

Monogeneans of *Colossoma macropomum* (Cuvier, 1818) (Characiformes: Serrasalminidae) farmed in the state of Acre, Amazon (Brazil)

Monogeneas de *Colossoma macropomum* (Cuvier, 1818) (Characiformes: Serrasalminidae) cultivados no estado do Acre, Amazônia (Brasil)

Maralina Torres da Silva^{1*} ; Pedro Hercílio de Oliveira Cavalcante²; Cláudia Portes Santos³

¹Instituto Federal do Acre – IFAC, Rio Branco, AC, Brasil

²Instituto Federal do Acre – IFAC, Xapuri, AC, Brasil

³Laboratório de Avaliação e Promoção da Saúde Ambiental, Instituto Oswaldo Cruz, Fiocruz, Rio de Janeiro, RJ, Brasil

How to cite: Silva MT, Cavalcante PHO, Santos CP. Monogeneans of *Colossoma macropomum* (Cuvier, 1818) (Characiformes: Serrasalminidae) farmed in the state of Acre, Amazon (Brazil). *Braz J Vet Parasitol* 2022; 31(3): e006522. <https://doi.org/10.1590/S1984-29612022042>

Abstract

Parasitism of *Colossoma macropomum* is of particular concern because it is the most commonly farmed native fish species in Brazil. Nevertheless, the parasitic fauna of this species in the state of Acre has been little studied. For this reason, an evaluation was made of the parasitic fauna of farmed *C. macropomum* in the municipality of Rio Branco in southwestern Amazon. Four monogenean species were found in the 122 fish examined: *Anacanthorus spathulatus*, *Linguadactyloides brinkmanni*, *Notozothecium janauachensis* and *Mymarothecium boegeri*. The most prevalent species was *A. spathulatus* (50%), followed by *N. janauachensis* (44.3%), *M. boegeri* (20.5%) and *L. brinkmanni* (9.0%). These results are the first data on the ecological indices of monogeneans in tambaqui in the state of Acre and will be useful for future comparisons of the influence of environmental factors on the parasite-host relationship.

Keywords: Fish farming, Monogenea, tambaqui.

Resumo

O parasitismo em *Colossoma macropomum* é particularmente preocupante porque é a espécie de peixe nativa mais cultivada no Brasil, no entanto a fauna parasitária dessa espécie no estado do Acre é pouco estudada. Assim, foi avaliada a fauna parasitária de *C. macropomum* cultivado no município de Rio Branco, no sudoeste da Amazônia. Foram encontradas quatro espécies de monogeneas nos 122 peixes examinados: *Anacanthorus spathulatus*, *Linguadactyloides brinkmanni*, *Notozothecium janauachensis* e *Mymarothecium boegeri*. As espécies mais prevalentes foram *A. spathulatus* (50%), seguido de *N. janauachensis* (44,3%), *M. boegeri* (20,5%) e *L. brinkmanni* (9,0%). Esses resultados são os primeiros dados sobre os índices ecológicos dos parasitos monogenéticos em tambaqui no estado do Acre e serão úteis para futuras comparações da influência dos fatores ambientais na relação parasito-hospedeiro.

Palavras-chave: Piscicultura, Monogenea, tambaqui.

Introduction

Current knowledge about the biodiversity of parasites in *Colossoma macropomum* (Cuvier, 1818), a Serrasalminidae popularly known as tambaqui, shows that monogeneans represent the majority of helminth species that reported parasitizing this fish species in different localities (Kritsky et al., 1979; Pamplona-Basilio et al., 2001; Fischer et al., 2003; Cohen & Kohn, 2005, 2009; Morais et al., 2009; Godoi et al., 2012; Soberon et al., 2014; Dias et al., 2015; Chagas et al., 2016; Baia et al., 2019; Fujimoto et al., 2019; Mangas et al., 2020).

Received May 2, 2022. Accepted July 5, 2022.

*Corresponding author: Maralina Torres da Silva. E-mail: maralina.silva@ifac.edu.br



This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Parasitism in *C. macropomum* is of particular concern because this is the most commonly farmed native fish species in Brazil (IBGE, 2019). According to Valladão et al. (2018), the species is usually farmed in intensive and super-intensive systems, which may favor the occurrence and dissemination of parasitic diseases (Jerônimo et al., 2017; Farias et al., 2021).

Studies have reported damages caused by species of the class Monogenea in farmed *C. macropomum* (Santos et al., 2013; Soberon et al., 2014; Dias et al., 2015; Mangas et al., 2020). Among these damages are displacement of gill epithelium, focal hyperplasia of epithelial cells, lamellar fusion, congestion and shortening of the secondary lamellae of gills, as well as a complete fusion of the secondary lamellae (Tavares-Dias et al., 2021). However, information is lacking when it comes to the Amazon region, especially in the state of Acre. In this study, we provide new geographic distribution and ecological indexes of the parasitic monogeneans of *C. macropomum* in culture systems that can serve as a basis of comparison for future studies.

Materials and Methods

Ethics statement

This study was authorized by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA, Permit No. 39106/2013), in accordance with the guidelines of the Brazilian College of Animal Experimentation (COBEA).

Study areas and collection of parasites

The fish were obtained from Colônia Santa Maria, a fish farm specializing in the production of fingerlings, in the municipality of Rio Branco (10°03'25.3"S 67°50'54.0"W), in the state of Acre, Southwestern Amazonia, Brazil. The gills and body surface of 122 *C. macropomum* were examined in saline medium under a stereomicroscope. The parasites were fixed in 70% ethanol or 4% formalin. The monogeneans were cleared in Berlese or Hoyer medium, and some of them were stained with Gomori trichrome and examined as permanent mounts in Canada balsam. Drawings were made with the aid of a drawing tube and redrawn using Adobe Illustrator CS6. Measurements are presented in micrometers as the range, followed by the mean in parentheses, unless otherwise stated.

