**FISH PARASITOLOGY - ORIGINAL PAPER**

# Parasite assemblages of whitemouth croaker, *Micropogonias furnieri*: comparison between marine and brackish waters from the Argentine Sea

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## Abstract

The whitemouth croaker, *Micropogonias furnieri*, a coastal demersal fish with wide distribution in the Southwest Atlantic Ocean, is a euryhaline species, inhabiting waters with a wide range in salinity. Here, the composition of parasite assemblages of *M. furnieri* caught along the coastal area off Mar del Plata, Argentina, was described and the infracommunity structure compared with fish from brackish waters to determine variations of its parasite communities due to fish migration between these environments. The relationships between the presence of parasites and the diet and ecological traits of this fish host were discussed. A total of 61 fish from Mar del Plata (MDP) were examined for parasites and compared with previously published data for whitemouth croakers from Mar Chiquita coastal lagoon (MCH), an estuarine system connected to the sea. *Corynosoma australe*, *Dichelyne sciaenidicola*, and *Neopterinotrematoides avaginata* were the most prevalent and abundant species in MDP. Comparisons of infracommunity descriptors showed that fish from MDP harbored a higher number of parasites, as well as richer and more diverse infracommunities than those of MCH. Significant differences occurred in the structure and composition of parasite assemblages of whitemouth croaker from MDP compared to those from MCH, in which *Neomacrovalvitrema argentinensis*, *N. avaginata*, *Neobrachiella chevreuxii*, *D. sciaenidicola*, and *C. australe* were the key discriminating species related to these differences. The present study provides comparative data, of great importance for the understanding of parasite-host-environment interactions, particularly in a host that alternates between brackish and marine waters during its life cycle.

**Keywords** Parasite ecology · Fishes · Sciaenidae · Community structure · Argentine Sea

## Introduction

The whitemouth croaker, *Micropogonias furnieri* (Desmarest, 1823), is a coastal demersal species, with wide distribution in the Southwest Atlantic Ocean, from Gulf of Mexico (20° 20′N) to San Jorge Gulf (47° 00′S) in Argentina (Sánchez et al. 1991; Cousseau and Perrota 2013). This

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species is an important euryhaline estuarine-dependent sciaenid, inhabiting waters with a wide salinity range. It is an important component of commercial and recreational fisheries of the coastal and estuarine areas in the southwestern Atlantic (Jaureguizar et al. 2003). In Argentina, it occurs in estuaries and coastal lagoons, which are variable and lower salinity systems, and in marine areas, with homogenous and higher salinity environments. The highest concentration of this resource is located in the Río de la Plata estuary, north to Mar del Plata, while toward the south, it also reaches significant concentrations in a zone known as El Rincón estuary (Acha et al. 2004; Carozza et al. 2004; Lucas et al. 2005).

In Argentina, *M. furnieri* is exploited by different types of fishing operations, using different fishing strategies, resulting in variable impact on this natural resource during some periods of the year. This fish is also included in a fishing practice known as "variado costero", which is based on the exploitation of different fish species as a single resource,

disregarding population dynamics of each species (Carozza et al. 2004). The most important landing ports for *M. furnieri* are found in the Buenos Aires Province, where in the port of Mar del Plata the species accounts for 65% of the total annual catch (Carozza et al. 2000). Therefore, studies regarding this fish are important, especially for the application of policies for the specific assessment methods or fishery management plans.

Whitemouth croakers have generalist-opportunistic trophic behavior, feeding mainly on benthic organisms (polychaetes, bivalves, snails, shrimp, and small crustaceans) (Martins and Haimovici 2020) and occasionally on small fish, such as anchovy (Cousseau and Perrota 2013). Juveniles often leave the open sea and enter streams and estuaries and have been found in estuarine environments in Buenos Aires Province, inhabiting shallow waters with low levels of salinity, along with adult whitemouth croakers (Sánchez et al. 1991; Jaureguizar et al. 2003, 2008). Thus, *M. furnieri* uses the World Reserve of Biosphere Mar Chiquita, a coastal lagoon, located in Buenos Aires Province, as a nursery and feeding area, where small-scale fishing is carried out by commercial fishermen year-round (Hozbor and García de la Rosa 2000; Cousseau et al. 2001).

