

Community of macroparasites of the Pacific barracuda *Sphyraena ensis* Jordan and Gilbert, 1882 (Perciformes, Sphyraenidae) from the north coast of Peru

D. Minaya, D. Ferre, M. García, L. Alvaríño, J. Iannacone

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Abstract

Community of macroparasites of the Pacific barracuda Sphyraena ensis Jordan and Gilbert, 1882 (Perciformes, Sphyraenidae) from the north coast of Peru. This study aimed to report the community of macroparasites of the Pacific barracuda *Sphyraena ensis* Jordan and Gilbert, 1882 (Perciformes, Sphyraenidae) from the north coast of Peru. From September to October 2019, 138 specimens of *S. ensis* were acquired from Caleta de Zorritos, Contralmirante Villar Province, Tumbes, on the north coast of Peru. The community of parasites found consisted of nine species of parasites including monogeneans, copepods, trematodes and nematodes. The total body length of the fish was negatively correlated with the mean intensity of infestation of *Pseudochauhannea* sp. The mean abundance of *Pseudochauhannea* sp. also showed a marked significant difference between the populations of male and female fish, being more associated with males. We provide a list of macroparasites recorded in fish of the genus *Sphyraena* in the Eastern Pacific Ocean.

Checklist dataset published through GBIF (Doi: [10.15470/5htffh](https://doi.org/10.15470/5htffh))

Key words: Ecology, Ectoparasites, Helminths, Ichthyology, Parasitology

Resumen

Comunidad de macroparásitos de la barracuda del Pacífico Sphyraena ensis Jordan and Gilbert, 1882 (Perciformes, Sphyraenidae) de la costa norte de Perú. El objetivo de este estudio es informar sobre la comunidad de macroparásitos de la barracuda del Pacífico *Sphyraena ensis* Jordan and Gilbert, 1882 (Perciformes, Sphyraenidae) de la costa norte de Perú. De septiembre a octubre de 2019 adquirimos 138 ejemplares de *S. ensis* en Caleta de Zorritos, provincia Contralmirante Villar, Tumbes, en la costa norte de Perú. La comunidad de parásitos encontrada estaba constituida por nueve especies de monogéneos, copépodos, trematodos y nematodos. La longitud corporal total de los peces se correlacionó negativamente con la intensidad media de infestación por *Pseudochauhannea* sp. Por otra parte, la abundancia media de *Pseudochauhannea* sp. mostró una marcada diferencia significativa entre las poblaciones de peces machos y hembras, estando más asociada a

los machos. Proporcionamos una lista de macroparásitos registrados en peces del género *Sphyaena* presentes en el océano Pacífico Oriental.

Lista de datos publicados en [GBIF](#) (Doi: [10.15470/5htffh](#))

Palabras clave: Ecología, Ectoparásitos, Helmintos, Ictiología, Parasitología

Resum

Comunitat de macroparàsits de la barracuda del Pacífic Sphyaena ensis Jordan and Gilbert, 1882 (Perciformes, Sphyaenidae) de la costa nord del Perú. L'objectiu d'aquest estudi és informar sobre la comunitat de macroparàsits de la barracuda del Pacífic *Sphyaena ensis* Jordan and Gilbert, 1882 (Perciformes, Sphyaenidae) de la costa nord del Perú. De setembre a octubre de 2019 vam adquirir 138 exemplars de *S. ensis* a Caleta de Zorritos, província Contraalmirante Villar, Tumbes, a la costa nord del Perú. La comunitat de paràsits trobada va estar constituïda per nou espècies de monogenis, copèpodes, trematodes i nematodes. La longitud corporal total dels peixos es va correlacionar negativament amb la intensitat mitjana d'infestació per *Pseudochauhannea* sp. D'altra banda, l'abundància mitjana de *Pseudochauhannea* sp. va mostrar una marcada diferència significativa entre les poblacions de peixos mascles i femelles i estava més associada als mascles. Proporcionem una llista de macroparàsits registrats en peixos del gènere *Sphyaena* presents a l'oceà Pacífic Oriental.

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Paraules clau: Ecologia, Ectoparàsits, Helmints, Ictiologia, Parasitologia

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David Minaya, Dalia Ferre, Malory García, Lorena Alvario, José Iannacone, Laboratorio de Ecología y Biodiversidad Animal, Facultad de Ciencias Naturales y Matemática, Universidad Nacional Federico Villarreal, Av. Rio de Chepen El Agustino, Lima 15007, Perú.– José Iannacone, Laboratorio de Ingeniería Ambiental, Facultad de Ciencias Ambientales, Universidad Científica del Sur, Panamericana Sur km 19 Villa, Lima 15067, Perú.

