ZOOLOGIA 39: e21034
ISSN 1984-4689 (online)


RESEARCH ARTICLE

# Community ecology of the metazoan parasites of the Atlantic anchoveta, *Cetengraulis edentulus* (Actinopterygii: Engraulidae) from the Sepetiba Bay, Rio de Janeiro, Brazil

Luana Benicio[1], Juliana Moreira[1], Fabiano Paschoal[2]

[1]*Laboratório de Parasitologia Animal, Centro de Estudos e Pesquisas em Biologia, Universidade Castelo Branco. Avenida Santa Cruz 1631, Realengo, 21710-255 Rio de Janeiro, RJ, Brazil.*
[2]*Programa de Pós-Graduação em Biodiversidade e Conservação, Departamento de Oceanografia e Limnologia, Universidade Federal do Maranhão. Avenida dos Portugueses 1966, 65080-805 São Luís, MA, Brazil.*
*Corresponding author: Fabiano Paschoal (paschoalfabiano@gmail.com)*

*https://zoobank.org/B26D6FED-6F39-412A-A0AD-469BCC1F1DB8*

ABSTRACT. The Atlantic anchoveta, *Cetengraulis edentulus* (Cuvier, 1829) is one of the most commercially important fish species in the littoral of Brazil. The present study evaluates the parasitic fauna of this engraulid fish from the southeastern Brazilian coast. Between October 2019 and March 2020, a total of 100 specimens of *C. edentulus* from the Sepetiba Bay, Rio de Janeiro, Brazil (22°57’44”S; 43°52’28”W), were examined. Eighty-five specimens of *C. edentulus* were parasitized by at least one species of metazoan, with a mean of 4.32 ± 6.12 parasites/fish. Eleven species of parasites were collected: five digeneans, two monogeneans, two copepods, one isopod and one nematode. The nematode *Hysterothylacium* sp. was the most abundant and dominant species, representing 51.85% of the metazoan parasites collected, showing positive correlation with the host’s total length and parasite abundance and prevalence. The mean abundance and prevalence of *Hysterothylacium* sp. was significantly higher in female hosts. One pair of larval endoparasites showed positive covariation. *Centengraulis edentulus* represents a new host record for nine species of parasites. A dominance of endoparasitic larval stages is documented in the parasite community of *C. edentulus*. This may be a function of the feeding habits of engraulid fish, which feed mainly on zooplanktonic organisms. It may also have to do with to the fact that *C. edentulus* is the intermediate and/or paratenic host of fish parasites, birds, and marine mammals.

KEY WORDS. Clupeiformes, engraulids, helminths, infracommunity, marine fish, parasitic crustaceans, structure of community.

## INTRODUCTION

The Sepetiba Bay is located west of the state of Rio de Janeiro, with an area of approximately 519 km$^2$ (Araujo et al. 2017). This bay is a microtidal estuarine lagoon, and one of the most important aquatic ecosystems in the state, with approximately 97 species of fish reported (Araujo et al. 1998). However, since the 1950s, with the expansion of urbanization and industrial development, this bay became a part of the geoeconomic center of Brazil, housing an important industrial park that includes the largest steel complex in Latin America (Araujo et al. 2017). The intensification of anthropogenic factors in recent decades has caused the emergence of new potential sources of diffused pollution (Pfeiffer et al. 1985, Araujo et al. 2017).

Species of Engraulidae are one of the most important fishing resources in many parts of the world. They represent about 25% of the total production of fish caught commercially in the world (Vasconcellos and Csirke 2011, Vicente et al. 2020). Currently, engraulids are represented by 150 species distributed in 17 genera around the world. Most species are found in shallow coastal waters and estuaries in tropical and temperate regions (Nelson 2016, Froese and Pauly 2021). The Atlantic anchoveta, *Cetengraulis edentulus* (Cuvier, 1829) is a brackish fish, commonly found in lagoons and estuaries with low salinity or even in freshwater environments. It is distributed from Cuba to southern Brazil (Silva et al. 2003, Froese and Pauly 2021). Usually occurring in large schools, these engraulids are presumably filter-feeders. Their diet is composed of phytoplankton and zooplankton (Froese and Pauly 2021). *Cetengraulis edentulus* is one of the most commercially important fish species in the littoral of Brazil, with annual catches over 1200 t. In the Sepetiba Bay *C. edentulus* represents the bulk of engraulid fish catches, followed by *Anchoa tricolor* (Spix & Agassiz, 1829) (Silva and Araujo 2000, Silva et al. 2003, Santos et al. 2020).

In the South Atlantic Ocean, studies regarding the metazoan parasite community of engraulids are scarce. Timi (2003) and Timi and Poulin (2003) studied the parasite population and ecological features of *Engraulis anchoita* Hubbs & Marini, 1935 from the coastal zone of Argentina, and Tavares et al. (2005) investigated the parasitic fauna of *A. tricolor* from the coastal zone of the State of Rio de Janeiro, Brazil. Studies focusing on the ecology of the parasitic fauna of *C. edentulus* are lacking. However, three species of parasites have been recorded from this fish in Brazilian waters: *Pseudanthocotyloides heterocotyle* (van Beneden, 1871) (Monogenea) off Rio de Janeiro, praniza larvae of *Gnathia* sp. (Isopod) off Pará and *Livoneca desterroensis* Thatcher, Souza-Conceição & Jost, 2003 (Isopod) off Pará and Santa Catarina (see Kohn et al. 1992, Thatcher et al. 2003, Monfort et al. 2009, Luque et al. 2013).

In the present contribution, we analyzed the composition and structure of the metazoan parasite community of *C. edentulus* from the Sepetiba Bay, Rio de Janeiro, Brazil.

