

Ectoparasite fauna of the lebranche mullet, *Mugil liza*, from a coastal lagoon in the Southwestern Atlantic

Fauna de ectoparasitos da tainha, *Mugil liza*, em uma lagoa costeira no Atlântico Sudoeste

Laura Frantelmo Cavalheiro¹ ; Rayane Duarte² ; Marco Antonio Santos Silva Júnior³ ; Rafael de Almeida Tubino⁴ ; Michelle Daniele dos Santos-Clapp⁵ 

¹Universidade Federal Rural do Rio de Janeiro - UFRRJ, Instituto de Ciências Biológicas e da Saúde, Programa de Pós-graduação em Biologia Animal, Laboratório de Biologia e Ecologia de Parasitos, Seropédica, RJ, Brasil

²Instituto Oswaldo Cruz, Fundação Oswaldo Cruz, Fiocruz, Programa de Pós-graduação em Biodiversidade e Saúde, Laboratório de Helmintos Parasitos de Peixes, Rio de Janeiro, RJ, Brasil

³Universidade Federal Rural do Rio de Janeiro - UFRRJ, Instituto de Ciências Biológicas e da Saúde, Laboratório de Biologia e Ecologia de Parasitos, Graduação em Ciências Biológicas, Seropédica, RJ, Brasil

⁴Universidade Federal Rural do Rio de Janeiro - UFRRJ, Instituto de Ciências Biológicas e da Saúde, Laboratório de Biologia Pesqueira e Modelagem Trófica de Ecossistemas Marinhos, Departamento de Biologia Animal, Programa de Pós-graduação em Biologia Animal, Seropédica, RJ, Brasil

⁵Universidade Federal Rural do Rio de Janeiro - UFRRJ, Instituto de Ciências Biológicas e da Saúde, Departamento de Biologia Animal, Laboratório de Biologia e Ecologia de Parasitos, Seropédica, RJ, Brasil

How to cite: Cavalheiro LF, Duarte R, Silva Júnior MAS, Tubino RA, Santos-Clapp MD. Ectoparasite fauna of the lebranche mullet, *Mugil liza*, from a coastal lagoon in the Southwestern Atlantic. *Rev Bras Parasitol Vet* 2026; 35(2): e005626. <https://doi.org/10.1590/S1984-29612026029>.

Abstract

Coastal lagoons are among the most productive aquatic ecosystems worldwide and are widely used by mugilid fishes. *Mugil liza* stands out as one of the main resources of lagoon fisheries in southern and southeastern Brazil. This study aimed to identify the species composing the ectoparasite fauna of *M. liza* from the Maricá Lagoon, Rio de Janeiro State, Brazil. A total of 44 specimens of *M. liza* were examined, of which 95.4% were parasitized by at least one ectoparasite species. Six ectoparasite species were recorded. The copepod *Ergasilus caraguatatubensis* was the most representative species, with prevalence (P) of 86.4%, followed by the copepods *Bomolochus nitidus* (P = 43.2%), *Caligus* sp. (P = 2.3%) and *Naobranchia lizae* (P = 2.3%). The polyopisthocotylan *Metamicrocotyla macracantha* showed prevalence of 18.2% and the myxozoan *Myxobolus episquamalis* presented a low prevalence (P = 2.3%). The ectoparasite fauna of *M. liza* exhibited diversity, comprising six distinct families, highlighting the host's gills as an important site for parasite diversity. The results expand the environmental distribution of *E. caraguatatubensis*, *B. nitidus*, *Caligus* sp., *N. lizae* and *M. macracantha* within Rio de Janeiro State, increasing the known occurrence sites of these parasites, including lagoon.


Keywords: Copepoda, Myxozoa, Polyopisthocotyla, Maricá Lagoon, Rio de Janeiro State.

Resumo

As lagoas costeiras estão entre os ecossistemas aquáticos mais produtivos do mundo, sendo amplamente utilizadas por mugilídeos. *Mugil liza* se destaca por ser um dos principais recursos da pesca lagunar na região sul e sudeste do Brasil. O objetivo deste estudo foi identificar as espécies componentes da fauna de ectoparasitos de *M. liza* na lagoa de Maricá, no estado do Rio de Janeiro. Foram examinados 44 espécimes de *M. liza*, dos quais 95,4% estavam parasitados por pelo menos uma espécie de ectoparasito. Foram registradas seis espécies de ectoparasitos. O copépode *Ergasilus caraguatatubensis* foi a espécie mais representativa, com prevalência (P) de 86,4%, seguido pelos copépodes *Bomolochus nitidus* (P = 43,2%), *Caligus* sp. (P = 2,3%) e *Naobranchia lizae* (P = 2,3%). O poliopistocotilídeo *Metamicrocotyla macracantha* apresentou prevalência de 18,2% e o mixozoário *Myxobolus episquamalis* apresentou baixa prevalência (P = 2,3%). A fauna ectoparasitária de *M. liza* apresentou diversidade, com seis famílias distintas, demonstrando como as brânquias deste hospedeiro abrigam uma fauna parasitária relevante. Os resultados gerados ampliam a distribuição ambiental de *E. caraguatatubensis*, *B. nitidus*, *Caligus* sp., *N. lizae* e *M. macracantha* dentro do estado do Rio de Janeiro, aumentando os locais de ocorrência desses parasitos, incluindo sistemas lagunares.

Palavras-chave: Copepoda, Myxozoa, Polyopisthocotyla, Lagoa de Maricá, estado do Rio de Janeiro.

Received March 20, 2026. Accepted May 18, 2026.

*Corresponding author: Laura Frantelmo Cavalheiro. Km 7, CEP 23890-000, Seropédica, RJ, Brasil, (+55) 2197270-0687, laurafrantelmoc26@gmail.com. 

Assistant Editor: Marcos Tavares Dias



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.

Introduction

Coastal lagoons are among the most productive aquatic ecosystems worldwide (Pérez-Ruzafa et al., 2024). They are transitional environments between the continent and the sea, where important coastal biogeochemical processes occur, contributing to the maintenance of biodiversity and the regulation of life cycles of marine, estuarine, and freshwater species, while serving as feeding and nursery areas (Behera et al., 2020; Blaber, 2000; Pérez-Ruzafa et al., 2011, 2020). In addition, coastal lagoons provide several ecosystem services, including flood control, erosion prevention, water supply, and coastal protection (Cataudella et al., 2015; Newton et al., 2018).

Among the fish species that frequently use lagoon environments are the mugilids. The mullet *Mugil liza* Valenciennes, 1836 stands out as one of the main resources of lagoon fisheries in southern and southeastern Brazil (Souza et al., 2017). *Mugil liza* is a catadromous species that develops to adulthood in freshwater or brackish environments but reproduces and spawns in marine waters (Garbin et al., 2014). It is distributed along the western Atlantic coast, from Florida (USA), Bermuda, and the Bahamas, throughout the Caribbean Sea to Argentina (Albieri et al., 2010; Froese & Pauly, 2026). This species exhibits a detritivorous feeding habit, also consuming planktonic material (Lebreton et al., 2011; Aguirre-Pabon et al., 2022). In Rio de Janeiro State, artisanal fisheries are an important subsistence activity, serving as a source of income and food for fishing communities (Santos et al., 2018). According to the *Ministério de Pesca e Aquicultura*, mullets are among the most commercially exploited fish species in Brazil (Brasil, 2015).

Fish parasites represent a significant component of global biodiversity, playing key roles in trophic webs and ecological interactions in transitional environments such as lagoons and estuaries (Giari et al., 2022). The study of fish parasite fauna in these environments is essential for assessing socioeconomic impacts related to fisheries and resource use, as it may reveal environmental changes, influence the health and commercial value of economically important fish species, and serve as indicators of ecological changes in highly exploited coastal ecosystems (Newton et al., 2014; Giari et al., 2022). According to Vidal-Martínez & Wunderlich (2017), parasites are effective bioindicators of host condition and habitat quality. Parasite populations may increase or decrease depending on their sensitivity to environmental quality (Lafferty, 1997).