Corresponding author: José Iannacone. E-mail: joseiannaconeoliver@gmail.com

ORCID ID: D. Minaya: 0000-0002-9085-5357; D. Ferre: 0000-0001-7055-3346;
M. García: 0000-0002-3780-9423; L. Alvario: 0000-0003-1544-511X;
J. Iannacone: 0000-0003-3699-4732

Introduction

Macroparasite communities in marine fish are composed of ectoparasites and endoparasites (Violante–González et al., 2019). These two groups exhibit different transmission strategies. Ectoparasites, for example, are often transmitted between individual hosts through contact, whereas endoparasites use trophic transmission routes (Violante–González et al., 2019). Biotic factors (nutritional component, age, host density, vagility, social behavior, and host body size) and environmental abiotic factors can cause fluctuations in the richness and diversity of the macroparasite species (Henríquez and González, 2012; Bellay et al., 2020; Santos–Bustos et al., 2020; Llopis–Belenguer et al., 2020; Minaya et al., 2020c). Macroparasites comprise a high proportion of global species diversity and provide essential functions and services to ecosystems (Bellay et al., 2020).

Several species of marine fish of the genus *Sphyaena* Artedi, 1793 have been evaluated in relation to their macroparasite communities in Kuwait (Abdul-Salam and Sreelatha, 1993, 1995), China (Zhang et al., 2003), India (Ravichandran et al., 2007), Mexico (Gómez del Prado-Rosas et al., 2007), New Caledonia (Moravec and Justine, 2015), Australia (Moravec and Beveridge, 2017) and Tunisia (Boussellaa et al., 2018), among others.

Pacific barracuda *Sphyaena ensis* Jordan and Gilbert, 1882 (Perciformes, Sphyaenidae) is a pelagic–neritic marine species found in the Eastern Pacific from Mexico to Chile, and including the Galapagos Islands (Froese and Pauly, 2020; SNP, 2020). Pacific barracuda inhabit depths in the range of 10 to 60 m. They can be found in waters with sandy and muddy bottoms, in coral reefs, and in rocky areas near the coast (Robertson and Allen, 2015). The diet of this barracuda consists mainly of bony neritic fish that form dense schools and zoobenthos, for which it is categorized as an opportunistic ichthyophage predator (Moreno-Sánchez et al., 2019; López-Peralta and Arcila, 2002). Fish diet can directly influence its parasitic fauna.

Sphyaena ensis is known as an important fish species for human consumption due to the quality of its meat and the low price (Ulloa-Ramírez et al., 2008; Zavala-Leal et al., 2018; Rodríguez-Segovia et al., 2020), in addition to the absence of records of zoonotic parasites. As few studies of this resource have been carried out to date, regulatory measures for its fishing and consumption are lacking (SNP, 2020). This species is listed as of Least Concern by the IUCN Red List (International Union for Conservation of Nature) (Robertson et al., 2010).

Despite the importance of this species, knowledge of the parasitic fauna of *S. ensis* is known for only three species of monogeneans: *Paramonaxine yamagutii* Bravo-Hollis, 1978 recorded in Baja California, Isla Rasa (Bravo-Hollis, 1978a), Baja California Sur, Cabo San Lucas (Bravo-Hollis, 1978b); *Pseudochauhannea elongatus* Kritsky, Bilqees and Leiby 1972 recorded in Nayarit, San Blás, México (Lamothe-Argumedo et al., 1997); and *Pseudochauhannea mexicana* Lamothe-Argumedo, 1966 recorded in Guerrero, Acapulco (Lamothe-Argumedo, 1966), Jalisco, Bahía de Chamela (Pérez-Ponce De León, et al., 1999) and in Nayarit, San Blás (Lamothe-Argumedo et al., 1997). All records are limited to Mexico, and literature referring to the parasitic fauna of *S. ensis* in other countries of Central America and South America is lacking. In this study we aimed to characterize the community of *S. ensis* macroparasites from the north coast of Peru and determine the relationship between body size and sex of this host and the macroparasite community. In addition, we present the list of helminths and arthropods recorded in fish of the genus *Sphyaena* Artedi, 1793 present in the Eastern Pacific Ocean.

Material and methods

From May to October 2019, 138 specimens of the *S. ensis* were collected from Caleta de Zorritos, Contralmirante Villar Province, Tumbes, on the north coast of Peru (80° 40' 29" LS; 03° 40' 39" LO).