Estuaries are transitional environments, especially regarding water salinity and temperature, two of the main factors affecting the distribution and abundance of marine parasites (Rohde 1992; Zander 2004). Therefore, changes in environmental conditions are expected to influence the composition of parasite communities of fish inhabiting (or visiting) estuarine waters. Previous parasite records in *M. furnieri* from Argentina included monogeneans, digeneans, nematodes, and trichodinid ciliophorans (Martorelli et al. 2007, 2013; Marcotegui and Martorelli 2009; Timi et al. 2009; Montes et al. 2016). However, studies of quantitative aspects of the parasite communities of *M. furnieri* from Mar del Plata coastal area, Bahía Samborombón, and Mar Chiquita coastal lagoon (Sardella et al. 1995; Alarcos and Etchegoin 2010) have not been used to date for comparing the structure of parasite assemblages. Therefore, the aim of this study was to describe the composition and structure of the parasite assemblages of the whitemouth croaker, inhabiting a marine environment in the Mar del Plata coastal area, to evaluate variations in the parasite communities due to fish migration between the marine-brackish water transition zones, as

well as to evaluate the relationships between the presence of parasites and the diet and ecological traits of this fish host.

## Materials and methods

### Fish and parasite sampling

Sixty-one specimens of *M. furnieri* were caught by commercial trawlers, 30 miles off the coast of Mar del Plata city (MDP), Buenos Aires Province, Argentina, in March 2007. Fish were either kept fresh or deep frozen at − 18 °C until examination. Whitemouth croakers were measured for total length (TL, mm). Body surface, gills, branchial and body cavities, viscera (stomach, intestine, heart, gonads, and mesenteries), swim bladder, and musculature were examined using a stereomicroscope and metazoan parasites were collected and preserved according to standardized protocols (Pritchard and Kruse 1982; Berland 1984).

In order to compare changes in parasite communities between whitemouth croakers inhabiting the marine coast and those moving into brackish area, previously published data from Mar Chiquita coastal lagoon (MCH) were included in the analysis (Alarcos and Etchegoin 2010). Data related to the 88 hosts analyzed in the present study, along with information on sampling areas, are presented in Table 1 and Fig. 1.

### General quantitative analysis of parasites

The prevalence (P) (the number of fish infected divided by the number of fish examined, expressed as a percentage) and mean abundance (MA) (number of parasite found in any fish, divided by the total number of hosts, infected or not) (Bush et al. 1997) were calculated for each parasite species at each sampling site. Sterne's exact 95% confidence limits, with 95% bootstrap confidence intervals, were calculated for P and MA using Quantitative Parasitology 3.0 software (QP3.0) (Rózsa et al. 2000; Reiczigel et al., 2019).

### Similarity analysis at infracommunity level

Comparative analyses were performed including the raw data by Alarcos and Etchegoin 2010 (N = 27, see

**Table 1** Location and composition of the samples of whitemouth croakers, *Micropogonias furnieri*, from two regions of the Argentine Sea. TL, total length

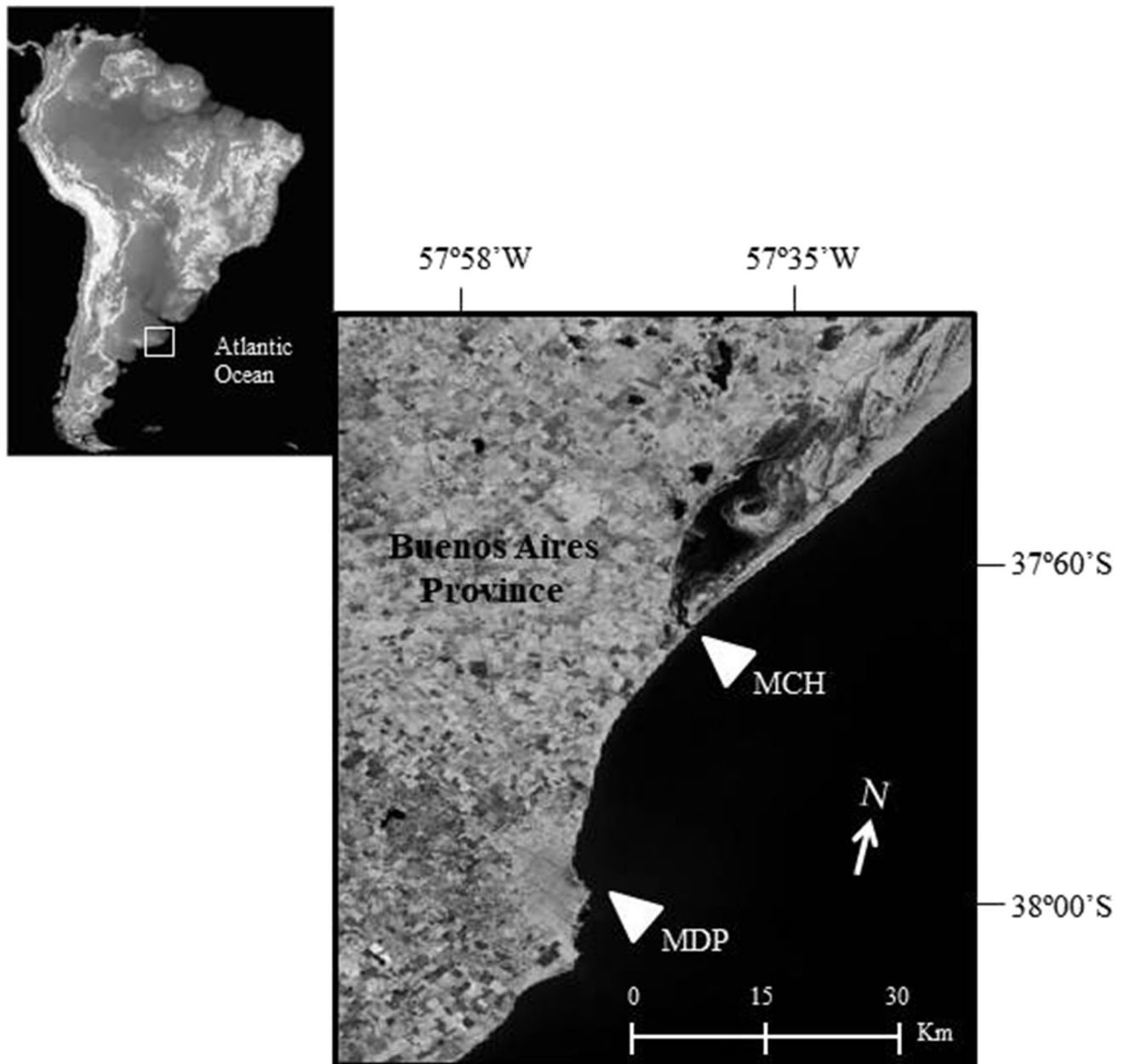| Locality | Capture coordinates | Date of capture | TL mean ± S.D. (range) (mm) | N | Source |
|---|---|---|---|---|---|
| Mar del Plata (MDP) | 38°08′S; 57°32′W | March 2007 | 491.3 ± 64.6 (380–635) | 61 | Present study |
| Mar Chiquita (MCH) | 37°46′S; 57°27′W | January–February 2005 April–May 2006 | 401.5 ± 99.6 (305–628) | 27 | Alarcos and Etchegoin 2010 |

