

An independent stock of *Engraulis anchoita* in north Patagonian waters? Parasite tags as evidence

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ABSTRACT

Fish parasites are widely used as biological indicators of stocks and populations of their hosts. In this work we examine the stability of the stock structure of Argentine anchovy, *Engraulis anchoita*, after a period of three decades using parasite tags. A total of 295 anchovies were examined for parasites. Two samples were collected at Northern stock (Necochea and El Rincón), two from the Southern stock (Rawson and San Jorge Gulf), and two from the intermediate zone between Northern and Southern stocks (San Matías Gulf and boundary between Northern and Southern stock). The structure and composition of both parasite infracommunities and component communities were analysed by uni and multivariate statistics. Our results showed certain compositional homogeneity after three decades as well as the presence of three groupings, with those from San Matías Gulf being part of a "central" stock or population distributed also outside the gulf on the continental shelf. This newly identified stock was probably overlooked in the previous study since all parasites were considered in the multivariate comparisons, whereas the present data were restricted to long-lived, and therefore more suitable biological tags, parasitic species. Further studies based on other kinds of evidence and carried out at broader temporal and spatial scales are necessary to corroborate the occurrence of a population in San Matías Gulf. In such a case, considering the ecosystem relevance of *E. anchoita*, the establishment of its temporal dynamics will be a first step for the conservation and safeguarding of the entire marine ecosystem at a regional scale.

1. Introduction

Small pelagic fishes (SPF) contribute up to 50 % of the total landing of marine species. They are most abundant in upwelling areas and make a considerable contribution to food security (FAO, IFAD, UNICEF, WFP and WHO, 2022). Furthermore, SPF are essential components of marine communities due to their large biomasses and their crucial intermediate position in the food web, exerting downward control over zooplankton and upward control over pelagic predators, termed as "wasp waist" type of control (Rice, 1995). In addition, because of their short generation times and large interannual fluctuations of abundance (Hilborn et al., 2022), they display large boom-and-bust dynamics, tightly linked to climate variability (Peck et al., 2013; Hilborn et al., 2022).

The Argentine anchovy *Engraulis anchoita* is the most abundant SPF in the southwest Atlantic Ocean, being distributed along a large latitudinal range from cape Sao Tomé (22°S) in southern Brazil to central Patagonia in Argentina (48°S) (Castello, 1997; Hansen, 2004). Like

other species of the genus *Engraulis*, this fish tolerates wide ranges of both temperature (8–23°C) and salinity (14–35). It plays an important role in the marine ecosystem (e.g., Koen Alonso et al., 2000; Yorio et al., 2017), as it provides food for numerous species of fish (Sánchez, 1995), birds (Marinao and Yorio, 2011; Gatto and Yorio, 2016; Yorio et al., 2017; Ciancio et al., 2021), and marine mammals (Koen Alonso et al., 1998, 2000; Dans et al., 2003). The Argentine anchovy has a great potential for exploitation throughout its distribution (Pastous Madureira et al., 2009). However, only in Argentina fishing activity has remained uninterrupted for almost a century, and has always been developed below its potential because of its high extraction costs and lack of market, among the main reasons (Hansen, 2004). Catches are destined for the salting and canning industries, which mainly sell their products on the foreign market (Defeo and Vasconcellos, 2020).

Three stocks have been identified within this wide distribution, the southeastern Brazilian Bight (20–28°S) in Brazilian waters, the Northern stock (28–41°S, southern Brazil, Uruguay, and northern Argentina) and

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the Southern or Patagonian stock (41–48°S, southern Argentina) (Hansen et al., 1984; Carvalho and Castello, 2013). Additionally, the existence of peripheral smaller stocks in open waters of the Bonaerense shelf, and in the San Matías Gulf has been suggested from age and growth analysis (Hansen et al., 1984; Brown et al., 2014).

Parasites of Argentine anchovy are relatively well known and have been previously used as indicators of stock composition in Argentine waters (Timi, 2003). Their parasite populations and assemblages showed marked latitudinal gradients along which four groups were identified, including a North Bonaerense group (34–40°S) and a South Bonaerense (40–42°S) occupying the transitional region between the Bonaerense and Patagonian Stocks around 41°S (Hansen et al., 1984). Samples of the latter were those caught south of 43°S (Timi, 2003). These groups were identified during spring. Finally, anchovies caught during autumn in North Bonaerense waters (35–37°S), with lower values of parasitism, were the most different, being attributed to a possible different stock. In this previous study, samples from San Matías Gulf, where a possible discrete stock has been proposed (Hansen et al., 1984; Brown et al., 2014), were not available.