Parasites were identified as proposed by Kritsky et al. (1979, 1996), Thatcher & Kritsky (1983), Belmont-Jégu et al. (2004), Cohen & Kohn (2005), Boeger et al. (2006) and Cohen et al. (2013).

The prevalence, mean intensity and mean abundance were calculated for each helminth species, according to Bush et al. (1997). The prevalence was the ratio between the number of infected animals and the total number of animals analyzed. The mean intensity was the total number of helminths of a certain species divided by the number of animals infected by this species. The dominance frequency, i.e. the percentage of the infracommunities in which a given parasite species is numerically dominant was calculated according to Rohde et al. (1995).

The dispersion index (ID) and Poulin discrepancy index (D) were employed to detect distribution patterns of the parasite infracommunity (Rózsa et al., 2000) in species with prevalence $\geq 10\%$. The dispersion index (ID) significance was tested using the d-statistic according to Ludwig & Reynolds (1988).

Specimens were deposited at the Helminthological Collection of the Oswaldo Cruz Institute (CHIOC), Brazil.

Results

One hundred and twenty-two specimens of *C. macropomum*, measuring 4–42 (17 ± 6.2) cm in length and weighed 1–1340 (110 ± 176.1) g, were examined for the presence of monogeneans and 73 (59.8%) were found to be parasitized by at least one species. A total of 3,624 monogeneans were collected in the gills and none was found on the body surface. The parasites comprised four species of Monogenea in the new geographical location: 10°03'25.3"S 67°50'54.0"W, Rio Branco, state of Acre, Brazil. The measurements corresponding of these species are presented in Table 1. Data on prevalence, mean intensity, mean abundance and number/range of parasites are displayed in Table 2. The following species were found:

Anacanthorus spathulatus Kritsky, Thatcher & Kayton, 1979 (Figure 1ABC) (Specimens deposited: CHIOC no. 38658).

Table 1. Measurements of monogeneans found parasitizing *Colossoma macropomum* farmed in the state of Acre, Amazon, Brazil.

Measurements	<i>Anacanthorus spathulatus</i>	<i>Linguadactyloides brinkmanni</i>	<i>Notozothecium janauachensis</i>	<i>Mymarothecium boegeri</i>
Body length	445–825 (626)	1100–1725 (146)	275–382.5 (318)	230
Body width	90–225 (159)	360–550 (456)	70–125 (96.3)	50
Haptor length	40–110 (70)	125–200 (158)	50–75 (60)	
Haptor width	100–175 (126)	180–275 (218)	62–95 (80)	45
Ventral bar			55–70 (61)	53–68 (60)
Dorsal bar			20–40 (27)	30–50 (44)
Ventral anchor length		50–63 (54)	37–50 (42)	20–28 (23)
Ventral anchor base width		18–25 (21)	32–45 (38)	13–23 (19)
Dorsal anchor length		38–43 (40)	15–22 (19)	20–25 (23)
Dorsal anchor base width		20–25 (23)	10–17 (12)	15–23(19)
Male copulatory organ	75–85 (78)		22–37 (28)	43–60 (49)

Table 2. Prevalence, mean abundance, mean intensity, total number of parasites, range of variation and dominance frequency of monogeneans of *Colossoma macropomum* farmed in the state of Acre, Amazon, Brazil.

Parasites	Prevalence (%)	Mean Abundance	Mean Intensity	Total number of parasites	Range of variation	Dominance frequency (%)
<i>Anacanthorus spathulatus</i>	50	17.1	34.1	2082	1-794	36.9
<i>Linguadactyloides brinkmanni</i>	9	0.2	2.0	22	1-5	0.8
<i>Notozothecium janauachensis</i>	44.3	8.6	19.4	1046	1-255	20.5
<i>Mymarothecium boegeri</i>	20.5	3.9	18.9	474	1-192	2.5

Linguadactyloides brinkmanni Thatcher & Kritsky, 1983 (Figures 2A to 2G) (Specimens deposited: CHIOC no. 38663).

Notozothecium janauachensis Belmont-Jégu, Domingues & Martins, 2004 (Figures 3A to 3H) (Specimens deposited: CHIOC no. 38662).

Mymarothecium boegeri Cohen & Kohn, 2005 (Figures 4A to 4G) (Specimens deposited: CHIOC no. 38664).

Anacanthorus spathulatus was the species with higher rates of prevalence (50%), mean abundance (17.1), mean intensity (34.1) and dominance frequency (36.9%), representing 57.4% of monogeneans collected total, followed by *N. janauachensis* (Table 2).

Forty-nine fish were not parasitized (40.1%). Twenty-three fish (18.9%) were infected by only one parasitic species, with *A. spathulatus* (52.2%) being the most frequent species, followed by *N. janauachensis* (43.4%) and *L. brinkmanni* (4.3%).

Twenty-seven hosts (22.1%) harbored two parasitic species, with *A. spathulatus* and *N. janauachensis* accounting for 77.7% of double infections, followed by *A. spathulatus* and *M. boegeri* (11.1%), *A. spathulatus* and *L. brinkmanni* (7.4%), and *N. janauachensis* and *M. boegeri* (3.7%). Eighteen fish (14.8%) were parasitized by three monogenean species as follow: *A. spathulatus*, *N. janauachensis* and *M. boegeri* (83.3%), *A. spathulatus*, *N. janauachensis* and *L. brinkmanni* (11.1%) and *A. spathulatus*, *M. boegeri* and *L. brinkmanni* (5.5%). Five fish (4.1%) were concurrently parasitized by four monogenean species (*A. spathulatus*, *N. janauachensis*, *M. boegeri* and *L. brinkmanni*).

The dispersion index (DI), statistical-*d* and discrepancy index (D) of the monogeneans of farmed *C. macropomum* showed a typical pattern of aggregated distribution (Table 3).