**Fig. 1** Location of sampling areas in Buenos Aires Province, Argentina: Mar Chiquita coastal lagoon (MCH) and Mar del Plata coastal area (MDP)

Table 1) and a subsample of fish from MDP ($N = 30$; TL mean [range] = 439.7 [380–480]) from the present study, selected so that TL of fish from MDP were comparable to those from MCH. At the infracommunity level, the following community descriptors were calculated: total abundance (the number of parasites per host, N), species richness (S), and Brillouin's index of diversity (HB) (because each infracommunity was fully censused) for each individual fish harboring two or more parasites species (Magurran 1988). The potential relationship of the infracommunity

indices (N, S, and HB) to host size was tested by mean of Spearman's rank correlation (Zar 1999).

Given the variability of the samples in relation to year of capture and fish length, we expected that a considerable proportion of the observed differences in parasite abundance would be explained by these factors. Consequently, multivariate analyses were conducted using both Bray–Curtis index (based on abundances) and Jaccard index (based on presence/absence) data to diminish the effect of year of capture and host length on parasite loads, allowing the

location effects to be more evident. The total length of fish was compared across the sites by Mann–Whitney rank sum test because the test for normality (Kolmogorov–Smirnov test) failed ($P > 0.05$).

The differences in infracommunity composition between samples were tested by 1-way permutational multivariate analysis of variance (PERMANOVA) using the abundance values for all the identified parasite species. Following Anderson et al. (2008), a permutation of residuals with a reduced model was used as the method of permutation. A sequential sum of squares (Type I SS) was applied because host size was introduced as a covariable (ANCOVA model) and the samples were unbalanced (different numbers of fish examined by sample). The differences in infracommunity composition between sites were tested, using a $1 \times 2$ factorial design, with "locality" as the fixed factor. The TL was included as a covariate. Differences in community structure between localities were tested using Bray–Curtis (abundances) and Jaccard (presence/absence) (Magurran 1988) indices as similarity measurements, respectively, for all identified parasite species.

Nonparametric statistics based on the Bray–Curtis and the Jaccard similarity matrices were calculated using parasite abundance between all possible pairs of hosts (infracommunities) in PERMANOVA + package implemented in PRIMER V6 (Clarke and Gorley 2006; Anderson et al. 2008). The Bray–Curtis index was used as a measure of dissimilarity on square-root-transformed data to decrease the weight of common species relative to rare species in the index. As PERMANOVA is sensitive to differences in multivariate dispersion between groups, the same models were tested for differences in dispersion using the routine PERMDISP (Anderson et al. 2008). Dispersion was measured as the distance to the centroids.