In recent times, in the southwestern Atlantic Ocean strong ocean surface warming hotspots have been observed mainly associated with Brazil Current, Brazil – Malvinas Confluence, the Río de la Plata and in northern Patagonia (Franco et al., 2020; Risaro et al., 2022). Although the anchovy is an eurythermal and euryhaline species (Hansen, 2004), it has a great potential to adjust its distribution to environmental changes (Buratti et al., 2022; Gianelli et al., 2023). Therefore, given the environmental changes recorded at regional scale, a review of the actual definitions of management units and of their persistent spatial patterns is essential for an efficient fishery management (Cadurin, 2020). The advantages of interdisciplinary inferences of spatial population

structure have been demonstrated (Cadurin et al., 2014) and integrating parasite tags into such studies can help to provide more robust information for these purposes (Timi and Buchmann, 2023). Additionally, routine sampling and analyses have been proposed among the best practices for defining spatial boundaries and spatial structure in stock assessment (Cadurin et al., 2023). Consequently, this study aims to assess the stability of the stock structure over a period of three decades, using parasites as biological tags, based on new samples of anchovies from the regions previously studied by Timi (2003), and including fish from San Matías Gulf. In this gulf, the parasite fauna of several fish species has shown the presence of discrete stocks (Sardella and Timi, 2004; Braicovich and Timi, 2008; Timi et al., 2010; Irigoitia et al. 2017; Levy et al., 2019) being, therefore, a promising region for similar studies on anchovies.

2. Materials and methods

Samples were obtained from both research cruises and commercial catches between August and November, 2022 at different latitudes in the Argentine Sea (Fig. 1; Table 1). These included two samples from the Northern stock (Necochea –NEC– and El Rincón –RIN–), two from the Southern stock (Rawson –RAW– and San Jorge Gulf –SJG–), one from the boundary between them (Rio Negro Province –BBS–), around 41°S (Hansen et al., 1984; Hansen, 2004), and a last one from San Matías Gulf (SMG). The BBS were caught during winter, when adults from shelf stocks are separated by a distance greater than 500 km (Hansen, 2004).

In total, 295 anchovies were deep frozen on board and preserved at –18°C until examination. After thawing, fish were measured for total length (L_t) in mm. Fish length was compared across samples by a Kruskal-Wallis One Way Analysis of Variance on Ranks (1×6 factorial

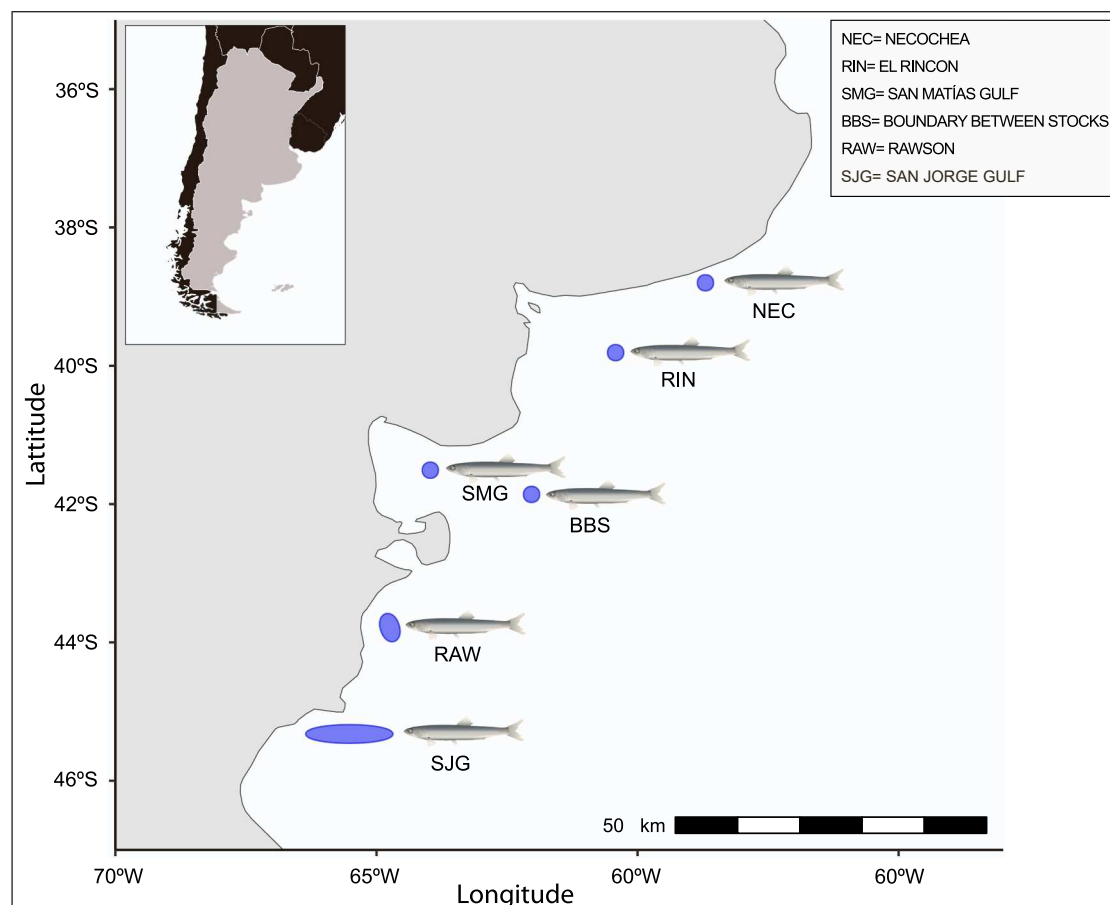


Fig. 1. Study area showing six sampling sites of adult *Engraulis anchoita* in the Argentine Sea.