Prior to necropsy of this marine fish, total body length (TBL) in cm and sex (S) were recorded. The skin, oral cavity, gills, coelomic cavity, stomach, intestine, mesentery, pyloric cecum, gonads, heart, swim bladder, kidneys, liver and spleen of the fish were examined for helminths and parasitic arthropods. All macroparasites collected were preserved in 70% ethyl alcohol (Eiras et al., 2006).

For the morphological study of the macroparasites, helminths were colored in carmine acetic acid and alternatively in gomori trichrome, dehydrated at concentrations of 50%, 70%, 90% and 100% of ethyl alcohol, diaphanized in clove oil and mounted in Canada balsam (Almeida and Almeida, 2014). Parasitic crustaceans were macerated in lactic acid or lactophenol for a 24–48 h exposure time, placed on slides and observed directly under

a microscope (Boxshall et al., 2015). Taxonomic classification of the macroparasites was carried out with the help of the general literature of Yamaguti (Yamaguti, 1963a) for monogeneans and Yamaguti (1963b) for copepods. The host and parasite nomenclature were corroborated in the World Register of Marine Species (WoRMS, 2021).

For the analysis of the parasitic population component, the parasitological ecological indices of percentage prevalence (P%), mean abundance (MA) and mean intensity (MI) of infection were calculated following the indications by Bush et al. (1997) and Bautista–Hernández et al. (2015). The type of strategy of each parasitic species was evaluated according to the P%, for which the species were classified as 'core or central' species for species with a prevalence greater than 45 %, 'secondary' species for those with a prevalence of between 10 % and 45 %, and 'satellite' species for those with a prevalence of less than 10 % (Bush and Holmes, 1986).

TBL of the fish was classified in ranges using the Sturges rule as the criterion to determine the number of intervals, from which the P%, MA and MI values of the parasites were calculated to evaluate the association between these parameters and the TBL. To determine the degree of association between the P% of the parasites and TBL, the Spearman correlation coefficient (r_s) was used, previously transforming the P% values to arcsine square root. Pearson's correlation coefficient (r) was used to determine the relationship of the TBL of the fish with the MA and MI of each species of parasite.

To calculate the degree of association between the sex of the host and P% of each species of parasite, 2 x 2 contingency tables were used, using Chi-square (χ^2) and Yates' correction (Y). The Student's t-test (t) was used to compare the MA and MI of each parasite and the sex of the host. The populations of the male and female fish were subjected to the Kolmogorov–Smirnov test with the modification of Lilliefors to corroborate the normality of the data and the homocasticity of variances based on the Levene (F) test (Zar, 2014).

The analysis of the parasites in relation to the TBL and the sex of the host was carried out only for the species with a P% greater than 10 % (Esch et al., 1990). The alpha diversity of the macroparasite community was determined for the total fish population of males and females of *S. ensis* using the following indices: total richness, mean richness, Margalef, Simpson (D), Shannon (H), Equitability (J) and Chao–1 (Iannaccone and Alvarino, 2013; Minaya et al., 2020a, 2020b). The Student's t test was used to compare mean richness, Shannon and Simpson. The level of significance was evaluated at a level of $\alpha = 0.05$. The descriptive and inferential statistics were performed using the statistical package IBM SPSS Statistics 24.0.

The non-metric multidimensional scaling (nMDS) technique was used to evaluate the pattern of the structure of the parasite community as a function of the abundance of parasite species, and was represented graphically. The similarity matrix was constructed using the Bray–Curtis index. We analysed the abundance of infection of each species of parasite in each host fish and its relationship with the host's sex using a multivariate analysis of similarity (ANOSIM) test, with 10,000 permutations (Minaya et al., 2020c; Paliy and Shankar, 2016).

The parasite specimens collected in this study were deposited in the collection of Helminths Parasites and Related Invertebrates – HPIA, of the zoological collection of the Museum of Natural History of the Universidad Nacional Federico Villarreal – MUFV, Lima, Peru. The codes are shown in table 1.

In addition, a checklist of the parasitic records of Pacific barracuda *S. ensis* was prepared up to June 2021. For the elaboration of the list, the summaries of scientific meetings and pre-degree theses were not considered. The scientific names of the parasite and host species were reviewed following the classification schemes of the World Register of Marine Species (WoRMS, 2021).

Table 1. Ecological descriptors of the macroparasite community of *Sphyaena ensis* Jordan and Gilbert, 1882 from the north coast of Peru: PH, parasitized hosts; P%, prevalence percentage; MA, mean abundance; MI, mean intensity.

