeast Atlantic basins | Luque et al. (2013) |
| | *Arapaima gigas* (Schinz) | Osteoglossiformes/Arapaimidae | Pisciculture | Jesus et al. (2017) |
| | *Hyphessobrycon eques* (Steindachner) | Characiformes/Characidae | Paraná basin | Narciso et al. (2019) |
| | *Serrasalmus* sp. | Characiformes/Serrasalmidae | Western Northeast Atlantic Basin | Ribeiro and Mugnai (2020) |

This study provides important information about the presence of previously unidentified isopod parasites on fishes of the São Francisco River basin, underscoring the need for further studies in this area. Low levels of infection were observed on *P. piraya*, represented by only one specimen of *B. nasuta*. The isopod *B. patagonica* had a higher infection rate compared to *B. nasuta* on *P. piraya*. The occurrence of these isopods in the lower São Francisco River in northeastern Brazil expands the geographic distribution of these two species and places *P. piraya* in the list of hosts for these two ectoparasites.

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## REFERENCES

Alves AM; Leonardo MG; Souza GTR; Takemoto RM; de Lima, FS; Tavares LER; Melo CM; Madi RR and Jeraldo VLS 2019. Occurrence of isopods in two species of snappers (Lutjanidae) from Northeast Brazil. *Journal of parasitology Research*, 2019(1): 1–8. https://doi.org/10.1155/2019/8176283

Alves AM; Freire JF; Coelho AS; Souza RGT and Jeraldo VDLS 2022. Ilustração científica na representação de isópodes parasitas. *Neotropical Helminthology*, 16(2): 91–105. https://doi.org/10.24039/rnh20221621407

Bittencourt LS; Pinheiro DA; Cárdenas MQ; Fernandes BM and Tavares-Dias M 2014. Parasites of native Cichlidae populations and invasive *Oreochromis niloticus* (Linnaeus, 1758) in tributary of Amazonas River (Brazil). *Revista Brasileira de Parasitologia Veterinária*, 23: 44–54. https://doi.org/10.1590/S1984-29612014006

Bruce NL 1987. Australian species of *Nerocila* Leach, 1818, and *Creniola* n.gen. (Isopoda: Cymothoidae), crustacean parasites of marine fishes. *Records of the Australian Museum*, 39(6): 355–412. https://media.australian.museum/media/Uploads/Journals/17680/174.pdf

Brusca RC 1981. A monograph on the Isopoda Cymothoidae (Crustacea) of the eastern Pacific. Zoological *Journal of the Linnean Society*, 73(2): 117–199. https://academic.oup.com/zoolinnean/article-abstract/73/2/117/2658789

Bush AO; Lafferty KD; Lotz JM and Shostak AW 1997. Parasitology meets ecology on its own terms: Margolis et al. Revisited. *Journal of Parasitology*, 83(4): 575–583. https://doi.org/10.2307/3284227

Carvalho LN; Arruda R and Del-Claro K 2004. Host-parasite interactions between the piranha *Pygocentrus nattereri* (Characiformes: Characidae) and isopods and branchiurans (Crustacea) in the rio Araguaia basin, Brazil. *Neotropical Ichthyology*, 2(2): 93–98. https://doi.org/10.1590/S1679-62252004000200006

Costa EFS and Chellapa S 2010. New host record for *Livoneca redmanni* (Leach, 1818) (Isopoda: Cymothoidae) in the brazilian coastal waters with aspects of host-parasite interaction, Brazilian *Journal of Oceanography*, 58: 73–77. https://www.scielo.br/j/bjoce/a/YHSy8VPLpLFNTwnZY5pXgvh/?format=pdf&lang=en

Dagosta FC and De Pinna M 2019. The fishes of the Amazon: distribution and biogeographical patterns, with a comprehensive list of species. *Bulletin of the American Museum of Natural History*, 2019 (431): 1–163. https://doi.org/10.1206/0003-0090.431.1.1

das Chagas RA; Barros MRF; Salimos RKC; dos Santos, WCR and Herrmann M 2015. Ocorrência de *Braga patagonica* (Isopoda, Cymothoidae) parasitando *Peprilus paru* (Osteichthyes: Stromateidae) em águas costeiras tropicais de São. *Acta of Fisheries and Aquatic Resources*, 3(2): 1–9. https://doi.org/10.2312/Actafish.2015.3.2.1-9

Dias MKR; Neves LR; Marinho RGB and Tavares-Dias M 2015. Parasitic infections in tambaqui from eight fish farms in Northern Brazil. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, 67: 1070–1076. https://doi.org/10.1590/1678-4162-7592