Nonmetric multidimensional scaling (nMDS) (Clarke and Gorley 2006) was performed to obtain a graphical ordination of patterns in the composition of parasite assemblages across the two locations. MDS was conducted using the Bray–Curtis and Jaccard similarity indices at the infracommunity level. The fit of the nMDS ordinations was quantified by a value of stress.

## Results

### General quantitative analysis of parasites

A total of 6722 parasites were quantified from MDP. Each whitemouth croaker was parasitized by at least three of 14 metazoan parasite species (3 Nematoda, 2 Acanthocephala, 2 Monogenea, 2 Digenea, 1 Aspidobothrea, 2 Cestoda, and 2 Copepoda) (Table 2). The acanthocephalan *Corynosoma australe*, the nematode *Dichelyne sciaenidicola*, and the

monogenean *Neopterinotrematoides avaginata* were the most prevalent and abundant species, representing together 90.87% of all the parasites recovered (75.66%, 8.09%, and 7.12%, respectively).

The fish from MDP harbored similar percentages of adult and larval stages of parasite species, representing 57.1% and 42.9% of the parasite richness, respectively (Table 2). The maximum infracommunity species richness (eight species) was found in only one fish from MDP.

### Similarity analysis at infracommunity level

When the subsamples from MDP and MCH were analyzed, significant differences were observed for all infracommunity indices, regarding richness ($H_1 = 18.893$, $P < 0.01$), total number of parasites ($H_1 = 23.352$, $P < 0.01$), and Brillouin's index of diversity ($H_1 = 9.957$, $P < 0.01$), for those hosts harboring one or more parasite species. Parasite abundance, species richness, and Brillouin's index were higher in MDP (Fig. 2). Diversity, species richness, and number of parasites increased significantly with the host length ($r^2 = 0.30$, $r^2 = 0.37$, and $r^2 = 0.44$, for fish from MDP and $r^2 = 0.32$, $r^2 = 0.31$, and $r^2 = 0.29$ for fish from MCH all $P < 0.01$, respectively).

Significant differences in fish TL were found, in which whitemouth croakers from MCH were smaller than those from MDP (Mann–Whitney $U$ test, $U = 557$, $P < 0.01$). PERMANOVA analyses on both Bray–Curtis (abundance) and Jaccard (presence/absence) of parasites of *M. furnieri* (Table 3) showed an effect of host TL on infracommunity structure and composition, although no interaction between host TL and the locality was observed (Table 3). Significant variability was detected between localities after considering the variations among samples due to host TL ($P_{(perm)} < 0.01$). A proportion of these differences can be attributed to differences in the multivariate dispersions of parasite infracommunities measured by their deviations from centroids because the PERMDISP results were significant for both the Bray–Curtis and Jaccard indices ($F_{1, 54} = 32.356$, and $F_{1, 54} = 25.288$, respectively, all $P_{(perm)} < 0.01$).

The nMDS ordination plot based on the Bray–Curtis index (abundances) (Fig. 3a) and Jaccard index (presence/absence) (Fig. 3b) showed a separation of the parasite assemblages, where the sample from MDP formed a distinct group from that of MCH, the latter being more dispersed. However, higher overlap of MCH and MDP was observed in the plot based on Jaccard index data (Fig. 3b). A relatively good fit was accomplished through these ordinations as the stress value was 0.14 for Bray–Curtis and 0.12 for Jaccard. The parasites that most contributed ($r > 0.4$) to this separation were the most abundant and prevalent species. Abundances of *Neomacrovalvitrema argentinensis*, *N. avaginata*, *Neobrachiella chevreuxii*, *D.*

**Table 2** Prevalence (P), mean abundance (MA), and site of infection of parasites of *Micropogonias furnieri*, from two regions of the Argentine Sea (MDP, Mar del Plata coastal area; MCH, Mar Chiquita coastal lagoon). The P and MA include 95% bootstrap confidence interval (BCI). $BCI_{inf}$, low limit; $BCI_{up}$, upper limit. Sterne's exact method up to N = 1000. Number of bootstrap replications = 2000. (l) larva, (a) adult