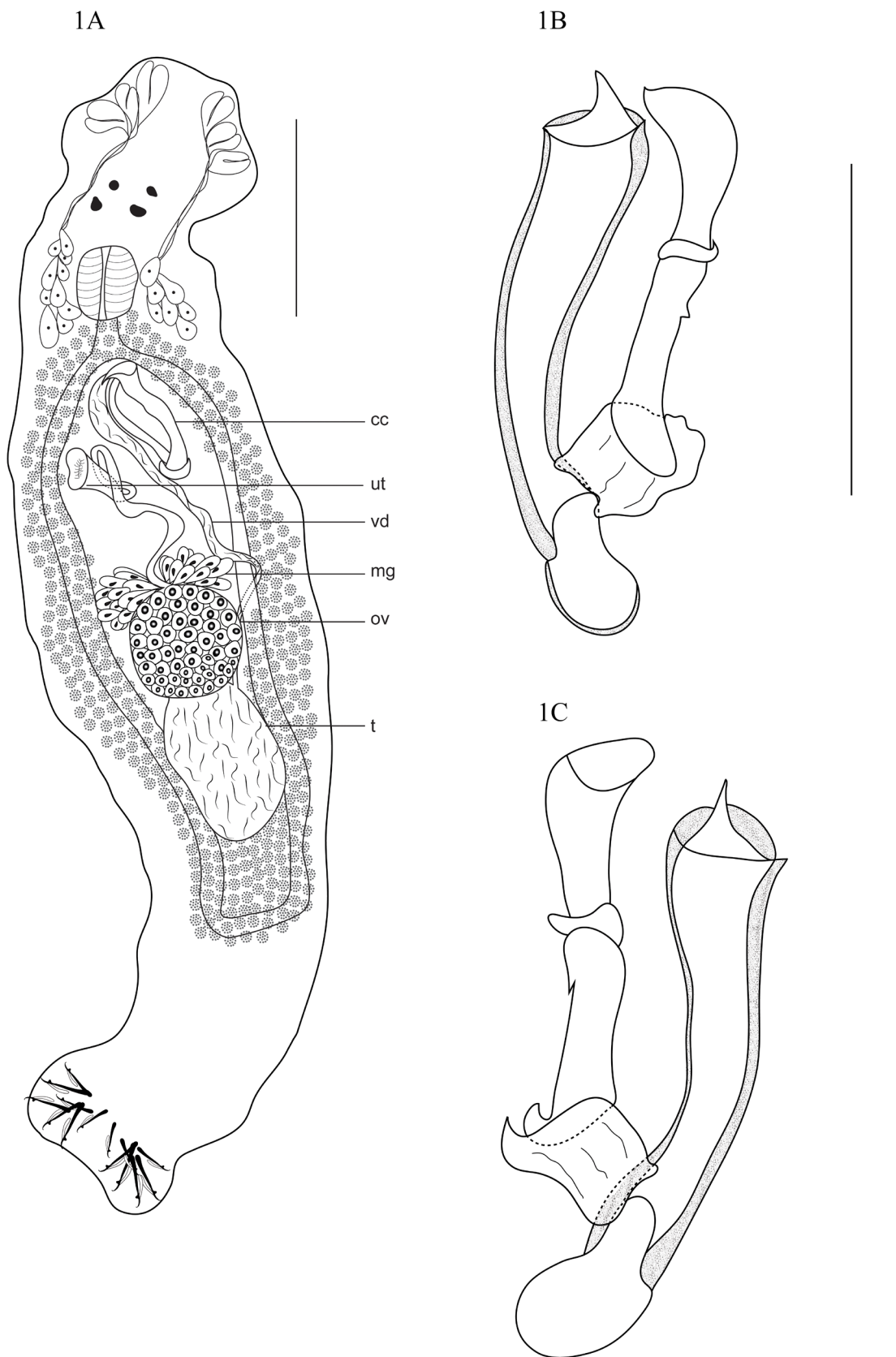


Figure 1. *Anacanthorus spathulatus*. **1A.** Total, ventral view (cc – copulatory complex; ut – uterus; vd – vas deferens; mg – Mehlis gland; ov – ovary; t – testis). **1B.** Copulatory complex, ventral view. **1C.** Copulatory complex, dorsal view. Scale bars: A = 100 μ m; B-C = 50 μ m.