Tabla 1. Descriptores ecológicos de la comunidad de macroparásitos de la agujilla *Sphyaena ensis* Jordan and Gilbert, 1882 procedentes de la costa norte de Perú: PH, hospederos parasitados; P%, porcentaje de prevalencia; MA, abundancia media; MI, intensidad media.

Parasites	Deposit code	Site of infection	Strategy type	Total				Males				Females			
				PH	P%	MA	MI	PH	P%	MA	MI	PH	P%	MA	MI
<i>Pseudochauhanea</i> sp.	HPIA:196	Gill	Secondary	62	44.93	1.88	4.19	39	50.65	2.39	4.72	23	37.70	1.25	3.30
<i>Metamicrocotyla macracanta</i>	HPIA:197	Gill	Satellite	7	5.07	0.14	2.71	4	5.19	0.14	2.75	3	4.92	0.13	2.67
<i>Scomberocotyle</i> sp.	HPIA:198	Gill	Satellite	2	1.45	0.01	1.00	2	2.60	0.03	1.00	–	–	–	–
<i>Caligus</i> sp.	HPIA:199	Gill	Satellite	3	2.17	0.04	1.67	2	2.60	0.05	2.00	1	1.64	0.02	1.00
<i>Naobranchia kabatana</i>	HPIA:200	Gill	Satellite	2	1.45	0.04	3.00	2	2.60	0.08	3.00	–	–	–	–
<i>Parabrachiella</i> sp	HPIA:201	Gill	Satellite	1	0.72	0.01	1.00	–	–	–	–	1	1.64	0.02	1.00
<i>Cybicola</i> sp	HPIA:202	Gill	Satellite	4	2.90	0.09	3.25	4	5.19	0.17	3.25	–	–	–	–
<i>Didymozoon</i> sp.	HPIA:203	Gill	Satellite	7	5.07	0.14	2.71	5	6.49	0.21	3.20	2	3.28	0.05	1.50
<i>Contracaecum</i> sp.	HPIA:204	Mesentery	Satellite	2	1.45	0.03	2.00	2	2.60	0.05	2.00	–	–	–	–
Parasitic community	–	–	–	83	60.14	2.38	3.96	54	70.13	3.12	4.44	29	47.54	1.46	3.07

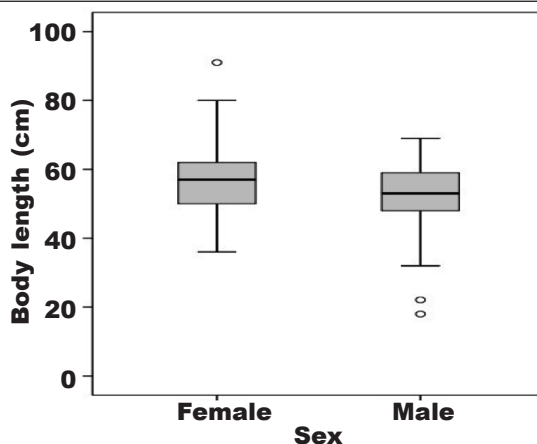


Fig. 1. Total body length of the Pacific barracuda *Sphyaena ensis* Jordan and Gilbert, 1882 from the north coast of Peru, in relation to sex.

Fig. 1. Longitud corporal total de la barracuda *Sphyaena ensis* Jordan and Gilbert, 1882 de la costa norte de Perú en relación con el sexo.

Results

The *S. ensis* population acquired consisted of 138 specimens, 55.8% of which were males ($n = 77$) and 44.2% were females ($n = 61$). The Kolmogorov–Smirnov test ($K-S = 0.07$, $p = 0.05$) for the TBL of males and females indicated that the data followed a normal distribution. The mean TBL of the *S. ensis* was 54.2 ± 9.8 cm, being 52.5 ± 9.6 cm in males and 56.3 ± 9.7 cm in females. The differences between females and males were significant ($t = 2.32$, $p = 0.02$) (fig. 1).

Table 1 shows the ecological descriptors of the Pacific barracuda *S. ensis* macroparasite community from the north coast of Peru (see also the checklist dataset published through GBIF, Doi: [10.15470/5htffh](https://doi.org/10.15470/5htffh)). This community consisted of 329 individuals distributed in four copepods, three monogeneans, a trematode and a nematode. Five macroparasite taxa were helminths and four were arthropods. In the total population of fish (males and females) the P% of infestation was 60.14% ($n = 83$). In the present study we observed a greater dominance of macroparasites in *S. ensis* by ectoparasites (88.89%) ($n = 8$) than by endoparasites ($n = 1$). The male populations presented higher parasitism by macroparasites, with a higher for P%, MA and MI than females (table 1). Of the nine macroparasites identified, 88.89% ($n = 8$) were found in the gills and only one was found in the intestines. Regarding the type of strategy, no species was considered satellite; only the monogenean *Pseudochauhannea* sp. presented the secondary strategy, and the remaining eight were satellites. This monogenean was the macroparasite species with the highest parasitological descriptor indices in the total population of fish, as well as in both sexes (table 1).