## MATERIAL AND METHODS

### Fish sampling and analysis of parasites

Between October 2019 and March 2020, 100 specimens of *C. edentulus* were obtained from the Sepetiba Bay (22°57’44”S; 43°52’28”W), Rio de Janeiro, Brazil. Specimens were necropsied for the study of their community of metazoan parasites. Fish that had been collected by local fishermen were purchased at the fish market. The specimens were identified according to Figueiredo and Menezes (1978); the nomenclature and classification were updated according to FishBase (Froese and Pauly 2021). Hosts were mostly fresh, but some specimens were kept frozen at -20 °C, until examination.

All organs (i.e., body surface, nostrils, gills, branchial, and body cavities, oesophagus, stomach, intestine, mesenteries, heart, liver, gonads, swim bladder and musculature) were individually examined for the presence of parasites, using a stereomicroscope. The metazoan parasites were picked, fixed, preserved and processed for identification, according to standard protocols (Eiras et al. 2006). Taxonomic identification of the metazoans followed specific literature, pertinent to each taxon.

### Statistical analyses of parasites and deposited specimens

The analysis included only parasite species with a prevalence higher than 10% (Bush et al. 1997). The variance-to-mean ratio of parasite abundance (index of dispersion) and the discrepancy index, computed using the program Quantitative Parasitology 3.0 (Rózsa et al. 2000), were used to detect the distribution patterns of the infrapopulations (Poulin 1993). The dominance frequency (percentage of infracommunities in which either parasite species was dominant) and the relative dominance (number of specimens of one species/total number of specimens of all species in the infracommunity) of each parasite species were calculated according to Rohde et al. (1995). The diversity of parasite species was calculated using the Brillouin index (H), because each fish analyzed corresponded to a fully censused community (Zar 1996). The Spearman’s rank correlation coefficient (rs) was calculated to determine a possible correlation between the host’s total length and parasite abundance. Pearson’s correlation coefficient (r) was used to indicate the relationship between the host’s total length and parasite prevalence, with previous arcsine transformation of the prevalence data (Zar 1996). The effect of host sex on abundance and prevalence of parasites was tested using the Zc (normal) approximation to the Mann-Whitney test and the Fisher exact test, respectively. The probable variation of diversity in relation to host sex (Mann-Whitney test) and to host’s total length (Spearman’s rank correlation coefficient) was tested. Possible interspecific association between concurrent species was determined using the chi-square test. Possible covariation among the abundance of concurrent species was analyzed using the Spearman’s rank correlation coefficient. The ecological terminology used follows Bush et al. (1997). Statistical significance level was evaluated at $p \leq 0.05$.

Voucher specimens of helminths were deposited in the Helminthological Collection of Institute Oswaldo Cruz (CHIOC), Rio de Janeiro, Brazil; copepods were deposited in the scientific collection of the Museum of Zoology (MZUSP), University of São Paulo, Brazil.

## RESULTS

The average total length of the fish was 12.3–16.5 (14.8 ± 0.82) cm, and the weight was 18–57 (31.2 ± 6.42) g. The average total length of male (14.52 ± 0.84 n = 58) and female (15.21 ± 0.63 n = 42) fish in the studied sample were not significantly different ($t = 4.660$, $p = 0.998$).

### Component community

Eleven species of metazoan parasites were collected (Table 1). *Cetengraulis edentulus* is a new host record for nine of the eleven species collected, with exceptions made for the monogenean *P. heterocotyle* (Kohn et al. 1992) and for the isopod *L. desterroensis* (Luque et al. 2013). The nematode *Hysterothylacium* sp. was the most abundant and dominant species, representing 51.85% of the metazoan parasites collected, with greatest values of mean relative dominance and frequency of dominance (Table 2). The monogenean *P. heterocotyle* was the most prevalent species (Table 1).

Larval endoparasites represented 55.32% of all parasites collected, adult endoparasites amounted to 22.45%, and ectoparasites made up 22.22%. All parasites of *C. edentulus* had the typically aggregated distribution pattern observed in many parasite systems (Table 3). The nematode *Hysterothylacium* sp. showed positively correlation between host’s total length and parasite abundance ($rs = 0.346$, $p < 0.001$) and prevalence

Table 1. Prevalence. mean intensity. mean abundance. and site of infection/infestation of metazoan parasites of *Cetengraulis edentulus* from the Sepetiba Bay, Rio de Janeiro, Brazil.

| Parasites | Voucher number | Prevalence (%) | Mean intensity | Mean abundance | Site of infection/infestation |
|---|---|---|---|---|---|
| Digenea | | | | | |
| *Monorchis* sp. | CHIOC # 39591 | 19 | 2.42 ± 2.01 | 0.46 ± 1.28 | Stomach |
| *Parahemiurus merus* | CHIOC # 39593 | 19 | 1.52 ± 0.77 | 0.29 ± 0.68 | Stomach |
| *Rhipidocotyle* sp. (metacercariae) | CHIOC # 39592 | 12 | 1.25 ± 0.45 | 0.15 ± 0.43 | Mesenteries |
| *Parahemiurus* sp. | CHIOC # 39589 | 8 | 1.62 ± 0.74 | 0.13 ± 0.48 | Stomach |
| *Lecithochirium microstomum* | CHIOC # 39588 | 6 | 1.51 ± 0.83 | 0.09 ± 0.40 | Stomach |
| Monogenea | | | | | |
| *Pseudanthocotyloides heterocotyle* | CHIOC # 39594 | 48 | 1.79 ± 1.39 | 0.86 ± 1.31 | Gills |
| *Cribomazocraes travassosi* | CHIOC # 39590 | 2 | 1 | 0.02 ± 0.14 | Gills |
| Nematoda | | | | | |
| *Hysterothylacium* sp. (larval) | CHIOC # 39103 | 40 | 5.61 ± 7.69 | 2.24 ± 5.55 | Mesenteries |
| Copepoda | | | | | |
| *Neobomolochus elongatus* | MZUSP # 42134 | 3 | 1 | 0.03 ± 0.17 | Opercular cavity |
| *Nothobomolochus cresseyi* | MZUSP # 42135 | 2 | 1 | 0.02 ± 0.14 | Opercular cavity |
| Isopoda | | | | | |
| *Livoneca desterroensis* | MZUSP # 42133 | 3 | 1.50 ± 0.70 | 0.03 ± 0.22 | Opercular cavity |