Duarte, R., Santos-Clapp, M. D. D., & Brasil-Sato, M. D. C. (2022). *Sebekia* sp.(Eupentastomida, Sebekidae) in Pygocentrus piraya (Actinopterygii: Serrasalmidae) from marginal lagoons of the middle São Francisco River basin, Brazil. *Revista Brasileira de Parasitologia Veterinária*, 31(4): e010522. https://doi.org/10.1590/S1984-29612022060

Eiras JC; Takemoto RM; Pavanelli GC and Adriano EA 2010. Diversidade dos parasitas de peixes de água doce do Brasil. Maringá, Clichetec, 333p.

Fadel A; Bessa M and Abdel-Aziz M 2020. *Livoneca redmanii* (Isopoda, Cymothoidae) in meagre *Argyrosomus regius*: Parasitological and molecular diagnosis and proposed control measure. *Diseases of Aquatic Organisms*, 140: 13–24. https://doi.org/10.3354/dao03490

Gonçalves BB; Oliveira MSB; Borges WF; Santos GG and Tavares-Dias M 2018. Diversity of metazoan parasites in *Colossoma macropomum* (Serrasalmidae) from the lower Jari River, a tributary of the Amazonas River in Brazil. *Acta Amazonica*, 48: 211–216. https://doi.org/10.1590/1809-4392201704371

Hoshino MDFG; Neves LR and Tavares-Dias M 2016. Parasite communities of the predatory fish, *Acestrorhynchus falcatus* and *Acestrorhynchus falcirostris*, living in sympatry in Brazilian Amazon. *Revista Brasileira de Parasitologia Veterinária*, 25: 207–216. https://doi.org/10.1590/S1984-29612016038

Huanto RB 2017. Assembleia de metazoários parasitos e histopatologias associadas às brânquias de *Odontesthes* (Atherinopsidae) em habitats aquáticos do extremo sul do Brasil. Porto Alegre, Universidade Federal do Rio Grande, Instituto de Ciências Biológicas, Pós-graduação em Biologia

de Ambientes Aquáticos Continentais, Master thesis, 59p. [Unpublished]. Available at https://repositorio.furg.br/handle/1/8970

Izdebska JN and Rolbiecki L 2010. Parasitic arthropods as the cause of parasitosis in aquatic animals. Arthropods. p. 125–135. In: Buckek A and Blaszak C (Eds.), Arthropods. Ecological and pathological aspects of parasite-host relationships. Lublin, Akapit. https://www.researchgate.net/profile/Leszek-Rolbiecki/publication/268512562_Parasitic_arthropods_as_the_cause_of_parasitoses_in_aquatic_animals/links/549f07290cf257a635fe71b3/Parasitic-arthropods-as-the-cause-of-parasitoses-in-aquatic-animals.pdf

Jesus EC; Cardoso L; Ferreira TH; Martins ML and Rodrigues MDN 2017. *Braga nasuta* (Cymothoidae): an ectoparasite of the Giant Amazonian fish *Arapaima gigas* (Osteoglossidae) fingerlings cultured in the Amazon region in Northern Brazil. *Acta Scientiarum. Biological Sciences*, 39(4): 507–511. https://doi.org/10.4025/actascibiolsci.v39i4.35080

Kensley B and Schotte M 1989. Guide to the marine isopod crustaceans of the Caribbean. Smithsonian Institution press, Washington, D.C., and London, 328p. https://doi.org/10.5962/bhl.title.10375

Luque JL; Pavanelli G; Vieira F; Takemoto R and Eiras J 2013. Checklist of Crustacea parasitizing fishes from Brazil. *Check List*, 9(6): 1449–1470. https://checklist.pensoft.net/article/18807/download/pdf/

Lymbery AJ; Morine M; Kanani HG; Beatty SJ and Morgan DL 2014. Co-invaders: the effects of alien parasites on native hosts. *International Journal for Parasitology: Parasites and Wildlife*, 3(2): 171–177. https://doi.org/10.1016/j.ijppaw.2014.04.002

Narciso RB; de Oliveira GP; Acosta AA and da Silva RJ 2019. Occurrence of *Braga nasuta* Schioedte & Meinert (1881) (Isopoda, Cymothoidae) parasitizing the ornamental fish *Hyphessobrycon eques* (Steindachner, 1882) (Characidae) from a Brazilian river. *Neotropical Helminthology*, 13(1): 17–23. http://dx.doi.org/10.24039/rnh2019131617