In Brazil, 68 parasite species have been reported infecting *M. liza*, of this 32 are ectoparasite species (Eiras et al., 2007, 2016; Mentz et al., 2016; Meira-Filho et al., 2017; Borges et al., 2018; Guerez et al., 2018; Oliveira et al., 2019; Duarte et al., 2020; Silva et al., 2024). In this context, the purpose of the present study was to identify the ectoparasite species composing the parasite fauna of *M. liza* in Maricá Lagoon, Rio de Janeiro State, Brazil.

Material and Methods

Between 2018 and 2023, 44 specimens of *M. liza* were collected from artisanal fishermen in the Maricá Lagoon (Figure 1), located in the municipality of Maricá, on the eastern coast of Rio de Janeiro State (22°56'41.1" S, 42°51'09.7" W). This lagoon is part of the Maricá–Guarapina Lagoon System, a predominantly brackish-water system (Dias et al.,

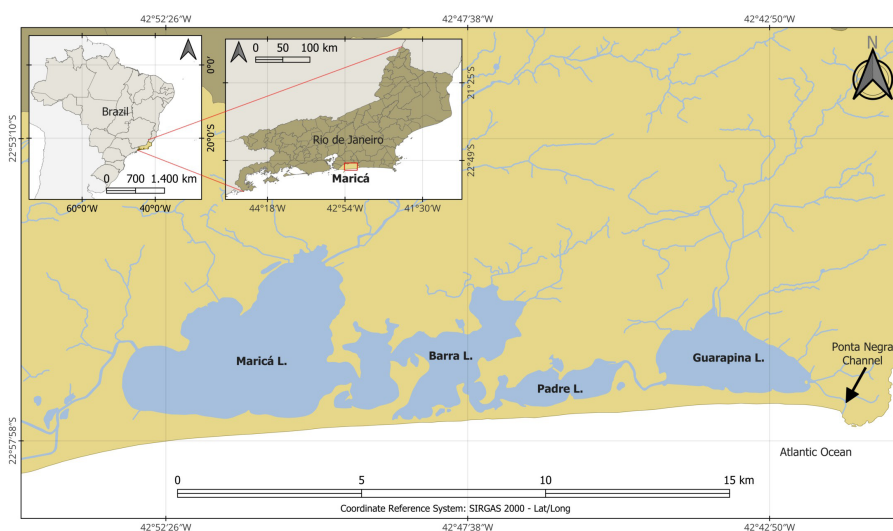


Figure 1. Maricá Lagoon, Rio de Janeiro State, Brazil, where specimens of *Mugil liza* were collected.

2021) composed of interconnected lagoons that are also connected to the adjacent marine environment and represent one of the largest lagoon systems in the state (Toledo et al., 2021).

The fish were obtained fresh, immediately after capture. They were individually placed in plastic bags and stored in insulated containers with ice. Subsequently, the specimens were transported to the *Laboratório de Biologia e Ecologia de Parasitos* (LABEPAR), *Departamento de Biologia Animal, Instituto de Ciências Biológicas e da Saúde da Universidade Federal Rural do Rio de Janeiro*, where they were kept refrigerated or frozen until necropsy. Host identification was performed according to Menezes & Figueiredo (1980, 1985).

The fish were weighed using a digital scale. Sex was determined, and total and standard lengths were measured. All data were recorded on necropsy forms following the protocol proposed by Amato et al. (1991). During necropsy, the body surface was examined, and the gills were removed from the opercular cavity and individually placed in bottles. Gills from mullet specimens collected in 2018 and 2019 were fixed in 3% formalin, whereas those from fish collected in 2022 and 2023 were preserved in 70% ethanol. Subsequently, the bottles were vigorously shaken to promote detachment of parasites from the gill filaments. The gills were examined under a stereomicroscope using tweezers, stylets, and brushes. All ectoparasites recovered, except for representatives of Myxozoa, which were examined fresh, were preserved in 70% ethanol for subsequent identification.

Specimens of Myxozoa were classified according to Azevedo et al. (2010) and identified following Rothwell et al. (1997) and Eiras et al. (2006). Polyopisthocotyla were classified according to Brabec et al. (2023) and identified following Kohn et al. (1994). Copepoda species were classified according to Boxshall & Halsey (2004) and identified following Amado & Rocha (1995) and Eiras et al. (2016).

Parasitological descriptors (prevalence, intensity, and abundance), as well as the ecological terms used, followed the recommendations of Bush et al. (1997). Statistical analyses were performed on ectoparasite species with prevalence equal to or greater than 10%, according to Bush et al. (1990), using GraphPad Prism version 10.2.3. The significance level was set at $p < 0.05$, following Zar (1999). Among the statistical tests, Spearman's correlation coefficient by ranks (r_s) and Pearson's correlation coefficient (r), after prior angular transformation of the data (Sturges, 1926), were used to evaluate parasite intensity and abundance in relation to host size, and parasite prevalence in relation to host size classes estimated using Sturges' formula, respectively. Parasitic dominance was calculated based on dominance frequency, shared dominance frequency, and mean relative dominance, following the method proposed by Rohde et al. (1995). The dispersion index (DI) was calculated for each identified species to determine the distribution pattern, and significance was tested using the d statistic ($d > 1.96$), as proposed by Ludwig & Reynolds (1988).

Myxozoa cysts were deposited in the *Museu de Zoologia da Universidade Federal Rural do Rio de Janeiro* (MZUFRRJ). A representative specimen of Polyopisthocotyla was deposited in the *Coleção Helminológica do Instituto Oswaldo Cruz* (CHIOC), and representative specimens of the Copepoda species were deposited in the *Coleção de Crustacea do Museu Nacional do Rio de Janeiro* (MNRJ-CARCINO). Accession numbers are provided in the results section.

Results

The mean total length of *M. liza* from the Maricá Lagoon was 35.6 ± 6.6 cm (26–52 cm), and the mean body weight was 435.0 ± 238.9 g (178–1.208 g). Among the examined specimens, eight were males, and five were females. The remaining 31 hosts were classified as juveniles due to their smaller total length and the absence of gonadal development. Of the 44 mullets analyzed, 42 (95.4%) were parasitized by at least one species of ectoparasite. Six ectoparasite species were identified: *Ergasilus caraguatatubensis* Amado & Rocha, 1995, *Bomolochus nitidus* Wilson, 1911, *Caligus* sp., *Naobranchia lizae* (Krøyer, 1863), *Metamicrocotyla macracantha* (Alexander, 1954), and *Myxobolus episquamalis* Egusa, Maeno & Sorimachi, 1990. Among these, only *E. caraguatatubensis* was recorded throughout the entire sampling period, whereas the other species were found in fish collected only between 2018 and 2019.

Parasite infracommunities

Among the ectoparasite fauna of *M. liza* from the Maricá Lagoon, *E. caraguatatubensis*, presented the highest parasitological indexes, followed by *B. nitidus*, and *M. macracantha*, as shown in Table 1. *Myxobolus episquamalis*, *Caligus* sp., and *N. lizae* showed prevalence values below 10% (Table 1).

Table 1. Occurrence of ectoparasites species of *Mugil liza* from Maricá Lagoon, RJ. Deposition numbers of voucher specimens (DN), prevalence (P), mean intensity (MI) and mean abundance (MA) and their respective standard deviation (SD), total number of specimens (TS) and site of infestation (SI) of the ectoparasites of *Mugil liza* from Maricá Lagoon, RJ, Brazil.