Table 1Composition of samples of Argentine anchovy, *Engraulis anchoita* from six localities of the Argentine Sea.

Locality	Locations code	Latitude S	Longitude W	Date	Capture	N	L_t (mm)±S.D.
Necochea	NEC	38°47'60''	58°42'00''	Aug. 24th, 2022	Commercial	40	145.2±15.4
El Rincón	RIN	39°48'36''	60°25'12''	Aug. 30th, 2022	Research Cruise	40	139.5±16.7
San Matías Gulf	SMG	41°00'36''	64°18'36''	Nov. 11th, 2022	Research Cruise	40	137.8±15.2
Boundary between stocks	BBS	41°51'36''	62°01'48''	Aug. 24th, 2022	Research Cruise	40	126.4±10.4
Rawson	RAW	43°42'00''	64°49'48''–64°59'24''	Aug. 3rd-Sep. 9th, 2022	Commercial	80	151.8±14.2
San Jorge Gulf	SJG	45°12'00''–45°14'24''	64°50'24''–66°12'00''	Sep. 3rd–5th, 2022	Research Cruise	55	137.1±7.3

design, ‘sample’ as fixed factor) (Zar, 1999) followed by post-hoc Dunn’s pairwise tests (Dunn, 1964).

Each fish was dissected under a stereoscopic microscope. The body surface, eyes, gills, branchial and body cavities, viscera (stomach, intestine, liver, gallbladder, heart, gonads and mesenteries), gas bladder, kidneys, and musculature were examined separately. Parasites were recovered from gills, body cavities, stomach, pyloric caeca, and intestine, counted and identified following standard procedures for each taxon (Pritchard and Kruse, 1982; Berland, 1984).

Prevalence and mean abundance (sensu Bush et al., 1997) were calculated for each parasite species in each sample. The Species Richness was calculated for each individual fish and the Brillouin’s index of diversity for those anchovies harbouring at least 1 parasite species (Magurran, 1988). Both infracommunity (sensu Bush et al., 1997) descriptors were compared across samples in the same way as fish length. For myxosporeans from the gallbladder only the prevalence was estimated. As the gallbladder couldn’t be found in some specimens, these parasites were not included in the calculations of Species Richness.

The structure of parasite assemblages across localities was evaluated by multivariate methods. The similarity in parasite assemblages was computed at infracommunity level by means of Bray-Curtis similarity indices (Magurran, 1988) on parasite abundance between all possible pairs of assemblages. Data were square-root transformed previously to all analyses in order to down-weight the importance of very abundant species so that the less dominant species played some role in determining similarity among samples (Clarke and Gorley, 2015), because large differences in abundance were observed across parasite species. As short-lived parasites (ectoparasites and transient gastrointestinal parasites) can be temporally variable, they are considered unsuitable as indicators for stock discrimination (Lester and MacKenzie, 2009; Braicovich et al., 2016). Therefore, they were excluded from analyses owing to the fact that anchovies were caught from winter to the end of spring. Consequently, only long-lived parasites, those larval helminths

parasitizing the body cavity or tissues, were retained for the comparisons (see Table 2).

A non-parametric multidimensional scaling (nMDS, Clarke and Gorley, 2015) was carried out to visualise if the geographic origin of the samples can be differentiated based on the abundance values of their parasites. The distances between the centroids of each sample were plotted by bootstrap averaging the original dataset (75 iterations with replacement) to show differences among samples more clearly (Clarke and Gorley, 2015). For this, mean values were visualised in nMDS plots, using as many dimensions as necessary in order to match the original data matrix as closely as possible (setting a $\rho = 0.99$ correlation coefficient), and their fitting was quantified by means of a stress value.

The influence of the origin of assemblages was further analysed by means of canonical analysis of principal coordinates (CAP) (Anderson and Willis, 2003), testing for significant differences by a permutation “trace” test, after 9999 permutations. Over-parameterization was prevented by choosing the number of PCO axes (m) that maximised success on a “leave-one-out” allocation to groups cross-validation method (Anderson and Robinson, 2003).

Since both nMDS and CAP analyses do not consider the influence of host size on the significance of the differences among samples, the differences in infracommunity structure between samples were tested using a one-way permutational multivariate analysis of the variance (PERMANOVA, Anderson et al., 2008), including L_t as a co-variable and “sample” as a factor (1×6 factorial design). Following Anderson et al. (2008) a permutation of residuals under a reduced model was used as a method of permutation. A sequential sum of squares (Type I SS) was applied because L_t was introduced as a co-variable. Because PERMANOVA is sensitive to differences in multivariate dispersion between groups (sensu homogeneity of variances, which can inflate Type I error even when centroids have identical locations), the same models were tested for differences in dispersion using the routine PERMDISP (Anderson et al., 2008). Dispersions were measured as distance to the

Table 2Microhabitat and prevalence (%) of parasites of *Engraulis anchoita* across six localities in the Argentine Sea.