Male fish were parasitized by eight species of macroparasites, four of which were exclusive to males, while only five species of macroparasites were found in females, of which only one species was exclusive to females (table 1).

Of the seven TBL intervals for Pacific barracuda, the largest fish populations ranged from 45.1 to 54 cm and from 54.1 to 63 cm. In both ranges, the P%, MA and MI values were higher than in other ranges of length, with the exception of the range of 18–27 cm

Table 2. Ecological descriptors of the monogenean *Pseudochauhannea* sp. by intervals of total body length (cm) of *Sphyaena ensis* Jordan and Gilbert, 1882 from the north coast of Peru: TBL, total body length; P%, percentage of prevalence; MA, mean abundance; MI, mean intensity.

Tabla 2. Descriptores ecológicos del monogéneo *Pseudochauhannea* sp. por intervalos de longitud corporal total (cm) de la barracuda *Sphyaena ensis* Jordan and Gilbert, 1882 de la costa norte de Perú: TBL, longitud corporal total; P%, porcentaje de prevalencia; MA, abundancia media; MI, intensidad media.

TBL interval	TBL average	N° fishes	P%	MA	MI
[18–27]	20.1	2	100	14.5	14.5
[27.1–36]	33.3	3	33.3	1.3	4
[36.1–45]	42.3	18	33.3	1.3	4
[45.1–54]	50.6	46	47.8	2	4.2
[54.1–63]	59.1	53	50.9	1.96	3.9
[63.1–72]	66.2	13	30.8	0.5	1.8
[72.1–91]	82.3	3	0	0	0

that presented the highest values for the three descriptors of parasitic ecology. None of the nine macroparasite species was found in fish with a TBL > 72.1 cm ($n = 3$) (table 2).

Regarding the degree of association between the morphological parameters of the fish and the parasitological descriptors of *Pseudochauhannea* sp., we found that the TBL of the fish correlated negatively with the MI of infestation; that is, the greater the body length of the host, the lower the MI of the parasite (table 3). It was also observed that the MA of this macroparasite had a marked significant difference between the populations of male and female fish, being more associated with males (table 3). No relationship was observed between the TBL and sex versus the remaining ecological descriptors of *Pseudochauhannea* sp.

For the alpha diversity indices of the macroparasite communities in *S. ensis*, the number of individuals, Margalef, Equitability, and richness estimation using Chao–2 showed the values in the population of female fish were lower than in male fish. The average richness of macroparasite taxa was higher in males than in females ($t = 3.25$; $p = 0.001$). The Shannon index for macroparasites was higher in males than in females ($t = 2.79$; $p = 0.005$). In contrast, for the community component of macroparasites, according to the Simpson index a greater dominance was observed in female fish than in males ($t = 1.97$; $p = 0.04$). In all cases, the sampling was as expected in general, according to the Chao–1 estimate (table 4).

The NMDS ranking, which evaluates the pattern of the structure of the parasite community as a function of the abundance of parasite species with respect to sex, suggested a high degree of homogeneity between the communities (fig. 2). The ANOSIM analysis confirmed the high homogeneity between the parasite community and the host sex ($R = -0.007$, $p = 0.64$).

Finally, we developed a list of macroparasites recorded in fish of the genus *Sphyaena* present in the Eastern Pacific Ocean. According to the literature, records of parasite species are reported for only two species of *Sphyaena* in the Pacific Ocean, and all of these were collected off the coast of Mexico. In the present study, *S. ensis* is reported as a new host with eight macroparasite species and new geographic records are added (table 5).

Table 3. Correlation between the morphological parameters of the Pacific barracuda *Sphyaena ensis* Jordan and Gilbert, 1882 and the ecological descriptors of the monogenean *Pseudochauhanea* sp.: p, level of significance; rs, Spearman's correlation; r, Pearson's correlation; χ^2 , Chi-square test; Y, Yates's correction; t, Student's t-test; F, Levene's test for homogeneity of variances. (For other abbreviations see table 2, p-values in bold indicate significant values).