Parasite species	DN	P (%)	MI ± SD	MA ± SD	TS	SI
Cnidaria						
Myxozoa						
<i>Myxobolus episquamalis</i> Egusa, Maeno & Sorimachi, 1990	MZURM TZ2020021	2.3	N	N	N	CF, BS
Platyhelminthes						
Polyopisthocotyla						
<i>Metamicrocotyla macracantha</i> (Alexander, 1954)	CHIOC 39808	18.2	1.9±0.9	0.3±0.86	15	G
Artropoda						
Copepoda						
<i>Bomolochus nitidus</i> Wilson, 1911	MNRJ31875	43.2	5.5±3.9	3.2±3.9	105	G
<i>Caligus</i> sp.	MNRJ31877	2.3	1.0±0.1	0.03±0.1	1	G
<i>Ergasilus caraguatatubensis</i> Amado & Rocha, 1995	MNRJ 31876	86.4	12.9±18.1	11.1±18.1	490	G
<i>Naobranchia lizae</i> (Krøyer, 1863)	MNRJ31878	2.3	6.0±0.9	0.1±0.9	6	G

N = countless cysts, G = gills, CF = caudal fin, and BS: body surface.

The infestation sites recorded were the gills, with a total of 617 ectoparasites represented by five species (*E. caraguatatubensis*-490 specimens; *B. nitidus*-105; *M. macracantha*-15; *N. lizae*-six; and *Caligus* sp.-one specimen), as well as the body surface and caudal fin, which harbored innumerable specimens of *M. episquamalis*. These latter sites were infested exclusively by *M. episquamalis*, and due to the extremely high number of spores, the actual number of specimens could not be quantified.

Regarding dominance, *E. caraguatatubensis* showed the highest values of dominance frequency and mean relative dominance (Table 2).

Table 2. Frequency of dominance, shared frequency of dominance, and mean relative dominance of the components of the infracommunities of ectoparasites of *Mugil liza* from Maricá Lagoon, RJ, Brazil.

Parasite species	Frequency of dominance	Shared Frequency of dominance	Mean relative dominance + Standard deviation
<i>Metamicrocotyla macracantha</i>	1	0	0.043 ± 0.126
<i>Bomolochus nitidus</i>	11	1	0.244 ± 0.350
<i>Ergasilus caraguatatubensis</i>	29	1	0.667 ± 0.390

According to the dispersion index and the significant *d* statistic values presented in Table 3, the parasite infrapopulations recorded in this study exhibited an aggregated distribution pattern.

The prevalence, intensity, and abundance of *B. nitidus* were higher in smaller fish, whereas the intensity and abundance of *E. caraguatatubensis* were higher in fish with greater total length (Table 4). Apparent negative correlations were observed between host size and the prevalence and abundance of *M. macracantha*, as well as between host size and the prevalence of *E. caraguatatubensis*; however, these relationships were not statistically significant (Table 4).

Table 3. Values of the dispersion index and the statistical *d*-test of the ectoparasites of *Mugil liza* from Maricá Lagoon, RJ, Brazil.

Parasite species	Dispersion index		
	Value	Distribution	<i>d</i>
<i>Metamicrocotyla macracantha</i>	0.74	Aggregate	4.45*
<i>Bomolochus nitidus</i>	6.57	Aggregate	14.55*
<i>Ergasilus caraguatatubensis</i>	29.56	Aggregate	41.20*

*significance level $d > 1.96$.

Table 4. Analysis of parasite indexes under possible influence of the total length of *Mugil liza* from Maricá Lagoon, RJ, Brazil.

Parasite species	Prevalence		Intensity		Abundance	
	<i>r</i>	<i>p</i>	<i>rs</i>	<i>p</i>	<i>rs</i>	<i>p</i>
<i>Metamicrocotyla macracantha</i>	-0.559	0.192	0.178	0.669	-0.044	0.775
<i>Bomolochus nitidus</i>	-0.904	0.005*	-0.533	0.018*	-0.442	0.002*
<i>Ergasilus caraguatatubensis</i>	-0.171	0.714	0.449	0.004*	0.370	0.013*

r = Pearson's correlation coefficient; *rs* = Spearman's rank correlation coefficient. *significance level $p < 0.05$.

Statistical analyses by host sex were not performed because most *M. liza* specimens collected were juveniles, which precluded this type of analysis.

Discussion

In the present study, *M. liza* exhibited an ectoparasite fauna composed of representatives of the phyla Cnidaria (subphylum Myxozoa), Platyhelminthes, and Arthropoda (subphylum Crustacea). The Myxozoa representative, *M. episquamalis*, was recorded parasitizing a single host. The low prevalence observed contrasts with the study by Vieira et al. (2022), in which two distinct species, *Myxobolus curemae* Vieira, Agostinho, Negrelli, Silva, Azevedo & Abdallah, 2022 and *Myxobolus maceioensis* Vieira, Agostinho, Negrelli, Silva, Azevedo & Abdallah, 2022, were reported with prevalence values of 27% and 40%, respectively, in *Mugil curema* Valenciennes, 1836 from São Paulo and Alagoas.

Myxozoans generally exhibit a life cycle characterized by host alternation, involving a definitive host and an intermediate host. The occurrence of *M. episquamalis* parasitizing *M. liza* suggests that this fish species acts as an intermediate host for this group in the Maricá Lagoon. The first record of *M. episquamalis* infecting *M. liza* in Brazil was reported by Duarte et al. (2020). This species has also been recorded in other fish hosts, such as *Mugil cephalus* Linnaeus, 1758, and *Chelon ramada* (Risso, 1827) in Egypt, and *Planiliza macrolepis* (Smith, 1846) in Thailand (Lin & Ho, 1997; Eissa et al., 2020).

Metamicrocotyla macracantha, the only species recorded representing the phylum Platyhelminthes, showed the third highest prevalence (18.2%) among the ectoparasites identified in this study, with 15 specimens distributed among eight fish and an infestation range of one to four parasites per host. *Metamicrocotyla macracantha* and *M. inoblita* Buhrnheim, 1970 have previously been reported in fish of the family Mugilidae (Kohn et al., 1994; Baptista-Farias et al., 1995; Baptista-Farias & Kohn, 1998; Cohen et al., 2004; Baptista-Farias & Cohen, 2005; Moutinho & Alves, 2014; Mentz et al., 2016) and can be distinguished mainly by body size, the size of the genital spines, the number of testes, and the size and number of clamps (Kohn et al., 1994; Mentz et al., 2016).

Studies indicate that *M. macracantha* also occurs in brackish systems and transitional zones between marine and freshwater environments, such as Charleston Harbor and estuaries in South Carolina, United States (Baker et al., 2005, 2008). In Brazil, *M. macracantha* has been recorded infecting *M. liza* along the coast of Rio de Janeiro State (Kohn et al., 1994; Baptista-Farias & Cohen, 2005), in the Marapendi Channel (Baptista-Farias et al., 1995; Cohen et al., 2004), and in the Tramandaí-Armazém Lagoon System (Mentz et al., 2016). Abiotic factors, such as temperature, may influence parasite population dynamics (Kirk et al., 2022), as higher temperatures tend to favor increased rates of embryonic development (Rawson, 1976; Atroch et al., 2026) and, consequently, population growth (Bychowsky,

1958). In the present study, *M. macracantha* specimens were recorded in mullets collected in January, during the summer, which may have contributed to the prevalence observed.

The class Copepoda was the most representative group in terms of both species' richness and number of specimens within the ectoparasite fauna of *M. liza* from the Maricá Lagoon, being represented by four species (*B. nitidus*, *E. caraguatatubensis*, *Caligus* sp., and *N. lizae*). Porto et al. (2022) highlighted the high parasite diversity associated with this class, reporting more than 7.000 described species, of which approximately 3.000 are recorded parasitizing freshwater fishes. Regardless of other factors that may be associated with the representativeness observed in the present study, there appears to be a tendency for mullets to harbor a greater number of representatives of this group, both in terms of species richness and total number of specimens, even when collected in brackish environments.