Table 2. Frequency of dominance and mean relative dominance of metazoan parasites of *Cetengraulis edentulus* from the Sepetiba Bay, Rio de Janeiro, Brazil.

| Parasites | Frequency of dominance | Frequency of dominance shared with one or more species | Mean relative dominance |
|---|---|---|---|
| *Hysterothylacium* sp. (larval) | 27 | 5 | 0.280 ± 0.398 |
| *Pseudanthocotyloides heterocotyle* | 24 | 8 | 0.273 ± 0.374 |
| *Parahemiurus merus* | 9 | 6 | 0.076 ± 0.196 |
| *Monorchis* sp. | 8 | 2 | 0.086 ± 0.219 |
| *Parahemiurus* sp. | 2 | 3 | 0.031 ± 0.127 |
| *Rhipidocotyle* sp. (metacercariae) | 2 | 2 | 0.038 ± 0.156 |

Table 3. Values of variance to mean ratio of parasite abundance (ID) and index of Discrepancy (D) of metazoan parasites of *Cetengraulis edentulus* from the Sepetiba Bay, Rio de Janeiro, Brazil.

| Parasites | ID | D |
|---|---|---|
| *Hysterothylacium* sp. (larval) | 14.183 | 0.830 |
| *Monorchis* sp. | 3.576 | 0.873 |
| *Pseudanthocotyloides heterocotyle* | 2.021 | 0.667 |
| *Parahemiurus merus* | 1.623 | 0.830 |
| *Rhipidocotyle* sp. (metacercariae) | 1.263 | 0.889 |

(r = 0.292, p = 0.003). The mean abundance and prevalence of *Hysterothylacium* sp. were significantly higher in the female (4.16 and 62%) than in the male (0.84 and 24.1%) hosts ($Z_c$ = -3.406, p< 0.001; F = 0.007).

Infracommunities

Eighty-five specimens (85%) of *C. edentulus* were parasitized by at least one parasite species. A total of 432 individual parasites were collected, with a mean of 4.32 ± 6.12 parasites/fish. Total host length and parasite abundance were not correlated (rs = 0.096, p = 0.340). The mean parasite species richness 1.63 ± 1.29, was not correlated with the total body length of the fish (rs = -0.028, p = 0.779). Forty-three specimens (43%) showed infection with one parasite species, and 19 (19%), 15 (15%), 5 (5%), 1 (1%) and 2 (2%), had multiple infections with 2, 3, 4, 5, 6 parasite species, respectively. Mean parasite species diversity (H = 0.101 ± 0.151) was not correlated with the total length of the host (rs = -0.038, p = 0.707) and no significant differences in parasite diversity were observed between male (H = 0.114 ± 0.164) and female (H = 0.082 ± 0.130) fish ($Z_c$ = 0.719, p = 0.236).

The endoparasites were separated into two groups – helminth larval stages (digeneans and nematodes) and adult endoparasites (digeneans) – and were used to determine possible interspecific associations. Ectoparasites were not included in this analysis because only one ectoparasitic species showed a prevalence higher than 10% (see Table 1). The helminth larval stages pair, *Rhipidocotyle* sp. – *Hysterothylacium* sp., did not share significant association ($\chi^2$ = 1.910, p = 0.167), but showed positive covariation (rs = 0.234, p = 0.018). The adult endoparasites pair, *Monorchis* sp. – *Parahemiurus merus* (Linton, 1910), did not share significant association and covariation ($\chi^2$ = 2.412, p = 0.120; rs = 0.138, p = 0.170).

## DISCUSSION

The present study showed that the parasitic fauna of *C. edentulus*is dominated by endoparasites in the larval stage. Sergipense et al. (1999) studied the feeding habits of *C. eden-*

*tulus* from the Sepetiba Bay and concluded that this species is a planktivorous filter-feeder fish. However, the dominance of endoparasitic larval stages found in our study may indicate that they consume zooplanktonic organisms, since they putatively act as intermediate and/or paratenic hosts for parasites of fish, birds and marine mammals. The occurrence of copepods in the diet of *C. edentulus* had been observed before at the mangrove of Itacorubi, Santa Catarina by Clezar et al. (1993) and at the Itaipu lagoon, Niterói, Rio de Janeiro, by Gay et al. (2002), who concluded that *C. edentulus* is a primarily phytoplanktophagus species that has no selective feeding habits, ingesting whatever is available in the environment. This may explain why copepods were found in the diet of *C. edentulus*. The presence of larval stages in engraulid fish had already reported by Timi (2003) and Tavares et al. (2005) (see introduction for localities and hosts). According to them, this is not surprising, because the anchovies feed mainly on zooplanktonic organisms, which are known to act as intermediate and/or paratenic hosts for parasites of several piscivorous vertebrates. In addition, the dominance of larval endoparasites has been described for some parasite communities of marine fish from the coastal zone of southeastern Brazil (Paraguassú et al. 2002, Luque et al. 2002, 2003, Sabas and Luque 2003, Alves and Luque 2006, Soares et al. 2014).

The nematode *Hysterothylacium* sp. was the most abundant and dominant species of the parasitic fauna of *C. edentulus*. The larval stages of *Hysterothylacium* have been reported infecting more than 30 fish species off the coast of Brazil (Luque and Poulin 2004, Tavares and Luque 2006, Knoff et al. 2007, Luque et al. 2011, Moreira et al. 2015, Pantoja et al. 2016), including *Anchoa marinii* Hildebrand, 1943 and *A. tricolor* (Tavares et al. 2005, Tavares 2006) (Engraulidae). The prevalence and abundance of larvae was low (less than 10%) in the last two, in comparison to *C. edentulus* (40%). The significant presence of ascaridoid nematodes is a major concern to public health and fish marketing, because the third larval stage (L3) can be accidentally consumed by humans when they eat raw or poorly cooked fish and that may cause anisakiasis disease (Limbery and Cheah 2007). However, according to some authors, the pathogenic potential *Hysterothylacium* nematodes is still controversial, and their involvement in human pathologies is questionable (Yagi et al. 1996, Cavallero et al. 2020). Based on morphological examination, *Hysterothylacium* sp. in the present study is similar to the third stage of *Hysterothylacium* type V of Pantoja et al. (2016).