Neves LR and Tavares-Dias M 2019. Low levels of crustacean parasite infestation in fish species from the Matapi River in the state of Amapá, Brazil. *Revista Brasileira de Parasitologia Veterinária*, 28: 493–498. https://doi.org/10.1590/S1984-29612019006

Neves LR; Braga ECR and Tavares-Dias M 2016. Diversity of parasites in *Curimata incompta* (Curimatidae), a host from Amazon river system in Brazil. *Journal of Parasitic Diseases*, 40(4): 1296-1300. https://doi.org/10.1007/s12639-015-0674-0

Oliveira MSB; Corrêa LL; Oliveira Ferreira D; Neves LR and Tavares-Dias M 2017. Records of new localities and hosts for crustacean parasites in fish from the eastern Amazon in northern Brazil. *Journal of Parasitic Diseases*, 41: 565–570. https://doi.org/10.1007/s12639-016-0852-8

Oliveira MSB; Corrêa LL; Gonçalves RA; Neves LR; Prestes L; Ferreira DO and Tavares Dias M 2019. New records of crustaceans infesting *Phractocephalus hemioliopterus* (Siluriformes: Pimelodidae), the large catfish from the Amazon. *Revista Mexicana de Biodiversidade*, 90: e901969. https://doi.org/10.22201/ib.20078706e.2019.90.1969

Poulin R 2017. Invasion ecology meets parasitology: advances and challenges. *International Journal for Parasitology: Parasites and Wildlife*, 6(3): 361–363. https://doi.org/10.1016/j.ijppaw.2017.03.006

Purivirojkul W and Songsuk A 2020. New records of fish parasitic isopods (Crustacea: Isopoda) from the Gulf of Thailand. *Animals*, 10(12): 2298. https://doi.org/10.3390/ani10122298

Ravichandran S; Vigneshwaran P and Rameshkumar G 2019. A taxonomic review of the fish parasitic isopod family Cymothoidae Leach, 1818 (Crustacea: Isopoda: Cymothooidea) of India. *Zootaxa*, 4622(1): 1–99. https://doi.org/10.11646/zootaxa.4622.1.1

Ribeiro AM and Mugnai R 2020. New distribution record and extension range of three species of cymothoid isopods (Isopoda: Cymothoidae) in Maranhão state, Brazil. *Comparative Parasitology*, 87(1): 85–88. https://doi.org/10.1654/1525-2647-87.1.85

Ribeiro FB; Huber AF and Araujo PB 2021. Redescription of the fish-parasitic isopod *Cymothoa ianuarii* Schioedte & Meinert, 1884 and further records of *C. excisa* Perty, 1833 and *C. oestrum* (Linnaeus, 1758) (Isopoda: Cymothoida: Cymothoidae) from Brazil. *Papéis Avulsos de Zoologia*, 61: e20216109. https://doi.org/10.11606/1807-0205/2021.61.09

Santos MD dos 2008. Comunidades parasitárias de três espécies de peixes carnívoros do Reservatório de Três Marias, Alto Rio São Francisco, Minas Gerais, Brasil. 2008. Seropédica, Universidade Federal Rural do Rio de Janeiro, Instituto de Veterinária, Doctoral thesis, 238p. [Unpublished]. Available at https://tede.ufrrj.br/handle/tede/762

Santos MD; Albuquerque MC; Monteiro CM; Martins NA; Ederli NB and Brasil-Sato MC 2009. First report of larval *Spiroxys* sp. (Nematoda, Gnathostomatidae) in three species of carnivorous fish from Três Marias Reservoir, São Francisco River, Brazil. *Pan American Journal of Aquatic Sciences*, 4(3): 306–311. https://panamjas.org/pdf_revistas/PANAMJAS_9(1).pdf#page=60

Santos-Clapp MD; Duarte R; Albuquerque MC and Brasil-Sato MC 2022. Helminth endoparasites of endemic fish *Pygocentrus piraya* (Characiformes, Serrasalmidae) from Três Marias reservoir, Minas Gerais, Brazil. *Anais da Academia Brasileira de Ciências*, 94(4): e20201425. https://doi.org/10.1590/0001-3765202220201425

Searle HR and Richardson H 1905. A monograph on the isopods of North America (No. 54). US Government Printing Office. https://doi.org/10.5479/si.03629236.54.i

Silva EDS and Souza-Filho JF 2017. Species of *Excorallana* (Isopoda, Corallanidae) from northern and northeastern Brazil, with description of a new species, *Excorallana lemoscastroi* sp. nov. *Nauplius*, 25: e2017026. https://doi.org/10.1590/2358-2936e2017026