Bomolochus nitidus was the second species to show high prevalence (43.2%) in mullets, with an infestation range of one to 14 specimens per host. This species has been frequently reported parasitizing the gills of fishes of the family Mugilidae, commonly occurring in association with *Ergasilus* spp. (Eiras et al., 2016; Golzio et al., 2017; Falkenberg et al., 2021). Although *B. nitidus* is typically associated with coastal marine environments, records of its occurrence in brackish and estuarine systems parasitizing *M. curema* (Golzio et al., 2017; Falkenberg et al., 2021) demonstrate its ability to persist in transitional environments between marine and freshwater environments, as observed in the present study. Additionally, this species has been reported infecting *Mugil platanus* Günther, 1880 (= *M. liza*) along the coast of Rio de Janeiro State (Knoff et al., 1994), reinforcing its affinity with mugilid hosts in coastal environments.

Ergasilidae is one of the copepod families most frequently reported parasitizing fishes (Montú & Boxshall, 2002; Al-Sahlany et al., 2024), with *Ergasilus* von Nordmann, 1832 representing the genus with the greatest species diversity. In Brazil, Couto et al. (2023) and Corrêa et al. (2024) inventoried 77 species of Copepoda distributed in 18 genera of Ergasilidae parasitizing fishes. Among these, *Ergasilus atafonensis* Amado & Rocha, 1995, *E. bahiensis* Amado & Rocha, 1995, *E. caraguatatubensis* Amado & Rocha, 1995, *E. lizae* (Krøyer, 1863), *E. longimanus* Krøyer, 1863, and *E. versicolor* Wilson, 1911 have been recorded infecting *M. liza* and *M. curema* (Knoff et al., 1994; Fonsêca et al., 2000; Golzio et al., 2017; Falkenberg et al., 2021).

Ergasilus caraguatatubensis was the only copepod species recorded in this study presenting high prevalence (86.4%), occurring in 38 of the 44 mullets examined, with an infestation range of one to 88 specimens per host. The occurrence of this parasite in hosts of the family Mugilidae corroborates previous observations reported by Fonsêca et al. (2000), Golzio et al. (2017), and Falkenberg et al. (2021). This species has been reported parasitizing *M. liza* along the coast of Rio de Janeiro State (Knoff et al., 1994) and in a fish-farming pond in Itamaracá, Pernambuco State (Fonseca et al., 2000).

The transmission of ectoparasites is favored by close contact between parasitized and non-parasitized hosts, a process particularly relevant in schooling fish such as mullets (Silva & Araújo, 2000). This behavior may have contributed to the high infestation levels of *E. caraguatatubensis* observed in *M. liza* from the Maricá Lagoon. Representatives of the family Ergasilidae are found across a wide range of salinity regimes, which may be associated with their high prevalence in fishes such as *M. liza*. During their ontogenetic migrations from estuarine waters to the open sea, mullets experience broad salinity fluctuations (Rosim et al., 2013; Al-Sahlany et al., 2024).

Parasites assigned to the family Caligidae are characterized by relatively large body size and are popularly known as "sea lice." *Caligus* spp. cause economic losses to fisheries, mainly by inducing stress in their hosts and causing severe damage to the skin and epidermal tissue, as well as secondary infections (Saraiva et al., 2015). Bondad-Reantaso et al. (2005) further noted that species of this genus may affect host growth, fecundity, and survival, as their feeding activity results in skin lesions. Species of *Caligus* are widely distributed in lagoon systems and saline waters worldwide (Knoff et al., 1994; Fonsêca et al., 2000; Fajer-Ávila et al., 2006; Mentz et al., 2016; Öktener et al., 2024). In Brazil, *Caligus* species previously recorded parasitizing *M. liza* include *Caligus minimus* Otto, 1821 and *C. praetextus* Bere, 1936, both reported by Fonsêca et al. (2000) in a fish-farming pond in Itamaracá, Pernambuco State, and *C. bonito* Wilson, 1905 along the coast of Rio de Janeiro State (Knoff et al., 1994). Additionally, *Caligus* sp. was documented parasitizing *M. liza* in the Tramandaí-Armazém Lagoon System by Mentz et al. (2016). In the present study, a single female specimen identified as *Caligus* sp. was recovered from the gills of a mullet in the Maricá Lagoon. Identification at the species level was hampered by the presence of *Udonella* sp. specimens attached to its external surface, an epibiotic platyhelminth frequently associated with caligid copepods (Kabata, 1973; Soares et al., 2021), which compromised the morphological structures required for precise identification.

Naobranchia lizae has previously been reported in Brazil parasitizing *M. liza* in the Guandu River (Azevedo et al., 2010), as well as *M. platanus* (= *M. liza*) along the coast of Rio de Janeiro State, where it presented a prevalence of 28.7% in a study conducted by Knoff et al. (1994). In estuarine environments, Baker et al. (2005) recorded *N. lizae* with prevalence of 17% parasitizing *M. cephalus* in South Carolina, and Teemer et al. (2016) reported its occurrence in the same estuary and host in the United States. The low prevalence observed for this species (2.3%) in mullets from the Maricá Lagoon contrasts with previous records, suggesting spatial variation or the influence of specific environmental factors. There is a lack of Brazilian studies evaluating *N. lizae* tolerance to lagoon environments characterized by salinity fluctuations and other environmental variables. In a study conducted in Egypt with *Naobranchia cygniformes* Hesse, 1863 parasitizing *Boops boops* (Linnaeus, 1758), Zayed et al. (2023) found significant correlations with physical factors, being positive with high salinity and temperature, and negative with low pH. In the present study, physical factors were not assessed, which precludes determining whether such variables influenced the low prevalence of *N. lizae* observed in the Maricá Lagoon, although a potential relationship cannot be ruled out.

Due to the fact that this study was conducted over a period that included sampling in 2018 and 2019, an interruption in 2020 and 2021 due to the COVID-19 pandemic, and the resumption of sampling in 2022 and 2023, the temporal scale is considered a potential limitation of this work.

Regarding possible changes in the occurrence dynamics of the recorded ectoparasite species, the persistence of *E. caraguatatubensis*, with similar parasitic indices over time, suggests temporal stability. On the other hand, the occurrence of the other species only in the pre-pandemic period may indicate that their presence is occasional, a pattern frequently observed in parasite communities, in which a few species are central and persistent, while others occur sporadically (Poulin, 1993).

Ergasilus caraguatatubensis, *B. nitidus*, and *M. macracantha* exhibited an aggregated distribution pattern, which is typical and characterized by the concentration of most parasites in a small number of hosts, whereas the majority of individuals show low parasite loads or are uninfected, a pattern commonly observed in fish parasites (Zuben, 1997). This finding corroborates the observations of the present study, in which higher parasite intensities were restricted to few hosts, while most mullets exhibited lower infestation intensities. Additionally, Poulin (1993) related parasite dispersion to physical environmental parameters, as well as to genetic factors and host immunological and behavioral susceptibility. Although these factors were not specifically assessed in the present study, they cannot be ruled out as potential drivers, particularly given that the study area is a coastal lagoon with a complex ecosystem that remains poorly investigated.

In accordance with Vilella et al. (2002), host body length reflects age and represents one of the factors influencing the size of parasite infrapopulations. Thus, the negative, albeit non-significant, correlations observed between host size and the prevalence and abundance of *M. macracantha* indicate that this parasite was more common and abundant in smaller fish. Total fish length influenced the intensity and abundance of *E. caraguatatubensis*, with larger hosts showing higher parasitism levels, a pattern also reported by Knoff et al. (1997) for the congeneric species *E. lizae* and *E. versicolor* parasitizing mullets from Rio de Janeiro. *Bomolochus nitidus* showed significantly higher prevalence, intensity, and abundance in smaller fish, indicating a significant negative correlation. Lizama et al. (2007) suggested that adult hosts may develop immunity to certain parasites, which could explain the higher infestation levels of some ectoparasites in juvenile fish and the reduced or absent infestation in adults.