Tabla 3. Correlación entre los parámetros morfológicos de la barracuda *Sphyaena ensis* Jordan and Gilbert, 1882 y los descriptores ecológicos del monogéneo *Pseudochauhanea* sp.: p, nivel de significancia; rs, correlación de Spearman; r, correlación de Pearson; χ^2 , prueba de Chi cuadrado; Y, corrección de Yates; t, prueba de t de Student; F, prueba de Levene para homogeneidad de varianzas. (Para las otras abreviaturas, véase tabla 2, los valores de p en negrita son significativos).

Association types	<i>Pseudochauhanea</i> sp.	
TBL vs. P%	rs = -0.67	p = 0.12
TBL vs. MA	r = -0.71	p = 0.08
TBL vs. MI	r = -0.83	p = 0.02
Sex vs. P%	χ^2 = 2.30	p = 0.13
	Y = 1.81	p = 0.18
Sex vs. MA	F = 10.57	p = 0.00
	t = 2.37	p = 0.02
Sex vs. MI	F = 0.90	p = 0.35
	t = 1.70	p = 0.09

Table 4. Alpha diversity indices for the macroparasitic community according to the total population and sex of the Pacific barracuda *Sphyaena ensis* Jordan and Gilbert, 1882 from the north coast of Peru.

Tabla 4. Índices de diversidad alfa para la comunidad de macroparásitos según la población total y el sexo de la barracuda *Sphyaena ensis* Jordan and Gilbert, 1882 de la costa de Perú.

Alpha diversity	Total	Males	Females
Species richness	9	8	5
Average species richness	2.38	3.11	1.45
Individuals	329	240	89
Margalef	1.38	1.27	0.89
Dominance de Simpson (D)	0.63	0.60	0.74
Shannon (H)	0.88	0.95	0.57
Equitability (J)	0.40	0.46	0.35
Chao-1	9	8	6

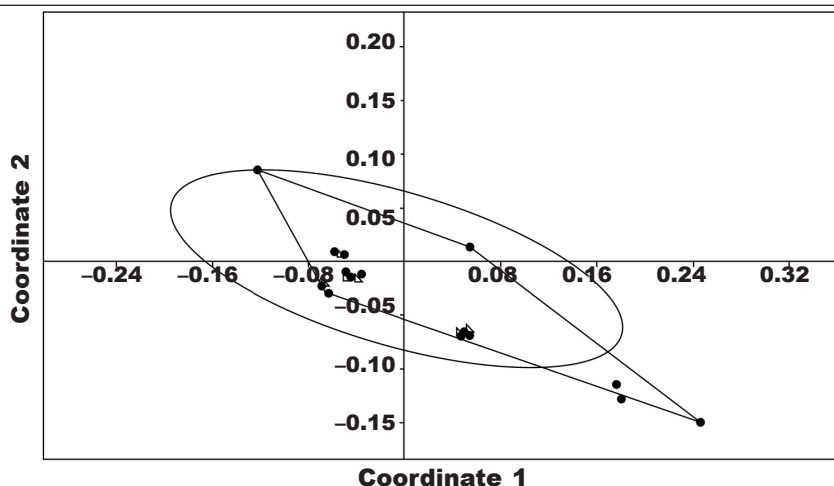


Fig. 2. Non-metric multidimensional scaling (NMDS) plotting sex results in the Pacific barracuda *Sphyræna ensis* Jordan and Gilbert, 1882 from the north coast of Peru (Δ females, ● males) in terms of the abundance of macroparasites. Bray Curtis similarity.

Fig. 2. Escalamiento multidimensional no métrico (NMDS) trazando los resultados del sexo en la barracuda *Sphyræna ensis* Jordan and Gilbert, 1882 de la costa de Perú (Δ hembras, ● machos) respecto a la abundancia de macroparásitos en la misma. Similitud de Bray Curtis.

Discussion

Our study shows that ectoparasites (monogenean, copepod) have a higher dominance in *S. ensis* than endoparasites. As the route of infestation of gastrointestinal endoparasites is closely associated to the host's diet (Poulin, 1995), it can be expected that opportunistic predatory fish that feed mainly on bony fish and zoobenthos, such as *S. ensis* (López-Peralta and Arcila, 2002; Moreno-Sánchez et al., 2019) are parasitized by a greater quantity and diversity of endoparasites. However, based on the collected samples of *S. ensis* parasites, these data come from the coast of Peru and additionally in the information in the literature (table 5), this does not occur in *S. ensis* because of the species of parasites reported for this fish; only two species are endoparasitic. According to Barber et al. (2000), some potential hosts may adopt a behavioral resistance, which consists of changing their behavior to reduce the risk of exposure. This change can occur in several ways, such as avoiding a specific habitat with a higher presence of parasites, or selecting prey, or by avoiding infected individuals to reduce the threat of being parasitized. Whether this is the case for *S. ensis* or whether it presents an effective immune response to the infestation of gastrointestinal parasites, the truth is that none of the alternatives apply to the ectoparasites found in this fish, which may present better strategies to avoid the resistance of the host.