Five species of digenetic trematodes were found in the gastrointestinal system of *C. edentulus* in the present study. Two, *Lecithochirium microstomum* Chandler, 1935 and *P. merus*, are cosmopolitan species found in several species of actinopterygian fish around the world (Bray 1990, Braicovich and Timi 2008). In the South Atlantic Ocean, *P. merus* can be found in five engraulid fish, namely, *A. tricolor*, *Anchoa argentivittata* (Regan, 1904), *E. anchoita*, *Engraulis ringens* Jenyns, 1842 and *Lycengraulis grossidens* (Spix & Agassiz, 1829), while *L. microstomum* was found only in *E. anchoita* (Timi et al. 1999a, Kohn et al. 2007). However, only *P. merus* has been reported in other representatives of Engraulidae in different oceans, i.e., *Engraulis australis* (White, 1790) from Australia, *Engraulis capensis* Gilchrist, 1913 from South Africa, *Engraulis encrasicolus* (Linnaeus, 1758) from Europe and Africa, *Engraulis japonicus* Temminck & Schlegel, 1846 from Japan, *Engraulis mordax* Girard, 1854 from the United States and *Thryssa setirostris* (Broussonet, 1782) from China (Bray 1990, Timi et al. 1999b, Sailaja and Madhavi 2012). Thus, the present findings reaffirm the presence of hemiuroid digeneans in engraulid fish, now including *C. edentulus*.

In the present study two species of bomolochid copepods are recorded by the first-time parasitizing *C. edentulus*. One of these, *Nothobomolochus cresseyi* Timi & Sardella, 1997, was previously reported on two engraulid fish in the South Atlantic, i.e., *E. anchoita* from the littoral of Argentina and *A. marinii* from the littoral of Brazil (Timi 2003, Luque and Tavares 2007). On the other hand, *Neobomolochus elongatus* Cressey, 1981 has been reported only on the clupeid fish *Opisthonema oglinum* (Lesueur, 1818) from two different localities, first off the coast of Florida, littoral of USA and recently in the Sepetiba Bay, littoral of Brazil (Cressey 1981, Chaves and Paschoal 2021). Clupeiformes is one of the major orders of fish, with seven families, 92 genera, and about 405 species (Nelson et al. 2016, Froese and Pauly 2021). In the Sepetiba Bay this order is represented by the families Clupeidae and Eugraulidae, each with four species. They form large schools that overlap spatially and can be mixed schools (Araujo et al. 1998, Silva and Araujo 2000, Paiva and Pereira 2003). According to Tavares and Luque (2004), the aggregated habits and high population density of some hosts may facilitate the transmission of some ectoparasites with a direct life cycle, such as copepods and monogeneans. Thus, it is reasonable to consider the possible flux of ectoparasites between these clupeiform host species. The present study records for the first time the copepod *N. elongatus* parasitizing a representative of Engraulidae.

The monogenean *Pseudanthocotyloides heterocotyle* presented the highest prevalence among the metazoan parasites collected in *C. edentulus* in this study. This parasite has been previously recorded in Brazil parasitizing the gills of *C. edentulus*. One specimen was found on the carangid fish *Decapterus punctatus* (Cuvier, 1829). Both records are from the coast of the state of Rio de Janeiro (Kohn et al. 1992). Despite the record in a representative of the Carangidae, this species apparently prefers Clupeiform fish, e.g. the clupeids *Clupea harengus* Linnaeus, 1758 and *Sprattus sprattus* (Linnaeus, 1758) (type host), and the engraulids *A. marini*, *C. edentulus*, *E. anchoita*, *E. encrasicolus* and *E. ringens* being distributed in the Mediterranean Sea; North Sea, east and west coast of Scotland, west coast of Sweden; coasts of Argentina, Brazil, Chile and Uruguay (Euzet and Prost 1969, Mamaev 1982, Kohn et al. 1992, Groenewald et al. 1996, Longshaw 1996, Timi et al. 1999b, Rahimian 1999, Valdivia et al. 2007). *Cribomazocraes travassosi* Santos & Kohn, 1992 was also collected from the gills of *C. edentulus* in the present study, but it was much less prevalent (2%) than *P. heterocotyle*. This species was first described by Santos and Kohn (1992) from the gills of *Harengula clupeola* (Cuvier, 1829) and later it was reported by Moreira et al. (2015) in *Sardinella brasiliensis* (Steindachner, 1879), both Clupeid fish from from the coast of Rio de Janeiro. Species of monogeneans are known to be specific to a single host species, a genus, a family, or even an order (see Whittington et al. 2000). Considering that the clupeiform fish occur in mixed schools at Sepetiba Bay (see the previous paragraph), the presence of *C. travassosi* on the studied fish is possible. This study records *C. travassosi* for the first time parasitizing a representative of Engraulidae.

Studies on the biology of *C. edentulus* revealed that sexual maturation in both sexes usually occurs when individuals reach 11 to 20 cm (Silva et al. 2003, Souza-Conceição et al. 2005). For Fréon and Misund (1999), the approximation of growth percentages in certain fish species is an adaptive strategy, especially in fish that that form large schools. In the present study, the correlation between the sex of *C. edentulus* and the abundance and prevalence of the larval nematode *Hysterothylacium* sp. were unexpected because the specimens of the Atlantic anchoveta studied were adults, and no significantly differences were detected between the size of males and females. According to Poulin (1996), factors such as female gonadal hormones, immune system competence and even pregnancy can increase the female's susceptibility to parasites and pathogens. Thus, territoriality, movement patterns, social interactions and diet can influence the exposure to infectious stages of the parasites (Poulin 1996). Positive correlations between the sex of the host and the infection levels of some components of the parasite communities were also detected in other Brazilian marine fish and suggest ecological and/or behavioral differences between host sexes (Luque et al. 1996, Knoff et al. 1997, Alves and Luque 2001, Tavares et al. 2005).