The records of *M. macracantha*, *B. nitidus*, *E. caraguatatubensis*, *Caligus* sp., and *N. lizae* parasitizing *M. liza* in the Maricá Lagoon are relevant, as they expand the known distribution of these ectoparasites previously recorded in this host in other localities, thereby contributing to studies on fish parasites in Brazil.

Conclusions

The ectoparasite fauna of *M. liza* from Maricá Lagoon was composed of one species of Myxozoa, one of Polyopisthocotyla, and four of Copepoda. All recorded taxa have previously been reported parasitizing mugilids in Brazil, reinforcing their association with the host and their geographic distribution.

The occurrence of *M. liza* in Maricá Lagoon expands the environmental distribution of *M. macracantha*, *E. caraguatatubensis*, *B. nitidus*, *Caligus* sp., and *N. lizae* in the state of Rio de Janeiro, increasing the number of recorded localities, particularly in lagoon systems. Notably, *B. nitidus* and *N. lizae* are recorded for the first time in a lagoon system in Brazil, as they had previously been reported only in marine environments. Additionally, *M. macracantha*, *E. caraguatatubensis*, and *Caligus* sp. are recorded for the first time in a lagoon system in the state of Rio de Janeiro.

Furthermore, mullets were shown to act as intermediate hosts within the local trophic community, particularly for *M. episquamalis*, reinforcing their ecological role in host–parasite dynamics in transitional environments.

Overall, this study contributes to the understanding of the diversity and distribution of fish parasites in coastal lagoon ecosystems, which remain relatively understudied in Brazil.

Acknowledgements

We thank the fisherman Mr. Lucielio de Moura Costa, in the municipality of Maricá, State of Rio de Janeiro, for giving us the fish that were analyzed in the current study. To Dr Marcelo Knoff and Dr Cristiana Serejo the curators of the Coleção Helminológica do Instituto Oswaldo Cruz (CHIOC, RJ) and Coleção de Crustacea do Museu Nacional do Rio de Janeiro (MNRJ-CARCINO), respectively and Museu de Zoologia da Universidade Federal Rural do Rio de Janeiro (MZUFRRJ) for depositing the voucher specimens.

Financial Support

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001 (88887.086561/2024-00), through a Master's scholarship granted to Laura Frantelmo Cavalheiro; by the Vice–Presidência de Pesquisa e Coleções Biológicas – VPPCB/Fiocruz, through a Postdoctoral Fellowship granted to Rayane Duarte; by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (PIBIC/CNPq), through an Undergraduate research scholarship granted to Marco Antonio Santos Silva Júnior; and by the Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ) – ARC 2019 (Auxílio ao Pesquisador Recém-Contratado), awarded to Rafael de Almeida Tubino (Grant # E-26/211.463/2019) and to Michelle Daniele dos Santos-Clapp (Grant # E-26/211.431/2019), for financial support.

Data Availability

The data supporting the findings of this study are available from the corresponding authors upon reasonable request.

Ethics declaration

This project was approved by Comissão de Ética no uso de Animais (CEUA/ICBS) of the UFRRJ under protocol no. 005/2019.

Conflict of interest

The authors declare that they have no conflict of interest.

Author contributions

Laura Frantelmo Cavalheiro contributed with fish necropsies, data collection, analysis, statistical tests, data interpretation and material preparation. Rayane Duarte contributed with data interpretation, material preparation, review and editing. Marco Antonio Santos Silva Júnior contributed with fish necropsies and data collection. Rafael de Almeida Tubino was responsible for the conception of the work and contributed with material and logistical support, review and editing. Michelle Daniele dos Santos-Clapp was responsible for the conception of the work and participated to the morphological identification of parasite specimens, data analysis and interpretation, as well as the planning and revision of the manuscript.

References

Aguirre-Pabon JC, Berdugo GO Jr, Narváez JC. Population structure and low genetic diversity in the threatened lebranche *Mugil liza* in the Colombian Caribbean. *Fish Res* 2022; 256: 106485. <https://doi.org/10.1016/j.fishres.2022.106485>.