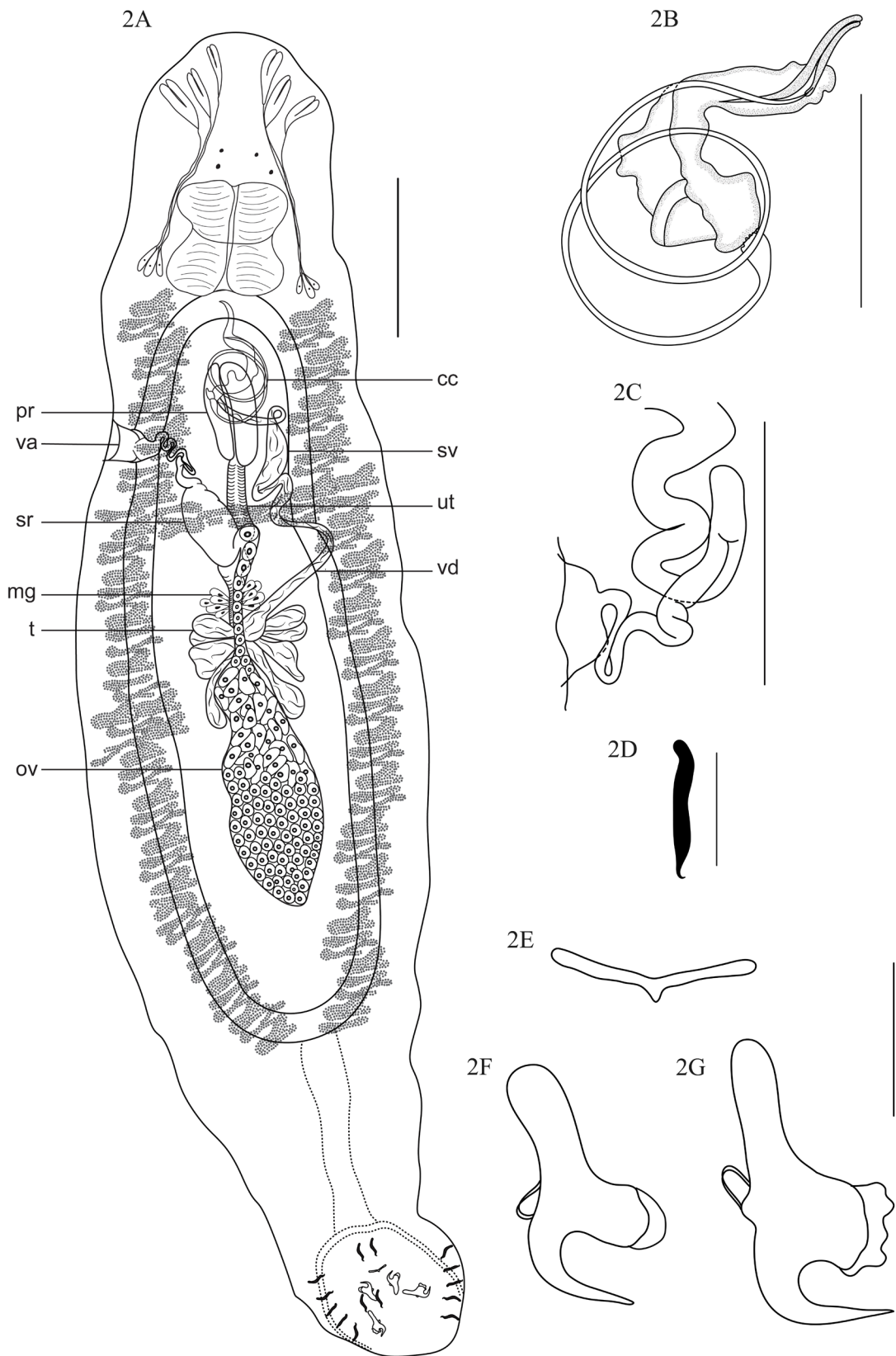


Figure 2. *Linguadactyloides brinkmanni*. **2A.** Total view (cc – copulatory complex; pr – prostatic reservoirs; va – vagina; sv – seminal vesicle; ut – uterus; sr – seminal receptacle; vd – vas deferens; mg – Mehlis gland; t – testis; ov – ovary). **2B.** Copulatory complex. **2C.** Vagina. **2D.** Hook. **2E.** Ventral bar. **2F.** Ventral anchor. **2G.** Dorsal anchor. Scale bars: A = 200 µm; B and C = 100 µm; D–G = 25 µm.