Parasite	Microhabitat	NEC	RIN	SMG	BBS	RAW	SJG
Monogenea							
<i>Pseudanthracotyloides heterocotyle</i>	Gills	0	0	0	5.0	0	3.6
<i>Mazocraes australis</i>	Gills	0	2.5	5.0	0	0	7.3
Digenea							
<i>Lecithochirum microstomum</i>	Stomach	2.5	0	5.0	0	2.5	0
<i>Parahemiurus merus</i>	Stomach	0	2.5	0	5.0	0	0
<i>Cardiocephaloides</i> sp.*	Eyes	0	0	2.5	0	0	0
Cestoda							
<i>Bothriocephalus</i> sp.	Pyloric caeca	0	0	0	0	0	2.5
<i>Scolex polymorphus</i>	Intestine	22.5	55	77.5	80.0	36.3	20.0
Nematoda							
<i>Hysterothylacium aduncum</i> *	Body cavity	95.0	97.5	5.0	32.5	97.5	78.2
<i>Contracaecum</i> sp.*	Body cavity	30.0	32.5	95.0	55.0	38.8	63.6
<i>Anisakis</i> sp.*	Body cavity	12.5	10	5.0	2.5	67.5	61.8
Acanthocephala							
<i>Corynosoma australe</i> *	Body cavity	0	2.5	2.5	0	0	0
Copepoda							
<i>Nothobomolochus cresseyi</i>	Gills	0	0	2.5	0	0	0
Myxozoa							
<i>Sphaeromyxa argentinensis</i>	Gall bladder	0	14.3	11.1	0	0	26.8

* Indicates those long-lived species selected for comparative analyses at infracommunity level.

centroid, and each term in the analysis was tested using 9999 permutations.

At the component community level, an nMDS was performed on the Bray-Curtis similarity index on untransformed data of prevalence to visualise possible geographic patterns in the composition of parasite assemblages across the samples. A hierarchical agglomerative clustering was applied to the component communities using group-average linking, and resemblance levels were overlaid on the nMDS plot (Clarke and Gorley, 2015).

All similarity and distance measures, as well as all multivariate analyses, were implemented in PRIMER V7 and PERMANOVA+ for PRIMER package (Anderson et al., 2008; Clarke and Gorley, 2015).

3. Results

Fish length varied significantly across samples ($H_{(5)}: 84.3, P < 0.01$), due to pairwise differences between BBS regarding all the other localities and of RAW from most of them (all $P < 0.05$), except NEC.

All examined anchovies were parasitised by at least one of 13 parasite species and a total of 5225 individual parasites (excluding myxozoans) was found, with variable values of prevalence across samples (Table 2). Most species were found at very low abundance, with the exception of the larval cestodes *Scolex polymorphus* and the larval nematodes *Hysterothylacium aduncum*, *Contracaecum* sp., and *Anisakis* sp., which were relatively abundant in some samples (Table 3). The Species Richness (Supplementary material) varied significantly across samples ($H_{(5)}: 32.5, P < 0.01$), due to differences of both RAW and SJG relative to both RIN and BBS (all $P < 0.05$). In general, individual anchovies harboured few parasite species (Supplementary material), with only 1 specimen harbouring 5 species and richness of 1 or 2 dominating the four northern samples, whereas higher proportions of infracommunities consisting of 2 or 3 species were observed in the southern Patagonian stock. Infracommunity diversity (Fig. 2) also varied significantly across samples ($H_{(5)}: 32.5, P < 0.01$) due to pairwise differences between anchovies from SMG and both samples of the Patagonian stock.

The selection of infracommunities of long-lived parasites excluded a number of anchovies parasitised exclusively by transient parasites, including 1 from NEC, 1 from RIN, 2 from SMG, and 12 from BBS. The bootstrap-average-based nMDS ordination of this subset of infracommunities (Fig. 3) showed an apparent homogeneity of some samples according to their population of origin, with a low value of stress (0.02). Both samples of the Northern population were homogeneous, and the same was shown by both Patagonian ones, which resulted in being located close to their northern counterparts on the right side of the biplot. On the other hand, anchovies from the central region (SMG and BBS) were located close to each other on the left side of the bi-

dimensional space, distant from the rest of the samples along the first axis. This homogeneity was corroborated by the CAP analysis on abundance, with data showing significant differences among samples ($tr = 0.66; P < 0.01$). Although a low percentage of correct allocations (39.92 %) was observed, cross-validation results showed that the percentages of correctly improved when anchovies were allocated to their “population” rather than to their locality (Table 4), with a considerably smaller number of fish from the central region being allocated to the northern and southern regions and vice-versa.