Comparing the parasite species richness (at component community level) of the engraulid fish studied so far in the southern Atlantic Ocean, *E. anchoita* (n = 13) (Timi 2003) has a greater number of parasite species than *C. edentulus* (N=11) (present study), and *A. tricolor* (n = 10) (Tavares et al. 2005). The greater number of parasite species in *E. anchoita* may result from the fact that this host has been extensively studied in Argentina. There have been studies of population stocks using parasites as indicators, and studies to model predictability for other parasite communities (Timi 2003, Timi and Poulin 2003). In contrast, the focus of the studies on *A. marini* and *C. edentulus* had a regional focus. Some characteristics, such as the presence of larval stages, mean infracommunity richness and total parasite prevalence, seem to be similar in these engraulid hosts, although their infracommunities vary in species composition, since only the digenean *P. merus*, a parasite with a wide spectrum of fish hosts in the South Atlantic, has been recorded in the three hosts. Among the ectoparasites, the copepod *N. cresseyi* and the monogenean *P. heterocotyle* have been recorded in *E. anchoita* and *C. edentulus*.

All metazoan parasites found in *C. edentulus* had the aggregated spatial distribution pattern, which is a common distribution pattern for parasites in marine fish (Rohde 2005, Iannacone et al. 2010, Amarante et al. 2015). According to Poulin (2013), aggregated distributions among individual hosts are a defining feature of metazoan parasite populations and the main explanations for that are the variations in how much individual hosts are exposed, and their susceptibility to infection.

*Cetengraulis edentulus* showed a lack of pairs of associated parasite species, a pattern that according to Rohde et al. (1995), is common to most marine fish studied. According to Poulin (2001), positive and negative associations between helminth species can provide strong evidence that species interactions exist and act on community structure. But it is also discussed that interspecific relationships can only be considered valid when tested under experimental conditions (Rohde et al. 1995, Poulin 2001, Chaves and Paschoal 2021).

## ACKNOWLEDGMENTS

Luana Cristina da Silva Benicio was supported by a student fellowship from Universidade Castelo Branco, Rio de Janeiro (Brazil). Fabiano Paschoal was supported in part by Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão (FAPEMA, process 84516/2022).

## LITERATURE CITED

Alves DR, Luque JL (2001) Community ecology of the metazoan parasites of the white croaker *Micropogonias furnieri* (Osteichthyes: Sciaenidae) from the coastal zone of the State of Rio de Janeiro, Brazil. Memórias do Instituto Oswaldo Cruz 96(2): 145–153. https://doi.org/10.1590/S0074-02762001000200002

Alves DR, Luque JL (2006) Ecologia das comunidades de metazoários parasitos de cinco espécies de escombrídeos (Perciformes: Scombridae) do litoral do estado do Rio de Janeiro, Brasil. Revista Brasileira de Parasitologia Veterinária 15(4): 167–181.

Amarante CF, Tassinari WS, Luque JL, Pereira MJS (2015) Factors associated with parasite aggregation levels in fishes from Brazil. Brazilian Journal of Veterinary Parasitology 24(2):174–182. https://doi.org/10.1590/S1984-29612015031

Araújo DF, Peres LGM, Yepez S, Mulholland DS, Machado W, Tonhá M, Garnier J (2017) Assessing man-induced environmental changes in the Sepetiba Bay (Southeastern Brazil) with geochemical and satellite data. Comptes Rendus Geoscience 349(6–7): 290–298. https://doi.org/10.1016/j.crte.2017.09.007

Araújo FG, Cruz-Filho AGD, Azevêdo MCCD, Santos ACAS (1998) Estrutura da comunidade de peixes demersais da baía de Sepetiba, RJ. Brazilian Jounal Biology 58(3): 417–430. https://doi.org/10.1590/S0034-71081998000300007

Braicovich PE, Timi JT (2008) Parasites as biological tags for stock discrimination of the Brazilian flathead *Percophis brasiliensis* in the south-west Atlantic. Journal of Fish Biology 73(3): 557–571. https://doi.org/10.1017/s0031182016001050

Bray RA (1990) A review of the genus *Parahemiurus* Vaz and Pereira, 1930 (Digenea: Hemiuridae). Systematic Parasitology 15: 1–21. https://doi.org/10.1007/BF00009914

Bush AO, Lafferty KD, Lotz JM, 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. PMid:9267395

Cavallero S, Lombardo F, Salvemini M, Pizzarelli A, Cantacessi C, D'Amelio S (2020) Comparative Transcriptomics Reveals Clues for Differences in Pathogenicity between *Hysterothylacium aduncum*, *Anisakis simplex* sensu stricto and *Anisakis pegreffii*. Genes 11(3): 321. https://doi.org/10.3390/genes11030321

Chaves L, Paschoal F (2021) Community ecology of the metazoan parasites of the Atlantic thread herring, *Opisthonema oglinum* (Lesueur, 1818) (Actinopterygii: Clupeidae) from the Sepetiba Bay, Rio de Janeiro, Brazil. Brazilian Journal of Biology 81(2): 418–23. https://doi.org/10.1590/1519-6984.229814

Clezar L, Hostim SM, Ribeiro GC, Ledo BSD (1993) Abundance and distribution of *Cetengraulis edentulus* (Cuvier, 1828) (Clupeiformes-Engraulididae) of the Itacorubi Mangrove, SC, Brazil. Brazilian Archives of Biology Technology 36(3): 567–576.

Cressey RF (1981) Parasitic copepods from the Gulf of Mexico and Caribbean Sea, I: *Holobomolochus* and *Neobomolochus*. Smithsonian Contributions to Zoology 339: 1–24. https://doi.org/10.5479/si.00810282.339.i

Eiras JC, Takemoto RM, Pavanelli GC (2006) Métodos de estudo e técnicas laboratoriais em parasitologia. Eduem, Maringá, 2nd ed., 199 pp.