- Albieri RJ, Araújo FG, Uehara W. Differences in reproductive strategies between two co-occurring mullets *Mugil curema* Valenciennes, 1836 and *Mugil liza* Valenciennes, 1836 (Mugilidae) in a tropical bay. *Trop Zool* 2010; 23(1): 51-62.
- Al-Sahlany BAA, Adday TK, Ali AH. A new *Ergasilus* Nordmann, 1832 species (Copepoda: Cyclopoida, Ergasilidae) from gills of two freshwater fishes at Al-Gharraf River, southern Iraq. *Egypt J Aquat Biol Fish* 2024; 28(6): 633-643. <https://doi.org/10.21608/ejabf.2024.392431>.
- Amado MAP, Rocha CEF. Três novas espécies de copépodes parasitas do gênero *Ergasilus* (Poecilostomatoida, Ergasilidae) coletadas em filamentos branquiais de peixes mugilídeos do Brasil. *Nauplius* 1995; 3: 33-48.
- Amato JFR, Boeger WA, Amato SB. *Protocolos para laboratório - coleta e processamento de parasitos de pescado*. Rio de Janeiro: Imprensa Universitária, Universidade Federal Rural do Rio de Janeiro; 1991.
- Atroch F, Rangel LF, Ayra-Pardo C, Santos MJ. Climate change, fish and shellfish, and parasite dynamics: a comprehensive review. *J Mar Sci Eng* 2026; 14(2): 167. <https://doi.org/10.3390/jmse14020167>.
- Azevedo RK, Abdallah VD, Luque JL. Acanthocephala, Annelida, Arthropoda, Myxozoa, Nematoda and Platyhelminthes parasites of fishes from the Guandu River, Rio de Janeiro, Brazil. *Check List* 2010; 6(4): 659-667. <https://doi.org/10.15560/6.4.659>.
- Baker TG, Pante E, de Buron I. Co-occurrence of *Naobranhia lizae* (Copepoda) and *Metamicrocotyla macracantha* (Monogenea), gill parasites of the striped mullet *Mugil cephalus*. *Parasitol Res* 2005; 97(6): 515-520. <https://doi.org/10.1007/s00436-005-1485-5>. PMID:16211412.
- Baker TG, Pante E, Levesque EM, Roumillat WA, de Buron I. *Metamicrocotyla macracantha*, a polyopisthocotylid gill parasite of the striped mullet, *Mugil cephalus*: population dynamics in South Carolina estuaries. *Parasitol Res* 2008; 102(5): 1085-1088. <https://doi.org/10.1007/s00436-008-0920-9>. PMID:18320224.
- Baptista-Farias MF, Kohn A. Ultrastructural observations of the vitelline cells of *Metamicrocotyla macracantha* (Monogenea, Microcotylidae). *Mem Inst Oswaldo Cruz* 1998; 93(4): 543-548. <https://doi.org/10.1590/S0074-02761998000400023>.
- Baptista-Farias MFD, Cohen SC. Ultrastructural studies of the Mehlis' gland in *Metamicrocotyla macracantha* (Monogenea, Microcotylidae), parasite of *Mugil liza* (Teleostei). *Braz J Vet Res Anim Sci* 2005; 42(5): 367-371. <https://doi.org/10.11606/issn.1678-4456.bjvras.2005.26413>.
- Baptista-Farias MFD, Kohn A, Barth OM. Ultrastructural aspects of spermatogenesis in *Metamicrocotyla macracantha* (Alexander, 1954) Koratha, 1955 (Monogenea, Microcotylidae). *Mem Inst Oswaldo Cruz* 1995; 90(5): 597-604. <https://doi.org/10.1590/S0074-02761995000500010>. PMID:8569475.
- Behera PR, Parida PK, Karna SK, Raman RK, Suresh VR, Behera BK, et al. Trophic fingerprinting of Chilika, a Ramsar site and the largest lagoon of Asia using Ecopath. *Reg Stud Mar Sci* 2020; 37: 101328. <https://doi.org/10.1016/j.rsma.2020.101328>.
- Blaber SJM. *Tropical estuarine fishes: ecology, exploitation and conservation*. Chichester: John Wiley & Sons; 2000. <https://doi.org/10.1002/9780470694985>.
- Bondad-Reantaso MG, Subasinghe RP, Arthur JR, Ogawa K, Chinabut S, Adlard R, et al. Disease and health management in Asian aquaculture. *Vet Parasitol* 2005; 132(3-4): 249-272. <https://doi.org/10.1016/j.vetpar.2005.07.005>. PMID:16099592.
- Borges JN, Lopes KC, Santos CP. Viability of *Ascocotyle (Phagicola) longa* (Trematoda: Heterophyidae) metacercariae from mullets (*Mugil liza*) from Rio de Janeiro, Brazil after exposure to freezing and heating in the temperature range from -35 °C to 180 °C. *Food Control* 2018; 89: 117-122. <https://doi.org/10.1016/j.foodcont.2017.11.037>.
- Boxshall G, Halsey SH. *An introduction to copepod diversity*. London: The Ray Society; 2004.
- Brabec J, Salomaki ED, Kolisko M, Scholz T, Kuchta R. The evolution of endoparasitism and complex life cycles in parasitic Platyhelminthes. *Curr Biol* 2023; 33(19): 4269-4275.e3. <https://doi.org/10.1016/j.cub.2023.08.064>. PMID:37729914.
- Brasil. Ministério da Pesca e Aquicultura. Ministério do Meio Ambiente. *Plano de gestão para o uso sustentável da tainha Mugil liza Valenciennes, 1836 no Sudeste e Sul do Brasil* [online]. Brasília: MPA/MMA; 2015 [cited 2026 April 18]. Available from: https://www.gov.br/icmbio/pt-br/assuntos/centros-de-pesquisa/biodiversidade-marinha-do-sudeste-e-sul/acervo-digital/relatorio-de-ordenamento/tainha/rel_2015_plano_gestao_tainha_mpa_mma_revisado.pdf/view
- Bush AO, Aho JM, Kennedy CR. Ecological versus phylogenetic determinants of helminth parasite community richness. *Evol Ecol* 1990; 4(1): 1-20. <https://doi.org/10.1007/BF02270711>.
- Bush AO, Lafferty KD, Shostak AW. Parasitology meets ecology on its own terms: Margolis et al. revisited. *J Parasitol* 1997; 83(4): 575-583. <https://doi.org/10.2307/3284227>. PMID:9267395.
- Bychowsky BE. *Monogenetic trematodes: their systematics and phylogeny*. Virginia: Virginia Institute of Marine Science; 1958. Translation Series.
- Cataudella S, Crosetti D, Massa F. *Mediterranean coastal lagoons: sustainable management and interactions among aquaculture, capture fisheries and the environment*. Rome: Food and Agriculture Organization of the United Nations; 2015. 278 p. (No. 95).

- Cohen SC, Kohn A, Baptista-Farias MFD. Ultrastructure of the tegument of *Metamicrocotyla macracantha* (Alexander, 1954) Koratha, 1955 (Monogenea, Microcotylidae). *Braz J Biol* 2004; 64(1): 27-31. <https://doi.org/10.1590/S1519-69842004000100004>. PMID:15195361.
- Corrêa AP, Pantoja DA, Corrêa CC, Pinto RCP, Miranda JVC, Pereira MFBC, et al. Ocorrência de *Ergasilus yumaricus* Malta & Varella, 1995 (Copepoda: Ergasilidae) infestando peixes serrasalmídeos na bacia Tocantins-Araguaia, norte do Brasil. *Obs Econ Latinoam* 2024; 22(10): e7410. <https://doi.org/10.55905/oelv22n10-218>.
- Couto JV, Pereira AN, Luque JL, Paschoal F, Pereira FB. Two new species of *Acusicola* Cressey, 1970 (Copepoda: Cyclopoida: Ergasilidae) parasitic on the gills of two estuarine actinopterygians off Brazil. *Syst Parasitol* 2023; 100(2): 133-148. <https://doi.org/10.1007/s11230-022-10076-y>. PMID:36471195.
- Dias FF, Costa BR, Vargas R, Costa MR, Monteiro-Neto C, Tubino RA. Lagoas costeiras do Leste Fluminense: origem, evolução, importância e aspectos demográficos. In: Costa MR, Monteiro-Neto C, Tubino RA, Angelini R, editors. *Sistemas lagunares do Leste Fluminense – pesca e sustentabilidade: passado, presente e futuro*. Rio de Janeiro: Alexandre Honorato Duarte Ferreira; 2021. p. 15-25.
- Duarte R, Martinatti BR, de Oliveira AA, Genovez-Oliveira J, de Lima VM, Tubino RA, et al. First report of *Myxobolus episquamalis* Egusa, Maeno & Sorimachi, 1990 (Myxozoa: Bivalvulida) in lebranche mullet *Mugil liza* Valenciennes, 1836 (Teleostei: Mugiliformes) from Neotropical region. *Parasitol Res* 2020; 119(11): 3869-3872. <https://doi.org/10.1007/s00436-020-06803-3>. PMID:32656657.
- Eiras JC, Abreu PC, Robaldo R, Pereira J Jr. *Myxobolus platanus* n. sp. (Myxosporaea, Myxobolidae), a parasite of *Mugil platanus* Günther, 1880 (Osteichthyes, Mugilidae) from Lagoa dos Patos, RS, Brazil. *Arq Bras Med Vet Zootec* 2007; 59(4): 895-898. <https://doi.org/10.1590/S0102-09352007000400012>.
- Eiras JC, Takemoto RM, Pavanelli GC. *Métodos de estudo e técnicas laboratoriais em parasitologia de peixes*. 2nd ed. Maringá: Eduem; 2006.
- Eiras JC, Velloso AL, Pereira J Jr. *Parasitas de peixes marinhos da América do Sul*. Rio Grande: FURG; 2016.
- Eissa AE, Abolghait SK, Younis NA, Dessouki AA, El-Lamie MM, Mhara AAA, et al. *Myxobolus episquamalis* infection in farmed flathead grey mullet *Mugil cephalus* L. and thin-lipped mullet *Liza ramada*. *Aquacult Int* 2020; 28(2): 363-376. <https://doi.org/10.1007/s10499-019-00467-2>.
- Fajer-Ávila EJ, García-Vásquez A, Plascencia-González H, Ríos-Sicairos J, García-De La Parra LM, Betancourt-Lozano M. Copepods and larvae of nematodes parasiting the white mullet *Mugil curema* (Valenciennes, 1836): indicators of anthropogenic impacts in tropical coastal lagoons? *Environ Monit Assess* 2006; 122(1-3): 221-237. <https://doi.org/10.1007/s10661-005-9177-2>. PMID:16758278.
- Falkenberg JM, Lacerda ACF, Vieira GHC. Co-occurrence and niche overlap among gill parasites of the white mullet (*Mugil curema* Valenciennes. (Osteichthyes: Mugilidae) from the western Atlantic, Brazil. *Parasitol Res* 2021; 120(3): 849-859. <https://doi.org/10.1007/s00436-020-07015-5>.
- Fonsêca FTB, Paranaguá MN, Amado MAM. Copepoda parasitas de peixes Mugilidae em cultivo estuarino – Itamaracá, Pernambuco, Brasil. *Trab Oceanogr da Univ Federal de PE* 2000; 28(2): 157-172.
- Froese R, Pauly D. *Mugil liza* Valenciennes, 1836. *Lebranche mullet* [online]. FishBase; 2026 [cited 2026 Feb 22]. Available from: https://www.fishbase.org/summary/Mugil_liza.html
- Garbin T, Castello JP, Kinas PG. Age, growth, and mortality of the mullet *Mugil liza* in Brazil's southern and southeastern coastal regions. *Fish Res* 2014; 149: 61-68. <https://doi.org/10.1016/j.fishres.2013.09.008>.
- Giari L, Castaldelli G, Timi JT. Ecology and effects of metazoan parasites of fish in transitional waters. *Parasitology* 2022; 149(14): 1829-1841. <https://doi.org/10.1017/S0031182022001068>. PMID:35946119.
- Golzio JESA, Falkenberg JM, Praxedes RCG, Coutinho AS, Laurindo MK, Pessanha A, et al. Gill parasites of fish from two estuaries in northeastern Brazil: new hosts and geographical records. *An Acad Bras Cienc* 2017; 89(3 Suppl.): 2281-2291. <https://doi.org/10.1590/0001-3765201720160883>.
- Gueretz JS, Cardoso L, Martins ML, Souza AP. *Nerocila* sp. (Isopoda: Cymothoidae) parasitizing *Mugil liza* (Teleostei: Mugilidae) in São Francisco do Sul, Santa Catarina, Brazil. *Biotemas* 2018; 31(1): 41-44. <https://doi.org/10.5007/2175-7925.2018v31n1p41>.
- Kabata Z. Distribution of *Udonella caligorum* Johnston, 1835 (Monogenea: Udonellidae) on *Caligus elongatus* Nordmann, 1832 (Copepoda: Caligidae). *J Fish Res Board Can* 1973; 30(12): 1793-1798. <https://doi.org/10.1139/f73-289>.
- Kirk D, O'Connor M, Mordecai EA. Scaling effects of temperature on parasitism from individuals to populations. *J Anim Ecol* 2022; 91(10): 2087-2102. <https://doi.org/10.1111/1365-2656.13786>. PMID:35900837.
- Knoff M, Luque JL, Amato JFR. Community ecology of the metazoan parasites of grey mullets, *Mugil platanus* (Osteichthyes: Mugilidae) from the littoral of the state of Rio de Janeiro, Brazil. *Rev Bras Biol* 1997; 57(3): 441-454. PMID:9430918.
- Knoff M, Luque JL, Takemoto M. Parasitic copepods on *Mugil platanus* Günther (Osteichthyes: Mugilidae) from the coast of the state of Rio de Janeiro, Brazil. *Rev Bras Parasitol Vet* 1994; 3(1): 45-56.