The results of PERMANOVA analyses (Table 5) showed a significant effect of host length on the response variables and an interaction between the host length and sample, indicating that the nature of the relationship between the covariate and the multivariate response differed within different levels of the factor. Furthermore, taking into account the variations among samples due to fish size, significant differences were detected among the parasite assemblages. Post-hoc pairwise comparisons showed significant differences ($t: 2.68\text{--}11.08$; all $P_{perm} < 0.01$) in the structure of parasite assemblages when samples were compared between regions, but not differences were detected within regions, namely NEC-RIN ($t: 0.18$; $P_{perm} = 0.91$); SMG-BBS ($t: 1.52$; $P_{perm} = 0.11$), and RAW-SJG ($t: 1.07$; $P_{perm} = 0.33$). Significant differences in the multivariate dispersions were observed across samples ($F_{5252}: 5.53$; $P_{perm} < 0.01$), with three pairs of samples differing from each other, namely NEC-RAW ($t: 3.87$; $P_{perm} < 0.01$), RIN-RAW ($t: 4.87$; $P_{perm} < 0.01$) and RIN-SJG ($t: 3.16$; $P_{perm} < 0.01$).

The nMDS and cluster analyses carried out at the level of component communities showed a similar pattern to those of infracommunities (Fig. 4).

4. Discussion

The examination of 295 anchovies caught in 2022, did not add new parasite records for this host species, as all the 13 parasite species found were previously reported parasitizing it in the study region (Timi, 2003; Timi and Poulin, 2003), evidencing certain compositional homogeneity after three decades. However, some species previously recorded at low abundances were not found in the present samples, since 19 species were reported in anchovies caught between 1993 and 1995 (Timi, 2003).

In the present paper, parasite communities of anchovies from SMG were examined for the first time. This gulf is an isolated coastal basin, with particular oceanographic characteristics that differ notably from those in the surrounding continental shelf. Indeed, the geomorphology of the gulf mouth restricts the interchange of water with open sea (Piola and Rivas, 1997). It is a semi-enclosed basin that has limited water exchange with the adjacent shelf and two large deep depressions between 160 and 216 m deep, one located south and the other north of 41°40' S.

Table 3
Mean abundance followed by the range in parentheses of parasites of *Engraulis anchoita* across six locations in the Argentine Sea.

Parasite	Necochea	El Rincón	San Matías Gulf	Boundary between stocks	Rawson	San Jorge Gulf
Monogenea						
<i>Pseudanthracotyloides heterocotyle</i>	-	-	-	0.08 (0–2)	-	0.04 (0–1)
<i>Mazocraes australis</i>	-	0.08 (0–3)	0.05 (0–1)	-	-	0.11 (0–2)
Digenea						
<i>Lecithochirum microstomum</i>	0.03 (0–1)	-	0.05 (0–1)	-	0.04 (0–2)	-
<i>Parahemiurus merus</i>	-	0.03 (0–1)	-	0.05 (0–1)	-	-
<i>Cardiocephaloides</i> sp.	-	-	0.03 (0–1)	-	-	-
Cestoda						
<i>Bothriocephalus</i> sp.	-	-	-	-	-	0.09 (0–2)
<i>Scolex polymorphus</i>	9.40 (0–46)	3.83 (0–27)	11.05 (0–104)	12.10 (0–72)	8.89 (0–105)	2.44 (0–53)
Nematoda						
<i>Hysterothylacium aduncum</i>	4.70 (0–25)	7.85 (0–55)	0.05 (0–1)	1.20 (0–15)	12.11 (0–87)	4.05 (0–16)
<i>Contracaecum</i> sp.	1.28 (0–12)	2.18 (0–22)	3.95 (0–26)	1.73 (0–12)	2.74 (0–48)	2.0 (0–12)
<i>Anisakis</i> sp.	0.23 (0–4)	0.30 (0–5)	0.05 (0–1)	0.10 (0–4)	2.33 (0–17)	4.38 (0–35)
Acanthocephala						
<i>Corynosoma australe</i>	-	0.05 (0–2)	0.05 (0–1)	-	-	-
Copepoda						
<i>Nothobomolochus cresseyi</i>	-	-	0.03 (0–1)	-	-	-

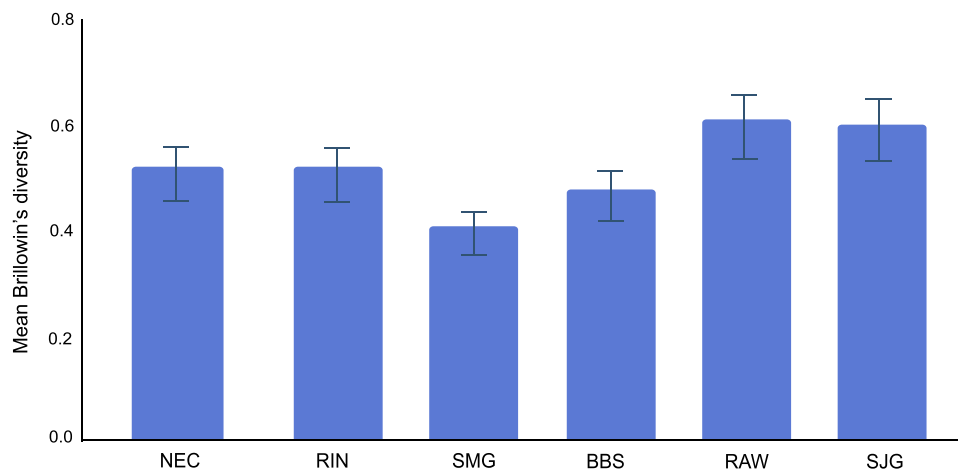


Fig. 2. Mean Brillouin's diversity of parasite assemblages of *Engraulis anchoita* across six samples caught in the Argentine Sea. Nec: Necochea; RIN: EL Rincón; SMG: San Matías Gulf; BBS: boundary between northern and southern stock; RAW: Rawson; SJG: San Jorge Gulf.