Smit NJ; Bruce NL and Hadfield KA 2014. Global diversity of fish parasitic isopod crustaceans of the family Cymothoidae. *International Journal for Parasitology Parasites Wildlife*, 3(2): 188–197. https://doi.org/10.1016/j.ijppaw.2014.03.004

Souza AKS 2018. Fauna de metazoários parasitos de Pellona castelnaeana Valenciennes, 1847 (Clupeiformes: Pristigasteridae) da Amazônia Brasileira. Instituto Nacional de Pesquisas da Amazônia (INPA), Programa de Pós-Graduacão em Biologia de Água Doce e Pesca Interior. Master thesis, 71p. [Unpublished]. Available at https://repositorio.inpa.gov.br/handle/1/11378

Souza AKS; Vitória MR da; Porto DB and Malta JDO 2018. Intramarsupial development of *Braga patagonica* Schiodt & Meinert, 1884 (Isopoda: Cymothoidae). *Neotropical Helminthology*, 12(1): 63–70. https://docs.wixstatic.com/ugd/1fc314_fac807986b354b21a8b589a80f0f091b.pdf

Tavares-Dias M; Araújo CSO; Barros MS and Viana GM 2014. New hosts and distribution records of *Braga patagonica*, a parasite Cymothoidae of fishes from the Amazon. Brazilian *Journal of Aquatic Science and Technology*, 18(1): 91–97. https://doi.org/10.14210/bjast.v18n1.p91-97

Tavares-Dias M; Goncalves RA; Oliveira MSB and Neves LR 2018. Parasites community in *Chaetobranchus flavescens* Heckel, 1840, (Cichliformes: Cichlidae) from the Eastern Amazon, Brazil. *Boletim do Instituto de Pesca*, 44(1): 10-16. http://dx.doi.org/10.20950/1678- 2305.2018.262.

Thatcher VE 1995. Comparative pleopod morphology of eleven species of parasitic isopods from Brazilian fish. *Amazoniana: Limnologia et Oecologia Regionalis Systematis Fluminis Amazonas*, 13(3/4): 305–314.

Thatcher VE 2006. Amazon fish parasites (vol. 1). Sofia, Moscow, Pensoft Publishers, 508p. https://books.google.com.br/books?hl=pt-BR&lr=&id=1CeI6irTVskC&oi=fnd&pg=PA2&dq=Thatcher+VE+2006.+Amazon+fish+parasites+(vol.+1).+Pensoft+Publishers,+508pp.,+Sofia+Moscow,+2006.&ots=EEl4e8Jxhs&sig=4oRQEGa--cHCcQsN5gnn_ez8RAw

Thatcher VE; Oliveira AA de and Garcia AM 2009. *Braga cigarra* comb. nov. for *Philostomella cigarra* (Crustacea: Isopoda: Cymothoidae) with a redescription of the species based on specimens from *Galeocharax kneri*, a freshwater fish of Minas Gerais State, Brazil. *Zoologia*, 26: 155–160. https://doi.org/10.1590/S1984-46702009000100021

Trilles JP 1991. Catalogue mondial des Cymothoidae. *Studia Marina*, 21/22(1-2): 5–288.

Vital JF; Varella AMB; Porto DB and Malta JCDO 2011. 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 Neotropica*, 11: 199–204. https://doi.org/10.1590/S1676-06032011000100021

Virgilio LR; Oliveira MSB; Almeida LS; Takemoto RM; Camargo LMA and Meneguetti, DUDO 2020. Isopods Cymothoidae ectoparasites of fish from the Amazon. *Revista Brasileira de Parasitologia Veterinária*, 29(4): e017920. https://doi.org/10.1590/S1984-29612020093

## ADDITIONAL INFORMATION AND DECLARATIONS

### Author Contributions

Conceptualization and Design: AMA, MFGB. Performed research: AMA, MVTG, UPJ, MFGB. Acquisition of data: MVTG, UPJ, MFGB. Analysis and interpretation of data: AMA, MFGB. Preparation of figures/tables/maps: AMA, MFGB. Writing – original draft: AMA, MFGB. Writing – critical review & editing: AMA, MVTG, UPJ, MFGB.

### Consent for publication

All authors declare that they have reviewed the content of the manuscript and gave their consent to submit the document.

### Competing interests

The author(s) declare(s) no competing interest.

### Data availability

All study date are included in the article.

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### Study permits

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