Euzet L, Prost M (1969) *Pseudanthocotyloides heterocotyle* (van Beneden, 1871) (Monogenea: Polyopisthocotylea), parasite de *Clupea sprattus* (L.) en Méditerranée. Revision anatomique et position systématique. Acta Parasitology Pol 17: 109–114.

Figueiredo JL, Menezes NA (1978) Manual de peixes marinhos do sudeste do Brasil II. Teleostei (1). Museu de Zoologia, São Paulo, 113 pp.

Fréon P, Missund AO (1999) Dynamics of pelagic fish distribution and behaviour: Effects on fisheries and stock assessment. Blackwell Science, Oxford, 365 pp.

Froese R, Pauly D (2021) FishBase. World Wide Web electronic publication, v. 08.2021, https://www.fishbase.org/search.php [Accessed: 02/11/2021]

Gay DOTI, Bassani C, Sergipense S (2002) Diel variation and selectivity in the diet of *Cetengraulis edentulus* (Cuvier 1828) (Engraulidae-Clupeiformes) in the Itaipu Lagoon, Niterói, Rio de Janeiro. Atlântica 24(2): 59–68.

Groenewold S, Berghahn R, Zander CD (1996) Parasite communities of four fish species in the Wadden Sea and the role of fish discarded by the shrimp fisheries in parasite transmission. Helgol Meeresunters 50(1): 69–85. https://doi.org/10.1007/bf02367137

Iannacone J, Moron L, Guizado S (2010) Between-year variation of metazoan parasite fauna on *Sciaena deliciosa* (Tschudi, 1846) (Perciformes: Sciaenidae) in Lima, Peru. Latin American Journal of Aquatic Research 38(2): 218–226.

Knoff M, Luque JL, Amato JF (1997) Community ecology of the metazoan parasites of grey mullets, *Mugil platanus* (Osteichthyes: Mugilidae) from the littoral of the state of Rio de Janeiro, Brazil. Revista Brasileira de Biologia 57(3): 441–454.

Knoff M, São Clemente SC, Fonseca MCG, Andrada CG, Padovani RS, Gomes DR (2007) Anisakidae parasitos de congro-rosa, *Genypterus brasiliensis Regan*, 1903 comercializados no estado do Rio de Janeiro, Brasil de interesse na saúde pública. Parasitologia latinoamericana 62(3–4): 127–133. https://doi.org/10.4067/S0717-77122007000200005

Kohn A, Santos CP, Baptista Farias MFD (1992) New host records and localities of some Monogenea from brazilian marine fishes with scanning electron microscopy of *Bicotylophora trachinoti* (Mac Callum, 1921). Mem*órias* do Instituto Oswaldo Cruz 87(1): 109–14. https://doi.org/10.1590/s0074-02761992000500023

Kohn A, Fernandes BMM, Cohen SC (2007) South American trematodes parasites of fishes. Imprinta Express, Rio de Janeiro, 318 pp.

Longshaw M (1996) Mortality of captive herring, *Clupea harengus* L. (Teleostei: Clupeidae) due to *Pseudanthocotyloides heterocotyle* (van Beneden, 1871) (Monogenea: Polyopisthocotylea: Mazocraeidae). Bulletin European Association Fish of Pathologists 16(4): 143–144.

Luque JL, Poulin R (2004) Use of fish as intermediate hosts by helminth parasites. Acta Parasitologica 49(4): 353–361.

Luque JL, Tavares LER (2007) Checklist of Copepoda associated with fishes from Brazil. Zootaxa 1579(1): 1–39. https://doi.org/10.11646/zootaxa.1579.1.1

Luque JL, Amato JFR, Takemoto RM (1996) Comparative analysis of the communities of metazoan parasites of *Orthopristis ruber* and *Haemulon steindachneri* (Osteichthyes: Haemulidae) from the southeastern Brazilian littoral: I. structure and influence of the size and sex of hosts. Brazilian Journal of Biology 56(2): 279–292.

Luque JL, Porrozzi F, Alves DR (2002) Community ecology of the metazoan parasites of Argentine Goatfish, *Mullus argentinae* (Osteichthyes: Mullidae) from the coastal zone of the State of Rio de Janeiro, Brazil. Revista Brasileira de Parasitologia Veterinária 11(1): 33–38.

Luque JL, Alves DR, Ribeiro RS (2003) Community ecology of the metazoan parasites of Banded Croaker, *Paralonchurus brasiliensis* (Osteichthyes: Sciaenidae), from the coastal zone of the State of Rio de Janeiro, Brazil. Acta Scientiarum 25(2): 273–278.

Luque JL, Aguiar JC, Vieira FM, Gibson DI, Santos CP (2011) Checklist of Nematoda associated with the fishes of Brazil. Zootaxa 3082(1): 1–88. https://doi.org/10.11646/zootaxa.3082.1.1

Luque JL, Vieira FM, Takemoto RM, Pavanelli GC, Eiras JC (2013) Checklist of Crustacea parasitizing fishes from Brazil. Check List 9(6): 1449–1470. https://doi.org/10.15560/9.6.1449

Lymbery AJ, Cheah FY (2007) Anisakid nematodes and anisakiasis. In: Murrell KD, Fried B (Eds) Food-borne parasitic zoonoses. Springer, Boston, 185–207. https://doi.org/10.1007/978-0-387-71358-8_5

Mamaev YL (1982) Notes on the systematics of mazocraeid monogeneans with a redescription of some poorly studied taxa. Helminthologia 19(1): 25–38.

Monfort KCF, Fujimoto RY, de Almeida Varella JE, Guimarães MDF, dos Santos AFL, Diniz DG, Pires MAB (2009) Ocorrência de *Livoneca desterroensis* (Isopoda, Cymothoidae), parasita de sardinha – *Cetengraulis edentulus* (Cuvier, 1828) (Engraulidae, Clupeiforme), capturadas na região do nordeste Paraense, Brasil. Boletim do Instituto de Pesca 35(4): 657–662.