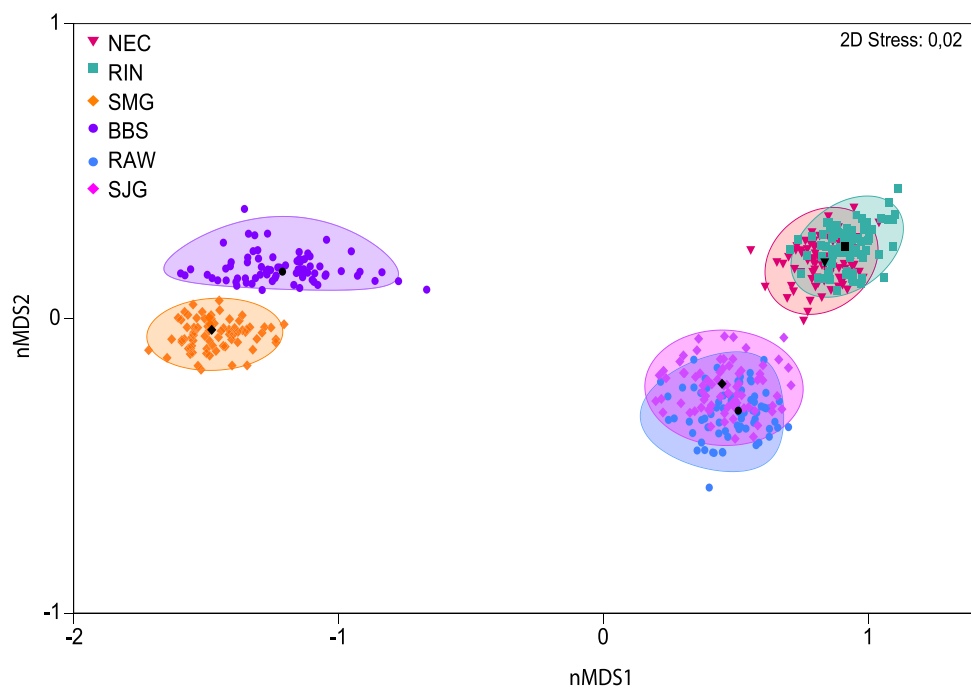


Fig. 3. Non-metric multi-dimensional scaling plot (nMDS) of bootstrap averages (75 repetitions) of parasite infracommunities in six samples of *Engraulis anchoita* caught in the Argentine Sea, based on Bray-Curtis dissimilarity of square root-transformed data of abundance. Black full symbols represent the overall centroids across all repetitions.

Table 4
Cross validation (*leave-one-out* allocation of individual fish to one of six localities) for the canonical analysis of principal coordinates (CAP). Rows correspond to localisations membership, including percentage of correctly classified hosts into their sample and region of origin.

Origin group	NEC	RIN	SMG	BBS	RAW	SJG	% correct	
							Same sample	Same region
Necochea (NEC)	1	20	0	5	3	4	3.03	63.64
El Rincón (RIN)	1	26	0	3	3	5	68.42	71.05
San Matías Gulf (SMG)	0	1	28	2	1	4	77.78	83.33
Boundary SMG (BBS)	0	3	15	5	0	0	21.74	86.96
Rawson (RAW)	1	18	8	2	35	9	47.95	60.27
San Jorge Gulf (SJG)	2	12	5	5	23	8	14.55	56.36

Approximately 55 % of its total area is deeper than 100 m (Piola and Scasso, 1988). Furthermore, a thermohaline front divides the north and south areas of the gulf and the presence of a cyclonic gyre in the north

region during summer is indicative of fish larvae retention into the gulf (Di Giacomo et al., 1993). Therefore the oceanographic conditions are determinants of the stock composition of fish inhabiting the gulf (Di

Table 5
One-factor PERMANOVA results of square-root transformed abundance of parasites of *Engraulis anchoita* in six locations from the Argentine Sea, based on the Bray-Curtis dissimilarity measure with host length as co-variable. *P*-values obtained after 9999 permutations.