| Parasite species | Site of infection | MDP | | MCH | |
|---|---|---|---|---|---|
| | | P | MA ($BCI_{inf}$—$BCI_{up}$) | P | MA ($BCI_{inf}$ -$BCI_{up}$) |
| Nematoda | | | | | |
| *Dichelyne sciaenidicola* (a) | Intestine | 96.7 (88.77–99.41) | 8.92 (6.82–12.21) | 81.5 (63.12–92.40) | 12.30 (4.96–33.44) |
| *Ascarophis marina* (a) | Intestine | 0.00 | 0.00 | 3.70 (0.19–18.12) | 0.04 (0.00–0.11) |
| *Anisakis* sp. (l) | Body cavity | 0.00 | 0.00 | 3.70 (0.19–18.12) | 0.04 (0.00–0.11) |
| *Lappetascaris* sp. (l) | Intestine | 0.00 | 0.00 | 3.70 (0.19–18.12) | 0.04 (0.00–0.11) |
| *Hysterothylacium* sp. (l) | Body cavity | 1.60 (0.09–8.73) | 0.02 (0.00–0.05) | 3.70 (0.19–18.12) | 0.04 (0.00–0.11) |
| *Hysterothylacium aduncum* (l) | Intestine | 6.60 (2.28–16.13) | 0.11 (0.02–0.31) | 0.00 | 0.00 |
| *Terranova* sp. (l) | Body cavity | 0.00 | 0.00 | 3.70 (0.19–18.12) | 0.04 (0.00–0.11) |
| Acanthocephala | | | | | |
| *Profilicollis chasmagnathi* (l) | Body cavity/intestine | 0.00 | 0.00 | 29.60 (14.77–50.00) | 3.30 (1.33–7.07) |
| *Corynosoma australe* (l) | Body cavity | 93.40 (83.87–97.72) | 83.38 (63.67–111.48) | 18.50 (7.60–36.88) | 1.63 (0.41–4.59) |
| *Corynosoma cetaceum* (l) | Body cavity | 9.80 (4.38–20.28) | 0.30 (0.11–0.59) | 3.70 (0.19–18.12) | 0.26 (0.00–0.78) |
| Monogenea | | | | | |
| *Neomacrovalvitrema argentinensis* (a) | Gills | 59.00 (45.88–70.60) | 3.72 (2.44–6.33) | 29.60 (14.77–50.00) | 0.78 (0.30–1.67) |
| *Neopterinotrematoies avaginata* (a) | Gills | 88.50 (78.03–94.49) | 7.85 (6.34–9.56) | 18.50 (7.60–36.88) | 1.19 (0.19–4.78) |
| Digenea | | | | | |
| *Lecitochirium microstomum* (a) | Stomach | 2.89 (0.52–9.93) | 0.26 (0.00–1.03) | 0.00 | 0.00 |
| *Pachycreadium gastrocotylum* (a) | Stomach/intestine | 26.20 (16.14–38.46) | 4.77 (2.02–11.46) | 3.70 (0.19–18.12) | 0.04 (0.00–0.11) |
| Aspidogastrea | | | | | |
| *Lobatostoma ringens* (a) | Intestine | 21.73 (12.50–3350) | 0.54 (0.23–1.31) | 7.40 (1.34–23.70) | 0.11 (0.00–0.33) |
| Cestoda | | | | | |
| *Pterobothrium* cf. *heteracanthum* (l) | Body cavity | 0.00 | 0.00 | 3.70 (0.19–18.12) | 0.04 (0.00–0.11) |
| *Scolex polymorphus* (l) | Intestine | 3.30 (0.59–11.23) | 0.11 (0.00–0.39) | 0.00 | 0.00 |
| *Callitetrarhynchus* cf. *gracilis* (l) | Body cavity | 3.30 (0.59–11.23) | 0.03 (0.00–0.08) | 0.00 | 0.00 |
| Copepoda | | | | | |
| *Clavellotis* sp. (a) | Gills | 6.60 (2.28–16.13) | 0.18 (0.03–0.62) | 3.70 (0.19–18.12) | 0.78 (0.00–2.33) |
| *Neobrachiella chevreuxii* (a) | Gills | 13.10 (6.15–24.39) | 0.25 (0.10–0.49) | 3.70 (0.19–18.12) | 0.11 (0.00–0.33) |

*sciaenidicola*, and *C. australe* were related to MDP samples, while *Profilicollis chasmagnathi* was the only species associated to MCH samples (Fig. 3a). A similar pattern was observed when the Jaccard index was applied, except that *D. sciaenidicola* was not important in the sample from MDP (Fig. 3b). When host TL was overlaid as an explanatory variable, it was evident that this variable contributed to the observed distribution pattern of samples (Fig. 3).