Moreira J, Paschoal F, Cezar AD, Luque JL (2015) Community ecology of the metazoan parasites of Brazilian sardinella, *Sardinella brasiliensis* (Steindachner, 1879) (Actinopterygii: Clupeidae) from the coastal zone of the State of Rio de Janeiro, Brazil. Brazilian Journal of Biology 75(3): 736–741. https://doi.org/10.1590/1519-6984.00114

Nelson JS, Grande TC, Wilson M (2016) Fishes of the World. John Wiley & Sons, Hoboken, 5th ed., 752 pp.

Paiva MP, Pereira RC (2003) Pescarias de sardinhas e manjubas ao longo da costa atlântica das Américas (1980-1999). Boletim Técnico Científico do CEPNOR 3(1): 229–233.

Pantoja CS, Pereira FB, Santos CP, Luque JL (2016) Morphology and molecular characterization hold hands: clarifying the taxonomy of *Hysterothylacium* (Nematoda: Anisakidae) larval forms. Parasitology Research 115(11): 4353–4364. https://doi.org/10.1007/s00436-016-5221-0

Paraguassú AR, Luque JL, Alves DR (2002) Community ecology of metazoan parasites of red porgy *Pagrus pagrus* (Linnaeus, 1758) (Osteichthyes, Sparidae) from the coastal zone, State of Rio de Janeiro, Brazil. Acta Scientiarum 24(2): 461–467.

Pfeiffer WC, Lacerda LD, Fiszman M, Lima NRW (1985) Metais pesados no pescado da Baía de Sepetiba, Rio de Janeiro. Ciência e Cultura 37(2): 297–302.

Poulin R (1993) The disparity between observed and uniform distributions: a new look at parasite aggregation. International Journal for Parasitology 23(7): 937–944. https://doi.org/10.1016/0020-7519(93)90060-C. PMid:8106186

Poulin R (1996) Sexual inequalities in helminth infections: a cost of being a male? The American Naturalist 147(2): 287–295. https://doi.org/10.1086/285851

Poulin R (2001) Interactions between species and the structure of helminth communities. Parasitology 122(S1): S3–S11. https://doi.org/10.1017/S0031182000016991

Poulin R (2013) Explaining variability in parasite aggregation levels among host samples. Parasitology 140(4): 541–546. https://doi.org/10.1017/S0031182012002053

Rahimian H, Longshaw M, MacKenzie K, Thulin J (1999) *Pseudanthocotyloides heterocotyle* (van Beneden, 1871) Euzet & Prost, 1969 (Monogenea: Polyopisthocotylea: Mazocraeidae), a parasite of herring *Clupea harengus* L. and sprat *Sprattus sprattus* L. (Teleostei: Clupeidae). Systematic Parasitology 42(3): 193–201. https://doi.org/10.1023/a:1006042302301

Rohde K (2005) Marine Parasitology. CSIRO Publishing, Clayton, 592 pp.

Rohde K, Hayward C, Heap M (1995) Aspects of the ecology of metazoan ectoparasites of marine fishes. International Journal for Parasitology 25(8): 945–970. https://doi.org/10.1016/0020-7519(95)00015-t

Rózsa L, Reiczigel J, Majoros G (2000) Quantifying parasites in samples of hosts. Journal of Parasitology 86(2): 228–232. https://doi.org/10.2307/3284760

Sabas CS, Luque JL (2003) Metazoan parasites of weakfish, *Cynoscion guatucupa* and *Macrodon ancylodon* (Osteichthyes: Sciaenidae), from the coastal zone of the state of Rio de Janeiro, Brazil. Revista Brasileira de Parasitologia Veterinária 12(4): 171–178.

Sailaja B, Madhavi R (2012) *Thryssatrema hanumantharaoi* n. gen., n. sp. (Digenea: Fellodistomidae) from the longjaw thryssa, *Thryssa setirostris* (Clupeiformes: Engraulidae), of the Visakhapatnam coast, Bay of Bengal. Zootaxa 3551(1): 59. https://doi.org/10.11646/zootaxa.3551.1.4

Santos CP, Kohn A (1992) Desciption of *Cribomazocraes travassosi* n. sp. (Monogenea: Mazocraeidae), a fish parasite from the Atlantic Ocean. Memórias do Instituto Oswaldo Cruz 87: 247–250. https://doi.org/10.1590/s0074-02761992000500046

Santos S, Galvão K, Adler G, Andrade-Tubino M, Vianna M (2020) Spatiotemporal distribution and population biology aspects of *Cetengraulis edentulus* (Actinopterygii: Clupeiformes: Engraulidae) in a South-western Atlantic estuary, with notes on the local Clupeiformes community: Conservation implications. Acta Ichthyologica et Piscatoria 50(2): 139–50. https://doi.org/10.3750/aiep/02511

Sergipense S, Caramaschi EP, Sazima I (1999) Morfologia e hábitos alimentares de duas espécies de Engraulidae (Teleostei, Clupeiformes) na Baía de Sepetiba, Rio de Janeiro. Brazilian Journal of Oceanography 47(2): 173–188. https://doi.org/10.1590/s1413-77391999000200006

Silva MA, Araújo FG (2000) Distribution and relative abundance of anchovies (Clupeiformes-engraulididae) in the Sepetiba Bay, Rio de Janeiro, Brazil. Brazilian Archives of Biology and Technology 43(4): 379–385. https://doi.org/10.1590/s1516-89132000000400005

Silva MA, Araújo FG, Azevedo MCC, Mendonça P (2003) Distribuição espacial e temporal de *Cetengraulis edentulus* (Cuvier) (Actinopterygii, Engraulidae) na Baía de Sepetiba, Rio de Janeiro, Brasil. Revista Brasileira de Zoologia 20(4): 577–581. https://doi.org/10.1590/s0101-81752003000400003