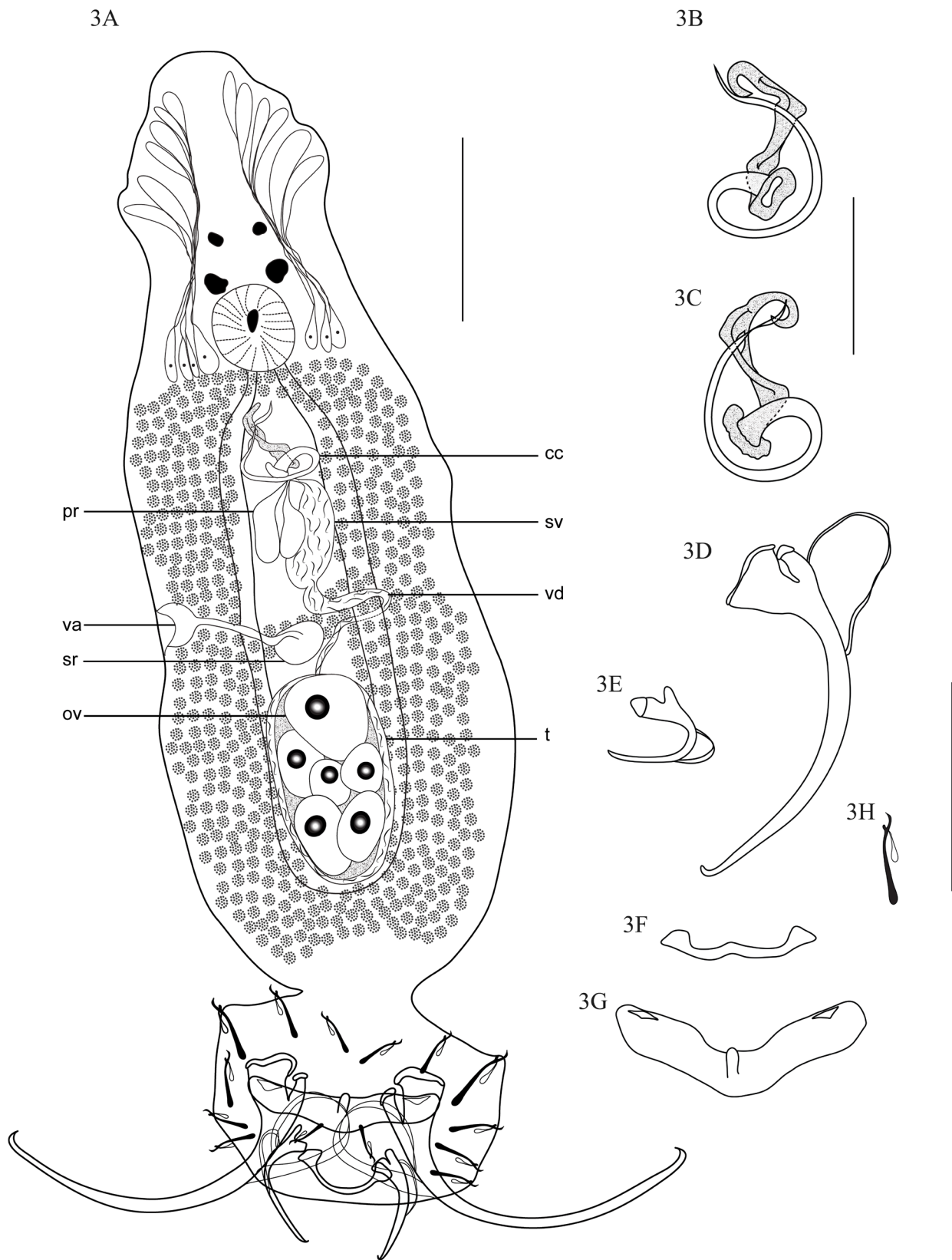


Figure 3. *Notozothecium janauachensis*. **3A.** Total, dorsal view (cc – copulatory complex; pr – prostatic reservoirs; sv – seminal vesicle; vd – vas deferens; va – vagina; sr – seminal receptacle; ov – ovary; t – testis). **3B.** Copulatory complex, ventral view. **3C.** Copulatory complex, dorsal view. **3D.** Ventral anchor. **3E.** Dorsal anchor. **3F.** Dorsal bar. **3G.** Ventral bar. **3H.** Hook. Scale bars: A, D–H = 50 µm; B and C = 25 µm.

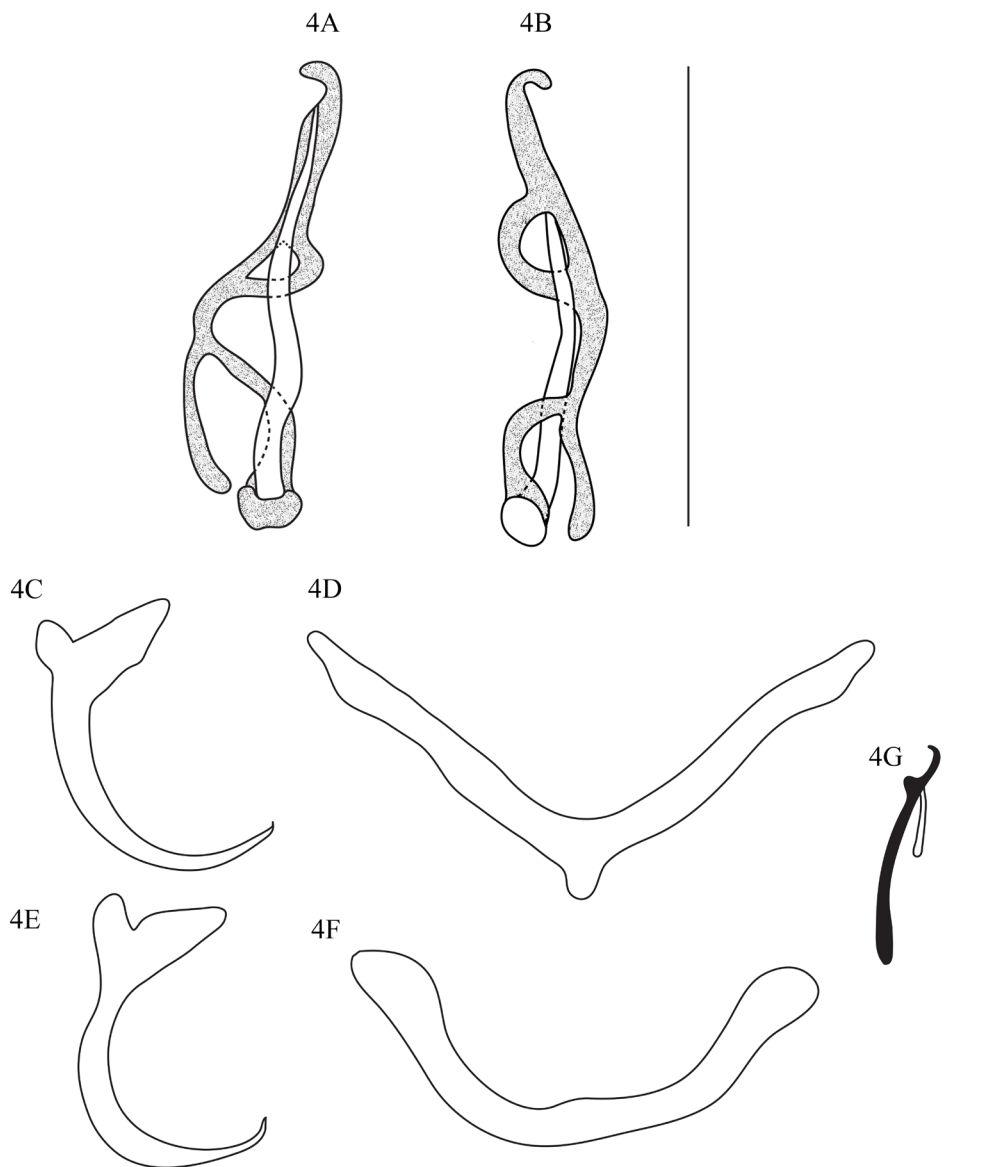


Figure 4. *Mymarothecium boegeri*. **4A.** Copulatory complex, ventral view. **4B.** Copulatory complex, dorsal view. **4C.** Ventral anchor. **4D.** Ventral bar. **4E.** Ventral anchor. **4F.** Dorsal bar. **4G.** Hook. Scale bars: A and B = 50 µm; C–F = 25 µm.

Table 3. The dispersion index (DI), statistical-*d* and discrepancy index (D) of the monogeneans of *Colossoma macropomum* farmed in the state of Acre, Amazon, Brazil*.

Parasites	DI	<i>d</i>	D	Dispersion
<i>Anacanthorus spathulatus</i>	322.72	266.89	0.857	Aggregated
<i>Notozothecium janauachensis</i>	108.59	146.38	0.875	Aggregated
<i>Mymarothecium boegeri</i>	94.57	134.88	0.934	Aggregated

*DI and D were employed in species with prevalence ≥10%.