## Discussion

Studies on parasites of *M. furnieri* from the Argentine coastal zone are mainly descriptive (Suriano 1966; Rohde et al. 1995; Sardella et al. 1995; Timi et al. 2009), although Alarcos and Etchegoin (2010) analyzed the influence of the brackish environment on the parasite species composition
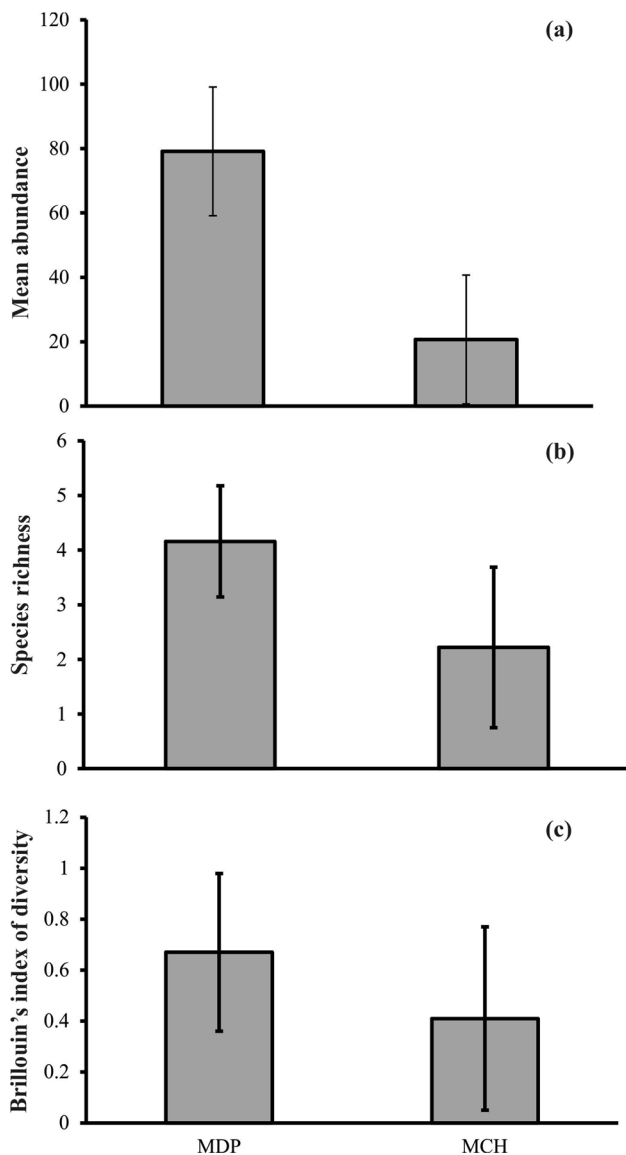
**Fig. 2** Mean infracommunity descriptors of *Micropogonias furnieri* in two localities from Argentine Sea. (**a**) Mean abundance, (**b**) species richness, and (**c**) Brillouin's index of diversity. MDP, Mar del Plata coastal area; MCH, Mar Chiquita coastal lagoon

of this fish from Mar Chiquita coastal lagoon. Previous records of helminth parasites in *M. furnieri* in Argentine include 3 monogeneans, 2 digeneans, 1 aspidogastrean, 1 cestode, 6 nematodes, and 4 acanthocephalans (Sardella et al. 1995; Timi et al. 2009; Alarcos and Etchegoin 2010); however, only 9 species were reported in the marine zone (Sardella et al. 1995). Thus, the present findings represent new host records in fish from the marine environment for the nematode *Hysterothylacium aduncum* and the cestodes *Scolex polymorphus* and *Callitetrarhynchus* cf. *gracilis*, increasing the known helminth parasites of *M. furnieri* to 19 species in this region. All the infracommunity indices

in whitemouth croakers from MDP were higher than those found from MCH. However, at the component community level, the total number of species found was lower in MDP than that in MCH, being 14 and 16 species, respectively, with 10 species shared in the two localities (Alarcos and Etchegoin 2010). In the whitemouth croakers from MCH, 3 nematodes (*Ascarophis marina*, *Anisakis* sp., and *Lappetascaris* sp.), 1 acanthocephalan (*P. chasmagnathi*), and 1 cestode (*Pterobothrium* cf. *heteracanthum*) were found at a prevalence lower than 10% (with the exception of *P. chasmagnathi*) (Alarcos and Etchegoin 2010), and these parasites were not found in MDP. These parasite species are involved in marine life cycles and such infections in the whitemouth croaker may be considered accidental and probably occur only occasionally, when fish make incursions into waters further offshore.