- Kohn A, Cohen SC, Baptista-Farias MFD. A redescription of the morphology of *Metamicrocotyla macracantha* (Alexander, 1954) Koratha, 1955 (Monogenea, Microcotylidae) from *Mugil liza* in Brazil. *Syst Parasitol* 1994; 27(2): 127-132. <https://doi.org/10.1007/BF00012270>.
- Lafferty KD. Environmental parasitology: what can parasites tell us about human impacts on the environment? *Parasitol Today* 1997; 13(7): 251-255. [https://doi.org/10.1016/S0169-4758\(97\)01072-7](https://doi.org/10.1016/S0169-4758(97)01072-7). PMID:15275061.
- Lebreton B, Richard P, Parlier EP, Guillou G, Blanchard GF. Trophic ecology of mullets during their spring migration in a European saltmarsh: a stable isotope study. *Estuar Coast Shelf Sci* 2011; 91(4): 502-510. <https://doi.org/10.1016/j.ecss.2010.12.001>.
- Lin C, Ho J. *Myxobolus episquamalis* (Myxosporea) occurring on the scales of the mullet *Liza macrolepis*, cultured in Taiwan. *Taiwan Shuichanxue Hui Kan* 1997; 24: 193-200. <https://doi.org/10.29822/JFST.199709.0002>.
- Lizama MAP, Takemoto RM, Ranzani-Paiva MJT, Ayroza LMS, Pavanelli GCL. Relação parasito-hospedeiro em peixes de pisciculturas da região de Assis, estado de São Paulo, Brasil. 1. *Oreochromis niloticus* (Linnaeus, 1757). *Acta Sci Biol Sci* 2007; 29(2): 223-231. <https://doi.org/10.4025/actascibiols.v29i2.594>.
- Ludwig JA, Reynolds JF. *Statistical ecology: a primer on methods and computing*. New York: Wiley-Interscience Publications; 1988.
- Meira-Filho MRC, Buitrago Ramirez JR, Vianna RT, Pereira J Jr. Efficacy of glacial acetic acid in the control of *Trichodina* sp. and *Apiosoma* sp. associated with *Mugil liza*. *Aquaculture* 2017; 479: 7-12. <https://doi.org/10.1016/j.aquaculture.2017.05.014>.
- Menezes NA, Figueiredo JL. *Manual de peixes marinhos do sudeste do Brasil. IV. Teleostei (3)*. São Paulo: Museu de Zoologia, Universidade de São Paulo; 1980.
- Menezes NA, Figueiredo JL. *Manual de peixes marinhos do sudeste do Brasil. V. Teleostei (4)*. São Paulo: Museu de Zoologia, Universidade de São Paulo; 1985.
- Mentz MB, Lanner M, Fagundes N, Sauter IP, Marques LS. Ectoparasites on *Mugil liza* (Osteichthyes: Mugilidae) from the Tramandai-Armazém lagoon system, Southern Brazil. *Pan-Am J Aquat Sci* 2016; 11(2): 130-134.
- Montú MA, Boxshall GA. *Gauchergasilus*, a new genus for *Ergasilus euripedesi* Montú, 1980, an abundant copepod from the Patos Lagoon in Southern Brazil. *Syst Parasitol* 2002; 51(1): 21-28. <https://doi.org/10.1023/A:1012985717903>. PMID:11721192.
- Moutinho FO, Alves DR. Metazoan parasites of *Mugil curema* (Osteichthyes: Mugilidae) from the coastal Rio de Janeiro. *Cad Unifoa* 2014; 9(24): 67-75. <https://doi.org/10.47385/cadunifoa.v9.n24.77>.
- Newton A, Brito AC, Icely JD, Derolez V, Clara I, Angus S, et al. Assessing, quantifying and valuing the ecosystem services of coastal lagoons. *J Nat Conserv* 2018; 44: 50-65. <https://doi.org/10.1016/j.jnc.2018.02.009>.
- Newton A, Icely J, Cristina S, Brito A, Cardoso AC, Colijn F, et al. An overview of ecological status, vulnerability and future perspectives of European large shallow, semienclosed coastal systems, lagoons and transitional waters. *Estuar Coast Shelf Sci* 2014; 140: 95-122. <https://doi.org/10.1016/j.ecss.2013.05.023>.
- Öktener A, Montes MM, Romero RC, Türker D, Trilles JP. *Caligus turkiyensis* n. sp. (Copepoda: Caligidae) on the flathead grey mullet, *Mugil cephalus* (Linnaeus) (Mugiliformes: Mugilidae) from the Sea of Marmara, Turkey. *Vie Milieu* 2024; 74(1-2): 44-66. <https://doi.org/10.57890/viemilieu/2024.74-1/2:44-66>.
- Oliveira JVF, Kuraiem BP, Fonseca MCG, Gomes DC, Knoff M. Trypanorhynch cestodes parasitizing *Mugil liza* (Mugiliformes: Mugilidae) commercialized in the state of Rio de Janeiro, Brazil. *Rev Bras Parasitol Vet* 2019; 28(4): 773-778. <https://doi.org/10.1590/s1984-29612019039>. PMID:31365718.
- Pérez-Ruzafa A, Marcos C, PérezRuzafa IM, PérezMarcos M. Coastal lagoons: “transitional ecosystems” between transitional and coastal waters. *J Coast Conserv* 2011; 15(3): 369-392. <https://doi.org/10.1007/s11852-010-0095-2>.
- Pérez-Ruzafa A, Molina-Cuberos GJ, García-Oliva M, Umgiesser G, Marcos C. Why coastal lagoons are so productive? Physical bases of fishing productivity in coastal lagoons. *Sci Total Environ* 2024; 922: 171264. <https://doi.org/10.1016/j.scitotenv.2024.171264>. PMID:38417507.
- Pérez-Ruzafa A, Morkune R, Marcos C, PérezRuzafa IM, RazinkovasBaziukas A. Can an oligotrophic coastal lagoon support high biological productivity? Sources and pathways of primary production. *Mar Environ Res* 2020; 153: 104824. <https://doi.org/10.1016/j.marenvres.2019.104824>. PMID:31735509.
- Porto SMA, Tavares-Dias M, Maciel PO, Castro LA. Crustáceos argulídeos e lerneídeos de peixes de água doce do Brasil. In: Rocha BD, Lobato ZIP, Marques AP Jr, Martins NRS, editors. *Doenças parasitárias em peixes de produção*. Belo Horizonte: Cadernos Técnicos de Veterinária e Zootecnia/FEPMVZ Editora; 2022. p. 109-153.
- Poulin R. The disparity between observed and uniform distributions: a new look at parasite aggregation. *Int J Parasitol* 1993; 23(7): 937-944. [https://doi.org/10.1016/0020-7519\(93\)90060-C](https://doi.org/10.1016/0020-7519(93)90060-C). PMID:8106186.
- Rawson MV Jr. Population biology of parasites of striped mullet, *Mugil cephalus* L. I. Monogenea. *J Fish Biol* 1976; 9(2): 185-194. <https://doi.org/10.1111/j.1095-8649.1976.tb04672.x>.