Discussion

Parasitism by monogeneans is the main cause of diseases and financial losses in aquaculture (Boijink et al., 2015; Soares et al., 2016). Seven species of monogeneans are known to parasitize *C. macropomum* in fish farms in Brazil: *Anacanthorus spathulatus*, *A. penilabiatus*, *Linguadactyloides brinkmanni*, *Mymarothecium boegeri*, *M. viatorum*, *Notozothecium euzeti* and *N. janauachensis* (Cohen & Kohn, 2005, 2009; Dias et al., 2015; Chagas et al., 2016;

Pamplona-Basilio et al., 2001; Silva, 2017). Four of these species (*A. spathulatus*, *L. brinkmanni*, *N. janauachensis* and *M. boegeri*) were found in this study, with morphology and measurements corresponding to those reported by Kritsky et al. (1979), Thatcher & Kritsky (1983), Belmont-Jégu et al. (2004) and Cohen & Kohn (2005), respectively.

Dias et al. (2015) and Morais et al. (2009) reported the occurrence of these same species parasitizing *C. macropomum* in fish farms in the states of Amapá and Amazonas. Chagas et al. (2016), found *A. spathulatus*, *N. janauachensis* and *M. boegeri* in *C. macropomum* farmed in the state of Amazonas. In the state of Rondônia, parasitism of *C. macropomum* at two fish farms included *A. spathulatus* (93 and 96%), *L. brinkmanni* (76 and 13.5%), *M. viatorum*, *Mymarothecium* sp. 1, *Mymarothecium* sp. 2 and *Notozothecium* spp. (79% and 94%) (Godoi et al., 2012). These data indicate a higher species diversity and higher prevalence rate of *A. spathulatus* and *Notozothecium* sp. than those found in our study. In Peruvian Amazonia, only *A. spathulatus* was reported parasitizing farmed *C. macropomum* presented low prevalence (27.8%).

Based on the studies mentioned above, the composition of the species found in the state of Acre is similar to the species described in the neighboring states of the Brazilian Amazon (Amapá, Amazonas, Pará and Rondonia) and the Peruvian Amazon. Thus, we can infer that the component communities of the monogeneans are not isolated, but communicate through the natural evolutionary process of parasitic colonization or free movement of fry and adults between the fish farms of these states, promoting the dispersion of the monogeneans.

The presence of the same species in the different states, as well as the similar prevalence and abundance values among them, indicate that the dispersal of the monogeneans among the different localities is consistent, although further studies involving deeper analyses on the ecology and biology of this community are needed.

Furthermore, the high temperatures that remain constant throughout the year in the Amazon Region may favor the life cycle of monogenetic species, as suggested by Dias et al. (2015), Dias & Tavares-Dias (2015) and Baia et al. (2019).

Acre is among the five states with the largest deforested areas in the Brazilian Amazon, and in the coming years may suffer from long periods of drought and large forest fires (Acre, 2013; Silva et al., 2021). These environmental changes are the main causes of global warming, which among other impacts, raise the planet's temperature and affect aquatic ecosystems, especially fish, altering aspects of their physiology and increasing susceptibility to disease (Brander et al., 2018; Costa et al., 2021).

Costa et al. (2021) studied the effects of climate change on the degree of monogenetic parasitism in tambaqui. The authors concluded that increasing temperature and CO₂ causes a rapid increase in this parasitism in seven days, which decreases in thirty days, but is still higher than in the control group. These data, indicate that special attention should be given to the culture of *C. macropomum*, especially in the state of Acre, where future forecasts indicate an increase in local average temperature (Silva et al., 2021), which may cause high rates of monogenetic parasitism, yield loss and consequent economic losses in farmed tambaqui (Costa et al., 2021).

In the present study, coexistence between monogenean species was common in 41% of hosts, which was explained by Salgado-Maldonado et al. (2019). These authors demonstrate that parasitic species can coexist in the same host population when their distributions among individual hosts are aggregated, as it occurs in aquaculture systems where high density rates are common, inevitably causing host aggregation and favoring the coexistence of parasitic species.

The aggregate distribution pattern of monogeneans of *C. macropomum* is in agreement with that reported by Gonçalves et al. (2018) in Pará state and Baia et al. (2019) in Amapá state. Poulin (2013) predicts that aggregate distributions are a common pattern in freshwater fishes and attributed the susceptibility to infection as one of the factors generating aggregation. We then conclude that as *C. macropomum* in fish farm are subject to high densities, poor management and changes in water quality, these factors make the animals more susceptible to disease occurrence and hence aggregation of parasites per host. Salgado-Maldonado et al. (2019) suggest that the greater the degree of species aggregation, the greater the intensity of infection. This positive correlation was observed in the present study, as *A. spathulatus* showed high aggregation values and high infection intensity.

Lastly, the results presented here are the first data on the ecological indices of monogenetic parasites of tambaqui in the state of Acre and will be useful for future comparisons of the influence of environmental factors on the parasite-host relationship.

Acknowledgements

This study received financial support from the Brazilian research funding agencies CNPq – Universal (National Council for Scientific and Technological Development), CAPES-Parasitologia Básica (Federal Agency for the Support and Improvement of Higher Education), Fundação Oswaldo Cruz Foundation (Fiocruz/ IOC/ PAEF), Federal Institute of Acre (IFAC), and FAPAC (Acre Research Foundation). M.T. Silva and C.P. Santos thank CNPq for the fellowships they were awarded. The research funding agencies played no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References