The cystacanth *C. australe*, the adult nematode *D. sciaenidicola*, and the monogeneans *N. avaginata* and *N. argentinensis* dominated the parasite community in MDP, while the nematode *D. sciaenidicola* and cystacanth *P. chasmagnathi* were the most prevalent and abundant species in MCH. The nematode *H. aduncum* and the cestodes *S. polymorphus* and *C.* cf. *gracilis* were found in the whitemouth croakers from MDP and absent in MCH. *Corynosoma australe* is reported frequently in various fishes from central and northern areas of Argentine Sea (Cantatore and Timi 2015; Canel et al. 2019), being highly abundant in other sciaenids (i.e., *Umbrina canosai*) in the same region. These sciaenid fishes may specialize for preying on intermediate hosts of *C. australe* (Canel et al. 2019), which could contribute to their abundance in whitemouth croakers from MDP, while in fish from MCH the effect of the smaller host size or lower host age may be responsible for the lower infection rates in MCH, as this parasite is long-lived and its infections tend to the cumulative over time (Braicovich et al. 2016). The adult nematode *D. sciaenidicola* was found in samples from both marine and estuarine habitats. Even though the intermediate host of this nematode is unknown, other congeners use polychaetes as intermediate hosts (Køie 2001). These nematodes are found in the intestine reflecting the dietary preferences of their hosts. Therefore, due to the high prevalence and abundance of *D. sciaenidicola* in whitemouth croakers from MDP and MCH as well as in croakers from other areas (Alves and Luque 2001), it could be assumed that polychaetes are not only present in the diet of young croakers, as previous studies suggested (Hozbor and García de la Rosa 2000), but also are important in the diet of larger fish. The monogeneans *N. avaginata* and *N. argentinensis* had high prevalence and abundance in the fish from MDP, and they were also present in MCH, but at lower infection levels. The same pattern was found in whitemouth croakers from Patos Lagoon estuary in Brazil, where the lower loads of *N. avaginata* and *N. argentinensis* in brackish environments

**Table 3** PERMANOVA results of comparisons of parasite communities of *Micropogonias furnieri* based on abundance (Bray–Curtis index) and presence-absence (Jaccard index) with host length as covariable across two samples from the Argentine Sea. *P* values obtained after 9999 permutations

| Response variable | Source | d.f | SS | MS | *Pseudo F* | *P (perm)* |
|---|---|---|---|---|---|---|
| Infracommunity structure Bray–Curtis similarity | Host size | 1 | 7054.8 | 7054.8 | 4.0075 | < 0.01 |
| | Locality | 1 | 30,630 | 30,630 | 17.4 | < 0.01 |
| | Host size × sample | 1 | 1724.8 | 1724.8 | 0.97977 | > 0.05 |
| | Residual | 52 | 91,541 | 1760.4 | | |
| | Total | 55 | $1.3095e^5$ | | | |
| Infracommunity structure Jaccard similarity | Host size | 1 | 6825.2 | 6825.2 | 3.921 | < 0.01 |
| | Locality | 1 | 25,363 | 25,363 | 14.571 | < 0.01 |
| | Host size × sample | 1 | 1466.4 | 1466.4 | 0.84246 | > 0.05 |
| | Residual | 52 | 90,515 | 1740.7 | | |
| | Total | 55 | $1.2417e^5$ | | | |

were related to the preference of these monogeneans for higher salinities (Velloso and Pereira Jr. 2010).
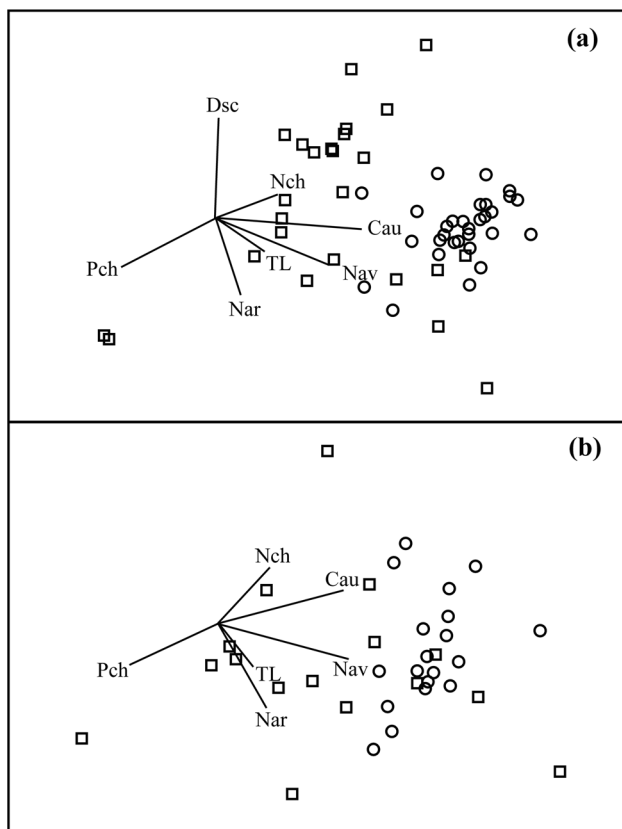


**Fig. 3** Non-metric two-dimensional scaling plot (nMDS) based on Bray–Curtis (abundances) (**a**) and Jaccard (presence/absence) (**b**) dissimilarity indices of parasite infracommunities of *Micropogonias furnieri* in two localities from the Argentine Sea. Vector overlays are Spearman correlations of parasite species and fish length with the nMDS axes (restricted to those having |r| > 0.4). Cau, *Corynosoma australe*; Dsc, *Dichelyne sciaenidicola*; Nar, *Neomacrovalvitrema argentinensis*; Nav, *Neopterinotrematoies avaginata*; Nch, *Neobrachiella chevreuxii*; Pch, *Profilicollis chasmagnathi*; TL, total fish length. Circles: MDP, Mar del Plata coastal area. Squares: Mar Chiquita coastal lagoon MCH