Source	d.f.	SS	MS	Pseudo F	P (perm)
Host length	1	36853	36853	33.103	<0.001
Locations	5	1.7698 e ⁵	35397	31.795	<0.001
Host length x location	5	16883	3376.6	3.033	<0.001
Residual	246	2.7387 e ⁵	1113.3		
Total	257	5.04559 e ⁵			

Giácomo et al., 1993; Volpedo and Cirelli, 2006; González et al., 2007; Machado-Schiaffino et al., 2011). Parasitological studies have shown that fishes inhabiting SMG often display quantitatively different parasite faunas (Sardella and Timi, 2004; Braicovich and Timi, 2008; Timi et al., 2008, 2010; Irigoitia et al., 2017; Levy et al., 2019). Indeed, some shared parasite species show similar patterns in different fish species. For example, larval *Contracaecum* sp. and *H. aduncum* are notably more and less prevalent, respectively, in hakes *M. hubbsi* from SMG (Sardella and

Timi, 2004), as observed in anchovies, their main prey item. Such similitude reflects the higher abundance, and therefore the availability, of the infective stages of these generalist parasites in SMG and the role of anchovies as prey and source of parasites for many ichthyophagus fish.

Based on differences in the length distribution of one-year-old anchovies, as well as on the estimated hatching dates, the existence of a peripheral small stock of *E. anchoita* in SMG has been proposed (Hansen et al., 1984; Brown et al., 2014). The permanent occurrence of small anchovies at the mouth of SMG (Hansen et al., 2001), seems to support this hypothesis. However, the presence of medium-sized and larger fish differing from year to year during the peak of the spawning season (Hansen et al., 2001), and the periodical entry of adults into other north patagonian gulf, such as Nuevo Gulf (Hansen, 2004), apparently indicates seasonal migratory movements of anchovies in the north patagonian waters. The similarity of parasite assemblages between anchovies from SMG and BBS (central area) agrees with the occurrence of migratory movements of adult anchovies connecting the gulf with neighbouring shelf waters. Such a connection, however, does not contradict the hypothesis on the existence of an independent stock related to SMG, notably different in terms of parasitism from those