- Acre. *Epi Info* [online]. 2013 [cited 2022 Jan 30]. Available from: <https://imc.ac.gov.br/wp-content/uploads/2016/09/O-SISA-Acre.pdf>
- Baia RR, Santos GG, Silva AS, Sousa BO, Tavares-Dias M. Parasite fauna of tambaqui reared in net-cages at two stocking densities. *Bol Inst Pesca* 2019; 45(3): e492. <http://dx.doi.org/10.20950/1678-2305.2019.45.3.492>.
- Belmont-Jégu E, Domingues MV, Martins ML. *Notozothecium janauachensis* n. sp. (Monogenea: Dactylogyridae) from wild and cultured tambaqui, *Colossoma macropomum* (Teleostei: Characidae: Serrasalminae) in Brazil. *Zootaxa* 2004; 736(1): 1-8.
- Boeger WA, Vianna RT, Thatcher VE. Monogenea. In: Adis J, Arias JR, Rueda-Delgado G, Wantzen KM, editors. *Aquatic biodiversity in Latin America: Amazon fish parasite*. 2nd ed. Sofia: Pensoft Publishers; 2006. p. 42-116.
- Boijink CL, Miranda WSC, Chagas EC, Dairiki JK, Inoue LAKA. Anthelmintic activity of eugenol in tambaquis with monogenean gill infection. *Aquaculture* 2015; 438: 138-140. <http://dx.doi.org/10.1016/j.aquaculture.2015.01.014>.
- Brander K, Cochrane K, Barange M, Soto D. Climate change implications for fisheries and aquaculture. In: Phillips BF, Pérez-Ramírez M, editors. *Climate change impacts on fisheries and aquaculture: a global analysis*. 1st ed. Hoboken: John Wiley & Sons; 2018. p. 45-63.
- Bush AO, Lafferty KD, Lotz JM, Shostak AW. Parasitology meets ecology on its own terms: Margolis et al.: revisited. *J Parasitol* 1997; 83(4): 575-583. <http://dx.doi.org/10.2307/3284227>. PMID:9267395.
- Chagas EC, Araújo LD, Martins ML, Gomes LC, Malta JCO, Varella AB, et al. Mebendazole dietary supplementation controls Monogenea (Platyhelminthes: Dactylogyridae) and does not alter the physiology of the freshwater fish *Colossoma macropomum* (Cuvier, 1818). *Aquaculture* 2016; 464: 185-189. <http://dx.doi.org/10.1016/j.aquaculture.2016.06.022>.
- Cohen SC, Justo MC, Kohn A. *South American monogenea parasites of fishes, amphibians and reptiles*. Rio de Janeiro: Oficina de livros; 2013.
- Cohen SC, Kohn A. A new species of *Mymarothecium* and new host and geographical records for *M. viatorum* (Monogenea: Dactylogyridae), parasites of freshwater fishes in Brazil. *Folia Parasitol (Praha)* 2005; 52(4): 307-310. <http://dx.doi.org/10.14411/fp.2005.042>. PMID:16405294.
- Cohen SC, Kohn A. On Dactylogyridae (Monogenea) of four species of characid fishes from Brazil. *Check List* 2009; 5(2): 351-356. <http://dx.doi.org/10.15560/5.2.351>.
- Costa JC, Souza SS, Castro JS, Amanajás RD, Val AL. Climate change affects the parasitism rate and impairs the regulation of genes related to oxidative stress and ionoregulation of *Colossoma macropomum*. *Sci Rep* 2021; 11(1): 22350. <http://dx.doi.org/10.1038/s41598-021-01830-1>. PMID:34785749.
- 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>.
- Dias MKR, Tavares-Dias M. Seasonality affects the parasitism levels in two fish species in the eastern Amazon region. *J Appl Ichthyology* 2015; 31(6): 1049-1055. <http://dx.doi.org/10.1111/jai.12865>.
- Farias CFS, Brandão FR, Sebastião FA, Souza DCD, Monteiro PC, Majolo C, et al. Albendazole and praziquantel for the control of *Neoechinorhynchus buttnerae* in tambaqui (*Colossoma macropomum*). *Aquacult Int* 2021; 29(4): 1495-1505. <http://dx.doi.org/10.1007/s10499-021-00687-5>.
- Fischer C, Malta JCO, Varella AMB. A fauna de parasitas do tambaqui, *Colossoma macropomum* (Cuvier, 1818) (Characiformes: Characidae) do médio rio Solimões, Estado do Amazonas (AM) e do baixo rio Amazonas, Estado do Pará (PA), e seu potencial como indicadores biológicos. *Acta Amaz* 2003; 33(4): 651-662. <http://dx.doi.org/10.1590/S0044-59672003000400012>.
- Fujimoto RY, Hide DMV, Paixão PEG, Abe HA, Dias JAR, Sousa NC, et al. Fauna parasitária e relação parasito-hospedeiro de tambaquis criados na região do Baixo São Francisco, nordeste do Brasil. *Arq Bras Med Vet Zootec* 2019; 71(2): 563-570. <http://dx.doi.org/10.1590/1678-4162-10306>.