The most prominent feature in the parasite assemblages of the whitemouth croakers from MCH was the high dominance in the intestine of the acanthocephalan cystacanths *P. chasmagnathi* (Alarcos and Etchegoin 2010), which also were found in mesenteries (A.J. Alarcos, personal observation). The parasite may be acquired through the consumption of decapods, e.g., the crabs *Cyrtograpsus angulatus* and *Neohelice granulata*, which serve as intermediate hosts for *P. chasmagnathi* in the lagoon (Etchegoin 1997; Alarcos and Etchegoin 2010; Lorenti et al. 2018). Recently, Levy et al. (2020) found a possible case of incipient parathenia of *P. chasmagnathi* in other fish hosts inhabiting MCH, which could explain the abundance of these cystacanths in the body cavity of the whitemouth croakers. Studies of the patterns of estuarine use and habitat shift based on otolith chemistry in *M. furnieri* from the coastal region of the Southwest Atlantic Ocean suggested that adult fish may remain in estuarine waters after reproduction (Albuquerque et al. 2012). Therefore, the high abundance of *P. chasmagnathi* in fish from MCH and their absence in those from marine habitats suggest that a proportion of adult fish remain for longer periods in estuarine areas, contributing to the different parasite community structure from that of fish from MDP.

Most of the parasite species recovered in the present study have been previously reported in *M. furnieri* from Argentina. Sardella et al. (1995) found fewer parasite species in juvenile and adult fish from the Mar del Plata and Bahía Samborombón coasts compared to the present study (11 vs. 19). Conversely, Alves and Luque (2001) found 28 parasite species infecting *M. furnieri* from the coastal zone of the State of Rio de Janeiro, Brazil. Environmental factors such as latitude and host traits such as diet and body size are all variables associated with the richness of parasite communities (Holmes and Price 1986; Esch et al. 1990; Sousa 1994). The observed differences in abundance and species composition of parasites from MDP and MCH could be a consequence in part of the variable size of fish from MCH. However, it is possible that small-scale characteristics of the coastal systems, mainly

caused by different biotic and abiotic conditions at these sites, also play a role in determining the parasite community structure and composition. It should be highlighted that an effect of year of capture on the parasite community structure cannot be disregarded.

The parasite community of *M. furnieri* was less diverse and showed lower parasite abundance than other sympatric sciaenids, such as *Cynoscion guatucuapa* and *Umbrina canosai* (Timi et al. 2005; Canel et al. 2019). Variations of both the number and type of prey and their relative contribution to diet determine the host trophic level. Consequently, hosts at higher levels should be exposed to more parasite infective stages and a broader range of intermediate hosts than those at lower trophic levels (Timi et al. 2011). Thus, the higher trophic level displayed in *C. guatucuapa* and *U. canosai* with respect to *M. furnieri* leads it to emerge as a possible explanatory factor for differences of parasite assemblages in these sciaenids.

Studies of parasites in wild fish populations generate important information regarding parasite-host-environment relationships, as well as contribute to a better understanding of parasite diversity (Oliveira et al. 2016). Mar Chiquita coastal lagoon is an ecotonal region that combines freshwater environments, wetlands with marshes, and coastal dunes and beaches, representing a transitional zone between freshwater and marine waters (Olivier et al. 1972). On the other hand, MDP is dominated by marine shelf waters penetrating the coastal region. This results from the closeness of the 50-m isobath to the coast and the lack of locally formed coastal water; consequently, it is a more homogeneous habitat (Jaureguizar et al. 2006) than MCH. Characteristics of local ecosystems can determine not only the richness but also the abundance of parasites in fishes (Luque and Poulin 2004). Fish from the two sites differed from each other in the structure of their infracommunities, being richer in MCH, though parasites were more abundant in MDP. In other words, larger hosts, present in MDP, can support more parasite specimens, while the heterogeneity of habitat in MCH contributes to greater diversity of parasite species.

While *M. furnieri* is a resource that sustains the most important demersal coastal fishery of the southwestern Atlantic (Haimovici and Cardoso 2017; Thykjaer et al. 2020), insufficient information exists on the status of their populations inhabiting marine coastal areas from Argentina. Therefore, knowledge of their parasite assemblages from different brackish and marine habitats provide further insight into the biology of this fish, complementing other ichthyological studies to date.

## Declarations

**Ethics approval** All fish used in this work were obtained from commercial catches. Therefore, no ethical statement is needed regarding use of animals for scientific purposes.

**Conflict of interest** The authors declare no competing interests.

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