- Rohde K, Hayward C, Heap M. Aspects of the ecology of metazoan ectoparasites of marine fishes. *Int J Parasitol* 1995; 25(8): 945-970. [https://doi.org/10.1016/0020-7519\(95\)00015-T](https://doi.org/10.1016/0020-7519(95)00015-T). PMID:8550295.
- Rosim DF, Boxshall GA, Ceccarelli PS. A novel microhabitat for parasitic copepods: a new genus of Ergasilidae (Copepoda: Cyclopoida) from the urinary bladder of a freshwater fish. *Parasitol Int* 2013; 62(4): 347-354. <https://doi.org/10.1016/j.parint.2013.03.003>. PMID:23523989.
- Rothwell JT, Virgona JL, Callinan RB, Nicholls PJ, Langdon JS. Occurrence of cutaneous infections of *Myxobolus episquamalis* (Myxozoa: Myxobolidae) in sea mullet, *Mugil cephalus* L., in Australia. *Aust Vet J* 1997; 75(5): 349-352. <https://doi.org/10.1111/j.1751-0813.1997.tb15709.x>. PMID:9196822.
- Santos RF, Monteiro EP, Nascimento JCS, Santos WJP. A pesca artesanal no nordeste paraense, município de Viseu – Pará. *Acta Fish Aquac Resour* 2018; 6(1): 35-43. <https://doi.org/10.2312/Actafish.2018.6.1.35-42>.
- Saraiva A, Costa J, Serrão J, Eiras JC, Cruz C. Study of the gill health status of farmed sea bass (*Dicentrarchus labrax* L., 1758) using different tools. *Aquaculture* 2015; 441: 16-20. <https://doi.org/10.1016/j.aquaculture.2015.02.004>.
- Silva CS, Brasil EM, Cipriano FS, Magnotti C, Rocha VM, Furtado WE, et al. Antiparasitic efficacy of essential oils for *Neobenedenia melleni* infecting farmed Lebranche mullet (*Mugil liza*). *Int Aquatic Research* 2024; 16(2): 187-194. <https://doi.org/10.22034/iar.2024.2008628.1671>.
- Silva MA, Araújo FG. Distribuição e abundância de tainhas e paratis (Osteichthyes: Mugilidae) na Baía de Sepetiba, Rio de Janeiro, Brasil. *Rev Bras Zool* 2000; 17(2): 473-480. <https://doi.org/10.1590/S0101-81752000000200018>.
- Soares GB, Domingues MV, Adriano EA. Morphological and molecular characterization of *Udonella brasiliensis* n. sp. (Monogenoidea), an epibiont on *Caligus* sp., parasite of Ariidae from the southeastern coast of Brazil. *Parasitol Int* 2021; 83: 102371. <https://doi.org/10.1016/j.parint.2021.102371>. PMID:33932600.
- Souza DS, Pereira Silva RC, Steenbock W. De quem é o peixe? Aspectos socioeconômicos da pesca industrial e artesanal de tainha (*Mugil liza*) em Santa Catarina. *Rev CEPESUL Biodivers Conserv* 2017; 6: e2017002. <https://doi.org/10.37002/revistacepsul.vol6.665e2017002>.
- Sturges HA. The choice of a class interval. *J Am Stat Assoc* 1926; 21(153): 65-66. <https://doi.org/10.1080/01621459.1926.10502161>.
- Teemer SR, Sparkes TC, De Buron I. Host–parasite relationships between the copepod *Naobranchia lizae* and its host (striped mullet, *Mugil cephalus*): a description of morphological development. *DePaul Discov* 2016; 5: 11.
- Toledo LM, Wall FCM, Obraczka M, Salomão ALS. Panorama do sistema lagunar de Maricá – RJ: indicadores de saneamento vs qualidade de água. *Rev Inter Cien* 2021; 11(1): 6-24. <https://doi.org/10.12957/ric.2021.51768>.
- Vidal-Martínez VM, Wunderlich AC. Parasites as bioindicators of environmental degradation in Latin America: a meta-analysis. *J Helminthol* 2017; 91(2): 165-173. <https://doi.org/10.1017/S0022149X16000432>. PMID:27346709.
- Vieira DHMD, Agostinho BN, Negrelli DC, da Silva RJ, Azevedo RK, Abdallah VD. Taxonomy and systematics of two new species of *Myxobolus* (Cnidaria: Myxobolidae) parasitizing the gills of *Mugil curema* (Mugilidae) from the Brazilian coast. *Acta Parasitol* 2022; 67(3): 1206-1216. <https://doi.org/10.1007/s11686-022-00569-7>. PMID:35593955.
- Vilella FS, Becker FG, Hartz SM. Diet of *Astyanax* species (Teleostei, Characidae) in an Atlantic Forest river in southern Brazil. *Braz Arch Biol Technol* 2002; 45(2): 223-232. <https://doi.org/10.1590/S1516-89132002000200015>.
- Zar JH. *Biostatistical analysis*. 4th ed. New Jersey: Prentice Hall; 1999.
- Zayed OE, Hellal AM, Zeina AF, Tayel SI. Distribution of some parasitic copepods on Actinopterygii fish from Egyptian water of Alexandria coast, with referencing to the histopathological alteration. *Egypt J Aquat Biol Fish* 2023; 27(4): 597-613. <https://doi.org/10.21608/ejabf.2023.312040>.
- Zuben CJV. Implicações da agregação espacial de parasitas para a dinâmica populacional na interação hospedeiro-parasita. *Rev Saude Publ* 1997; 31(5): 523-530. <https://doi.org/10.1590/S0034-89101997000600014>.