- Godoi MMIM, Engracia V, Lizama MLAP, Takemoto RM. Parasite-host relationship between the tambaqui (*Colossoma macropomum* Cuvier 1818) and ectoparasites, collected from fish farms in the City of Rolim de Moura, State of Rondônia, Western Amazon, Brazil. *Acta Amaz* 2012; 42(4): 515-524. <http://dx.doi.org/10.1590/S0044-59672012000400009>.
- 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>.
- Instituto Brasileiro de Geografia e Estatística – IBGE. *Produção da Pecuária Municipal 2019* [online]. 2019 [cited 2021 May 20]. Available from: https://biblioteca.ibge.gov.br/visualizacao/periodicos/84/ppm_2019_v47_br_informativo.pdf
- Jerônimo GT, Pádua SB, Belo MAA, Chagas EC, Taboga SR, Maciel PO, et al. *Neoechinorhynchus buttnerae* (Acanthocephala) infection in farmed *Colossoma macropomum*: A pathological approach. *Aquaculture* 2017; 469: 124-127. <http://dx.doi.org/10.1016/j.aquaculture.2016.11.027>.
- Kritsky DL, Boeger WA, Jégu M. Neotropical Monogeneoidea. 28. Ancyrocephalinae (Dactylogyridae) of Piranha and Their relatives (Teleostei, Serrasalmidae) from Brazil and French Guiana; Species of *Notozothecium* Boeger and Kritsky, 1988, and *Mymarothecium* gen. *J Helminthol Soc Wash* 1996; 63(2): 153-175.
- Kritsky DL, Thatcher VE, Kayton RJ. Neotropical Monogeneoidea. 2. The Anacanthorinae Price, 1967, with the proposal of four new species of *Anacanthorus* Mizelle & Price, 1965, from Amazonian fishes. *Acta Amaz* 1979; 9(2): 355-361. <http://dx.doi.org/10.1590/1809-43921979092355>.
- Ludwig JA, Reynolds JF. *Statistical ecology*. New York: John Wiley; 1988.
- Mangas TP, Silva FNL, Oliveira LC, Oliveira LAA. Tambaqui death (*Colossoma macropomum*) by helminths in Marajó Island, Pará, Brazil. *Ciênc Anim* 2020; 30(2): 161-166.
- Morais AM, Varella AMB, Villacorta-Correa MA, Malta JCO. A fauna de parasitos em juvenis de tambaqui *Colossoma macropomum* (Cuvier, 1818) (Characidae: Serrasalmidae) criados em tanques-rede em Lago de várzea da Amazônia Central. *Biol Geral Exper* 2009; 9(1): 14-23.
- Pamplona-Basilio MC, Kohn A, Feitosa VA. New host records and description of the egg of *Anacanthorus penilabiatus* (Monogenea, Dactylogyridae). *Mem Inst Oswaldo Cruz* 2001; 96(5): 667-668. <http://dx.doi.org/10.1590/S0074-02762001000500014>. PMID:11500767.
- Poulin R. Explaining variability in parasite aggregation levels among host samples. *Parasitology* 2013; 140(4): 541-546. <http://dx.doi.org/10.1017/S0031182012002053>. PMID:23343821.
- Rohde K, Hayward C, Heap M. Aspects of the ecology of metazoan ectoparasites of marine fishes. *Int J Parasitol* 1995; 25(8): 945-970. [http://dx.doi.org/10.1016/0020-7519\(95\)00015-T](http://dx.doi.org/10.1016/0020-7519(95)00015-T). PMID:8550295.
- Rózsa L, Reiczigel J, Majoros G. Quantifying parasites in samples of hosts. *J Parasitol* 2000; 86(2): 228-232. [http://dx.doi.org/10.1645/0022-3395\(2000\)086\[0228:QPISOH\]2.0.CO;2](http://dx.doi.org/10.1645/0022-3395(2000)086[0228:QPISOH]2.0.CO;2). PMID:10780537.
- Salgado-Maldonado G, Mendoza-Franco EF, Caspeta-Mandujano JM, Ramírez-Martínez C. Aggregation and negative interactions in low-diversity and unsaturated monogenean (Platyhelminthes) communities in *Astyanax aeneus* (Teleostei) populations in a neotropical river of Mexico. *Int J Parasitol Parasites Wildl* 2019; 8: 203-215. <http://dx.doi.org/10.1016/j.ijppaw.2019.02.005>. PMID:30891400.
- Santos EF, Tavares-Dias M, Pinheiro DA, Neves LR, Marinho RGB, Dias MKR. Fauna parasitária de tambaqui *Colossoma macropomum* (Characidae) cultivado em tanque-rede no estado do Amapá, Amazônia oriental. *Acta Amaz* 2013; 43(1): 105-112. <http://dx.doi.org/10.1590/S0044-59672013000100013>.
- Silva MT. *Biodiversidade de helmintos de Arapaima gigas (Schinz) e Colossoma macropomum (Cuvier) em sistemas de cultivo no estado do Acre, sudoeste da Amazônia* [tese]. Rio de Janeiro: Instituto Oswaldo Cruz; 2017.
- Silva SS, Oliveira I, Morello TF, Anderson LO, Karlokoski A, Brando PM, et al. Burning in southwestern Brazilian Amazonia, 2016–2019. *J Environ Manage* 2021; 286: 112189. <http://dx.doi.org/10.1016/j.jenvman.2021.112189>. PMID:33677342.
- Soares BV, Neves LR, Oliveira MSB, Chaves FCM, Dias MKR, Chagas EC, et al. Antiparasitic activity of the essential oil of *Lippia alba* on ectoparasites of *Colossoma macropomum* (tambaqui) and its physiological and histopathological effects. *Aquaculture* 2016; 452: 107-114. <http://dx.doi.org/10.1016/j.aquaculture.2015.10.029>.
- Soberon L, Mathews P, Malherios A. Hematological parameters of *Colossoma macropomum* naturally parasitized by *Anacanthorus spathulatus* (Monogenea: Dactylogyridae) in fish farm in the Peruvian Amazon. *Int Aquat Res* 2014; 6(4): 251-255. <http://dx.doi.org/10.1007/s40071-014-0087-1>.
- Tavares-Dias M, Ferreira GV, Videira MN. Histopathological alterations caused by monogenean parasites the gills of tambaqui *Colossoma macropomum* (Serrasalmidae). *Semina: Ciênc Agrár* 2021; 42(3): 2057-2064. <http://dx.doi.org/10.5433/1679-0359.2021v42n3Supl1p2057>.

Monogeneans of tambaqui farmed in Acre state

Thatcher VE, Kritsky DC. Neotropical monogenoidea. 4. *Linguadactyloides brinkmanni* gen. et sp. n. (Dactylogyridae: Linguadactyloidea subfam. n.) with observations on its pathology in a Brazilian freshwater fish, *Colossoma macropomum* (Cuvier). *Proc Helminthol Soc Wash* 1983; 50(2): 305-311.

Valladão GMR, Gallani SU, Pilarski F. South American fish for continental aquaculture. *Rev Aquacult* 2018; 10(2): 351-369. <http://dx.doi.org/10.1111/raq.12164>.