The values of the ecological-parasitological descriptors presented in *Pseudochauhanæa* sp. demonstrate that it is the dominant species compared to other species of ectoparasites that share the same habitat. This monogenean was the only species with a P% above 10% and it also showed the highest MA and MI values. Only the TBL of *S. ensis* and the

Table 5. List of helminths and arthropods recorded in fish of the genus *Sphyaena* Artedi, 1793 present in the Eastern Pacific Ocean: ** new geographic records; * new records for the host.

Tabla 5. Lista de helmintos y artrópodos registrados en los peces del género *Sphyaena* Artedi, 1793 presentes en el océano Pacífico Oriental: ** nuevos registros geográficos; * nuevos registros para el huésped.

Host	Parasites	Taxa	Site of infection	Location	Reference
<i>Sphyaena argentea</i> (Girard, 1854)					
	<i>Paramonaxine yamagutii</i> (Bravo–Hollis, 1978)	Monogenean	Gill	Mexico	Bravo–Hollis, 1981
	<i>Bomolochus soleae</i> (Claus, 1864)	Copepod	Unknown	Mexico	Causey, 1960
	<i>Caligodes laciniatus</i> (Krøyer, 1863)	Copepod	Unknown	Mexico	Causey, 1960
	<i>Caligus productus</i> (Dana, 1852)	Copepod	Unknown	Mexico	Causey, 1960
	<i>Lepeophtheirus dissimulatus</i> (Wilson C.B., 1905)	Copepod	Unknown	Mexico	Causey, 1960
<i>Sphyaena ensis</i> (Jordan and Gilbert, 1882)					
	<i>Paramonaxine yamagutii</i> (Bravo–Hollis, 1978)	Monogenean	Gill	Mexico	Bravo–Hollis, 1978a, 1978b
	<i>Pseudochauhanea mexicana</i> (Lamothe, 1967)	Monogenean	Gill	Mexico	Lamothe–Argumedo et al., 1997; Lamothe–Argumedo, 1966; Pérez–Ponce De León et al., 1999
	<i>Pseudochauhanea elongata</i> (Kritsky, Bilqees and Leiby, 1972)	Monogenean	Gill	Mexico	Lamothe–Argumedo et al., 1997
	<i>Pseudochauhanea</i> sp.	Monogenean	Gill	Peru**	Present study
	<i>Metamicrocotyla macracantha</i> (Alexander, 1954)*	Monogenean	Gill	Peru	Present study
	<i>Scomberocotyle</i> sp.*	Monogenean	Gill	Peru**	Present study
	<i>Caligus</i> sp.*	Copepod	Gill	Peru	Present study
	<i>Naobranchia kabatana</i> (Dippenaar and Jordaan, 2008)*	Copepod	Gill	Peru**	Present study
	<i>Parabrachiella</i> sp.*	Copepod	Gill	Peru	Present study
	<i>Cybicola</i> sp.*	Copepod	Gill	Peru	Present study
	<i>Didymozoon</i> sp.*	Trematode	Gill	Peru	Present study
	<i>Contracaecum</i> sp.*	Nematode	Mesentery	Peru	Present study