Soares IA, Vieira FM, Luque JL (2014) Parasite community of *Pagrus pagrus* (Sparidae) from Rio de Janeiro, Brazil: evidence of temporal stability. Revista Brasileira Parasitologia Veterinária 23(2): 216–223. https://doi.org/10.1590/s1984-29612014047

Souza-Conceição JM, Rodrigues-Ribeiro M, Castro-Silva MA (2005) Dinâmica populacional, biologia reprodutiva e o ictioplâncton de *Cetengraulis edentulus* Cuvier (Pisces, Clupeiformes, Engraulidae) na enseada do Saco dos Limões, Florianópolis, Santa Catarina, Brasil. Revista Brasileira de Zoologia 22(4): 953–961. https://doi.org/10.1590/s0101-81752005000400023

Tavares LER (2006) Composição e estrutura das comunidades de metazoários parasitos de *Aspistor luniscutis* e *Genidens barbus* (Osteichthyes: Ariidae) e *Anchoa marinii* e *A. tricolor* (Osteichthyes: Engraulididae) do litoral do estado do Rio de Janeiro, Brasil. PhD Thesis, Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro, Brazil, 136 pp. Available online at: http://www.dominiopublico.gov.br/pesquisa/DetalheObraForm.do?select_action=&co_obra=24201

Tavares LER, Luque JL (2004) Community ecology of metazoan parasites of the later juvenile common snook *Centropomus undecimalis* (Osteichthyes: Centropomidae) from the coastal zone of the state of Rio de Janeiro, Brazil. Brazilian Journal of Biology 64(3): 523–529. https://doi.org/10.1590/s1519-69842004000300015

Tavares LER, Luque JL (2006) Sistemática, biologia e importância em saúde coletiva de larvas de Anisakidae (Nematoda, Ascaridoidea) parasitas de peixes ósseos marinhos do Estado do Rio de Janeiro, Brasil. In: Silva-Souza AT (Ed.) Sanidade de organismos aquáticos no Brasil. ABRAPOA, Maringá, 297–328.

Tavares LER, Luque JL, Bicudo AJA (2005) Community ecology of metazoan parasites of the anchovy *Anchoa tricolor* (Osteichthyes: Engraulidae) from the coastal zone of the state of Rio de Janeiro, Brazil. Brazilian Journal of Biology 65(3): 533–540. https://doi.org/10.1590/s1519-69842005000300019

Thatcher VE, Souza-Conceição JM, Jost GF (2003) *Lironeca desterroensis* sp. nov. (Isopoda, Cymothoidae) from the gills of a marine fish, *Cetengraulis edentulus* Cuvier, of Santa Catarina Island, Brazil. Revista Brasileira de Zoologia 20(2): 251–255. https://doi.org/10.1590/S0101-81752003000200013

Timi JT (2003) Parasites of Argentine anchovy in the southwest Atlantic: latitudinal patterns and their use for discrimination of host populations. Journal Fish of Biology 63(1): 90–107. https://doi.org/10.1046/j.1095-8649.2003.00131.x

Timi JT, Poulin R (2003) Parasite community structure within and across host populations of a marine pelagic fish: how repeatable is it? International Journal of Parasitology 33(12): 1353–1362. https://doi.org/10.1016/s0020-7519(03)00203-0

Timi JT, Martorelli SR, Sardella N (1999a) Digenetic trematodes parasitic on *Engraulis anchoita* (Pises: Engraulidae) from Argentina and Uruguay. Folia Parasitology 46(2): 132–138.

Timi JT, Sardella NH, Etchegoin JA (1999b) Mazocraeid Monogeneans Parasitic on Engraulid Fishes in the Southwest Atlantic. Journal of Parasitology 85(1): 28–32. https://doi.org/10.2307/3285695

Valdivia IM, Chávez RA, Oliva ME (2007) Metazoan parasites of *Engraulis ringens* as tools for stock discrimination along the Chilean coast. Journal Fish of Biology 70(5): 1504–1511. https://doi.org/10.1111/j.1095-8649.2007.01429.x

Vasconcellos M, Csirke J (2011) Southwest Atlantic. In: FAO (Ed.) Review of the state of world marine fishery resources. FAO, Rome, 93–106. http://www.fao.org/3/i2389e/i2389e.pdf

Vicente F, Loeb MV, Paiva ACG, Sampaio CLS, Argolo LA, Jacobina UP (2020) Integrative systematics unveils the controversial identity of Engraulidae fishing stocks in a Neotropical estuary, northeast Brazil. Neotropical Ichthyology 18(4): e200037. https://doi.org/10.1590/1982-0224-2020-0037

Whittington ID, Cribb BW, Hamwood TE, Halliday JA (2000) Host-specificity of monogenean (platyhelminth) parasites: a role for anterior adhesive areas? International Journal for Parasitology 30(3): 305–320. https://doi.org/10.1016/s0020-7519(00)00006-0

Yagi K, Nagasawa K, Ishikura H, Nakagawa A, Sato N, Kikuchi K, Ishikura H (1996) Female worm *Hysterothylacium aduncum* excreted from human: A case report. Journal of Parasitology 45: 12–23.

Zar JH (1996) Biostatistical analysis. Prentice-Hall/Pearson, Upper Saddle River, 3rd ed., 662 pp.

Submitted: November 8, 2021
Accepted: April 18, 2022
Editorial responsibility: Walter A.P. Boeger

**Author Contributions**

LB, JM and FP contributed equally to this article.

**Competing Interests**

The authors have declared that no competing interests exist.

**How to cite this article**

Benicio L, Moreira J, Paschoal F (2022) Community ecology of the metazoan parasites of the Atlantic anchoveta, *Cetengraulis edentulus* (Actinopterygii: Engraulidae) from the Sepetiba Bay, Rio de Janeiro, Brazil. Zoologia (Curitiba) 39: e21034. https://doi.org/10.1590/S1984-4689.v39.e21034

**Published by**

Sociedade Brasileira de Zoologia at Scientific Electronic Library Online (https://www.scielo.br/zool)