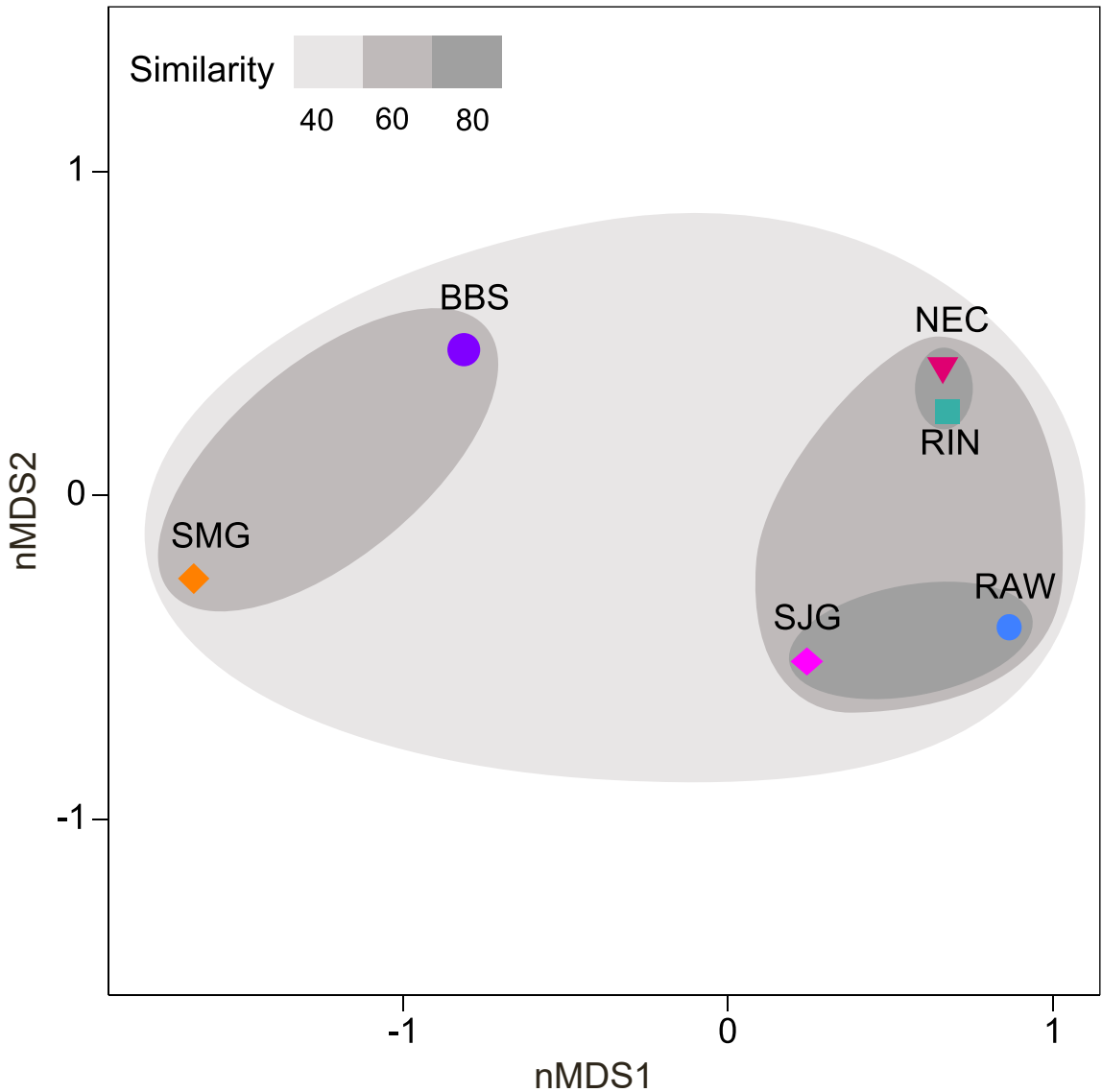


Fig. 4. Non-metric multi-dimensional scaling plot (nMDS) and cluster analysis of parasite component communities in six samples of *Engraulis anchoita* caught in the Argentine Sea, based on Bray-Curtis dissimilarity of square root-transformed data prevalence. Stress value= 0. Results of a hierarchical agglomerative clustering are overlaid on the nMDS plot with similarity levels represented by grey scale.

northern and southern ones known on shelf waters.

Although previous ichthyological studies considered the 41° S parallel as the boundary between the Northern and Southern stock (Hansen et al., 1984), three decades ago parasites showed a somewhat different structure (Timi, 2003). Indeed, according to their parasite communities, anchovies caught between 40° S and 42° S were more similar to northern ones than to their southern counterparts at south of 43° S, but constituting a distinguishable group regarding fish caught north of 40° S (Timi, 2003). Present parasitological data agreed with those obtained thirty years before in the groupings of samples according to the latitude of capture, with significant differences between those of the central region (SMG and BBS) regarding both from northern and southern areas, which remain clearly identifiable as two distinct stocks. The main difference with the previous work is a higher similarity of northern (NEC and RIN) and southern samples (RAW and SJG) to each other than to central (SMG and BBS) samples. Such differences between works could be because short-lived parasites were included in the analyses of the previous study. Indeed, adult parasites, such as ectoparasites and most gastrointestinal species are not considered as suitable indicators for stock assessment purposes because their population parameters can be variable temporally and heterogeneously at small spatial scales (Soares et al., 2018). However, the population structure of *E. anchoita* seems to have remained unaltered over time, in spite anchovies having been identified as having a high potential for adjusting its distribution in response to the recorded ocean warming in the region and is catalogued as having the lowest sensitivity (Gianelli et al., 2023).

Compositional changes seem to have occurred in the parasite assemblages of *E. anchoita*. The analysis of temporal changes in parasite community structure is beyond the aim of this work, but such processes should be expected considering the statistically significant trends of sea surface temperature anomalies are found on the Northern Patagonian Shelf with a warming area delimited between 42° S and 45° S (Risaro et al., 2022). Indeed, changes in the structure of parasite assemblages of *Cynoscion guatucupa* in the northern zone of the same region and along the same period have been recently recorded, including variations in some parasites shared with anchovies (Lanfranchi et al., 2024). However, beyond the temporal differences in the structure of parasite assemblages, that of the population of *C. guatucupa* remained stable in this period, even under a warming process that seems to have affected its parasite assemblages (Lanfranchi et al., 2024). Similarly, the stock structure of the Argentine anchovy based on comparisons of its parasites showed, as observed three decades earlier (Timi, 2003), the presence of three stocks in the continental shelf, with those from SMG being part of a “central” stock or population distributing also outside the gulf on the continental shelf. Further studies at broader temporal and spatial scales are necessary to corroborate this hypothesis. The existence of a discrete “central” stock of anchovies, especially its possible contribution as a putative source of genetic variability to the species, such as been suggested for other species like hakes, would be of relevance for fishery management purposes (Machado-Schiaffino et al., 2011).

Engraulis anchoita is not only the most abundant species inhabiting the Argentine Sea (Sánchez, 1995), but it is also a keystone species in the trophic web, being preyed upon by more than fifty species of squids, fish, and marine birds and mammals (Angelescu, 1982; Hansen, 2004). When harbouring unique populations of long-dispersal species, gulfs are suitable habitats for designing marine protected areas or at least they merit gulf-specific management strategies (Machado-Schiaffino et al., 2011). In this case, considering the ecosystem relevance of *E. anchoita*, the corroboration of the occurrence of a population in SMG and the establishment of its temporal dynamics will be a first step for the conservation and safeguarding of the entire marine ecosystem at a regional scale.

There is interest in verifying whether the abundance of anchovy in SMG can allow the development of a fishery that diversifies the productive matrix of the Río Negro province. Therefore, the use of different methodologies to assess whether the anchovy present there constitutes a different stock is key for an adequate fishery management. In this sense,

genetic studies, analysis of meristic and morphometric characters, from the perspective of the integrative taxonomy (Zamani et al., 2022).

CRedit authorship contribution statement

Paula Marcotegui: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Manuela Parietti:** Writing – review & editing, Methodology. **Juan Timi:** Supervision, Project administration, Funding acquisition, Formal analysis, Conceptualization. **Maria Paz Gutierrez:** Writing – review & editing, Writing – original draft. **Claudio Buratti:** Writing – review & editing, Methodology. **Matias Merlo:** Writing – review & editing, Writing – original draft, Methodology.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.fishres.2024.107148.

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