MI of the monogeneans *Pseudochauhannea* sp. were negatively associated, with smaller fish presenting the highest parasitic load. Therefore, a more adequate explanation could be that the small specimens and juveniles of *S. ensis* are gregarious and form schools, while adults of large species are solitary or less gregarious (Zavala-Leal et al., 2018). For example, it is known that ectoparasite populations may be more abundant in fish with a schooling behavior than in solitary species because the probability of a transmission stage (e.g. eggs, larvae) contacting a host increases with greater host density (Santos-Bustos et al., 2020). Therefore, the aggregation behavior of smaller fish than larger fish favors the transmission of ectoparasites in *S. ensis*, such as the monogenean *Pseudochauhannea* sp., increasing its MI with the lower TBL of *S. ensis* (Poulin, 2011). Poulin (2011) reported that hosts with a greater TBL can provide the parasites with a greater supply of nutrients, making this the preferential fish population for parasite species and explaining why a greater diversity and parasite load would be expected (Iyaji et al., 2009). On the contrary, in this study we observed a negative correlation only between the TBL of *S. ensis* versus the MI of *Pseudochauhannea* sp. and most of the alpha diversity indices of macroparasites. This difference could be associated with several factors, such as a change in the feeding behavior of the host, in which the fish stops feeding on a certain organism that functions as a host and intermediate of a parasite, and it would explain the presence of endoparasites (Barber et al., 2000). Another possible explanation is the development of an immune reaction in older fish (Adams, 1985; Iyaji et al., 2009). The latter possibility could explain why the higher TBL ranges of the fish had a lower P% and parasite load (see table 2), although age and TBL are factors directly related to an increase in parasitism (Iyaji et al., 2009). However, it seems that the herding behavior of the *S. ensis* with the smallest TBL might more adequately explain the higher species richness, Margalef, Shannon, Equitability and Chao-1, and lower values of Simpson dominance of macroparasites.

Endoparasites were restricted to four nematode larvae specimens in the mesentery of two male *S. ensis* hosts. The route of infestation of gastrointestinal endoparasites is closely associated with the host's diet (Poulin, 1995). Taking this into account, it is to be expected that *S. ensis*, a predatory fish and opportunistic ichthyophagous, which feeds mainly on bony fish that form schools such as *Sardinops* spp. (40.36%), *Hemiramphus saltator* (40.24%), and also zoobenthos (López-Peralta and Arcila, 2002; Moreno-Sánchez et al., 2019) would be parasitized by a high number and diversity of endoparasites. Moreno-Sánchez et al. (2019) found no differences between the diet and the TBL and the sex of *S. ensis*. Based on the parasites found in *S. ensis* from the north coast of Peru, and according to the literature, this does not occur in *S. ensis*, since of the nine species of parasites registered in this fish (table 5), only one species is of the endoparasitic type, specifically the nematode found in this study. Although *Contracaecum* is considered zoonotic, the low prevalence makes it of low concern. Even so, it is important to make subsequent evaluations in *S. ensis* to observe changes in the dynamics of *Contracaecum* and if with time it becomes a secondary or main parasite in the community of parasites of the Pacific barracuda.

According to Barber et al. (2020), some potential hosts may adopt 'behavioral resistance', which consists of changing their behavior to reduce the risk of exposure. This change can occur in different ways such as avoiding a specific habitat with a greater presence of parasites or selecting prey or avoiding infected individuals in order to reduce the threat of becoming parasitized. Whether these changes are adopted by *S. ensis* or that these fish present an effective immune response against the infestation of gastrointestinal parasites remains to be determined, although neither of the latter options applies to the ectoparasites found in this fish, indicating that they may present other strategies to avoid resistance of the host.

The richness, diversity and parasite load of these parasites was greater in male fish than in female fish. When evaluating only the monogenean *Pseudochauhannea* sp., the dependence on the sex of *S. ensis* and the MI of *Pseudochauhannea* sp. is a clear indication of the preference of the parasites for male hosts. Indeed, experimental field studies have described that male fish specimens tend to be more parasitized than females from the same

fish population (Reimchem and Nosil, 2001). This occurs perhaps due to the effort made by males in sexual selection, which generates an energy cost and in turn brings them close to their physiological limits, resulting in higher stress levels and thereby making them more susceptible to infestation by parasitic organisms (Poulin, 1996; Wedekind and Jacobson, 1998; Iyaji et al., 2009). In the present study, *S. ensis* males presented a lower TBL than females, similar to that observed by Zavala-Leal et al. (2018), and this may be another factor to explain the higher parasite load in *S. ensis* males.

Sphyaena ensis has been documented as a host for three species of parasitic monogeneans with its records being restricted to only Mexico (Mendoza-Garfias et al., 2017). We report nine species of parasites in this study and the list is expanded to 11 species, eight of which are new records for the host fish (table 5). This list contributes to summarizing the current knowledge of the records of parasites in the genus *Sphyaena* from the eastern Pacific and serves as a point of comparison between what has already been documented what this study adds.

In Peru, studies related to parasitology in Pacific barracuda (*Sphyaenidae*) have not been addressed to date. This is the first study to document the macroparasite community of helminths and arthropods of *S. ensis* on the north coast of Peru. Likewise, it is the first ecological–parasitic study to address the association between the morphological parameters of the length and sex of *S. ensis* and the accompanying parasitic fauna and the possible influence of these parameters on their presence.

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