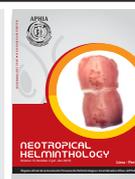




## Neotropical Helminthology



ORIGINAL ARTICLE / ARTÍCULO ORIGINAL

### COMMUNITY ECOLOGY OF THE METAZOAN PARASITES OF THREE BENTHOPELAGIC FISH SPECIES (PISCES: ACTINOPTERYGII) FROM THE COASTAL ZONE OF CALLAO, PERU

### ECOLOGÍA COMUNITARIA DE LOS METAZOOS PARÁSITOS DE TRES ESPECIES DE PECES BENTOPÉLAGICOS (PISCES: ACTINOPTERYGII) DE LA ZONA COSTERA DEL CALLAO, PERÚ

Jhon D. Chero<sup>1,2</sup>; Hernán Ortega<sup>2,3</sup>; Celso L. Cruces<sup>1</sup>; Gloria Sáez<sup>1</sup> & José Iannacone<sup>4,5\*</sup>

<sup>1</sup>Laboratorio de Parasitología General y Especializada, Facultad de Ciencias Naturales y Matemática (FCNNM), Universidad Nacional Federico Villarreal (UNFV), El Agustino, Lima, Perú

<sup>2</sup>Unidad de Posgrado, Facultad de Ciencias Biológicas, Universidad Nacional Mayor de San Marcos, Lima, Perú

<sup>3</sup>Departamento de Ictiología, Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Lima, Perú

<sup>4</sup>Facultad de Ciencias Biológicas, Universidad Ricardo Palma (URP), Santiago de Surco, Lima, Perú

<sup>5</sup>Laboratorio de Ecología y Biodiversidad Animal (LEBA), Facultad de Ciencias Naturales y Matemática (FCNNM), Universidad Nacional Federico Villarreal (UNFV), El Agustino, Lima, Perú

Corresponding author:\* E-mail: joseiannacone@gmail.com

## ABSTRACT

One hundred and eighteen benthopelagic fish specimens from the coastal zone of the Callao region, Peru, were necropsied from May 2015 to January 2016 to study their metazoan parasite community: 38 specimens of *Cheilodactylus variegatus* Valenciennes, 1833 (Cheilodactylidae), 66 of *Mugil cephalus* Linnaeus, 1758 (Mugilidae) and 14 of *Paralabrax humeralis* (Valenciennes, 1828) (Serranidae). Nineteen taxa of metazoan parasites were collected: 10 in *Ch. variegatus*, 4 in *M. cephalus* and 7 in *P. humeralis*. Only *Cheilodactylus variegatus* is a new host record for 7 species. Four species of parasites are new geographic records. The digeneans were the majority of the parasite specimens collected (37.85%) in *Ch. variegatus*. In *M. cephalus*, the majority of the parasite specimens collected were copepods and monogeneans which accounted for 77.78% of individuals collected. Five larval stages were found. The parasites of three host species showed the typical pattern of aggregate distribution observed in many communities of metazoan parasites of marine fish of Peru. In *M. cephalus*, the total length was correlated with the prevalence of 2 species of parasites. In *Ch. variegatus*, and *P. humeralis*, no relationship between the prevalence and abundance versus the length and sex of host was observed.

**Keywords:** ectoparasites – endoparasites – marine fish – parasite ecology – parasite of fish – South America

## RESUMEN

Ciento dieciocho especímenes de peces bentopelágicos de la zona costera de la región del Callao, Perú, fueron sometidas a una autopsia de mayo de 2015 a enero de 2016 para estudiar su comunidad de parásitos metazoos: 38 especímenes de *Cheilodactylus variegatus* Valenciennes, 1833 (Cheilodactylidae), 66 de *Mugil cephalus* Linnaeus, 1758 (Mugilidae) y 14 de *Paralabrax humeralis* (Valenciennes, 1828) (Serranidae). Diecinueve taxones de metazoos parásitos fueron recolectados: 10 en *Ch. variegatus*, 4 en *M. cephalus* y 7 en *P. humeralis*. Solo *Cheilodactylus variegatus* es un nuevo registro de huésped para 7 especies. Cuatro especies de parásitos son nuevos registros geográficos. Los digeneos fueron la mayoría de los especímenes de parásitos recolectados (37,85%) en *Ch. variegatus*. En *M. cephalus*, la mayoría de las muestras de parásitos recolectadas fueron copépodos y monogeneos con 77,78% de los individuos recolectados. Se encontraron cinco estadios larvarios. Los parásitos de tres especies hospedadoras mostraron el patrón típico de distribución agregada observado en muchas comunidades de parásitos metazoos de peces marinos del Perú. En *M. cephalus*, la longitud total se correlacionó con la prevalencia de 2 especies de parásitos. *Ch. variegatus* y *P. humeralis*, no se observó relación entre la prevalencia y la abundancia versus la longitud y el sexo del huésped.

**Palabras clave:** ectoparásitos – endoparásitos – peces marinos – ecología parasitaria – parásito de peces – América del Sur

## INTRODUCTION

Three hierarchical levels in studies of parasite communities are recognized: (a) infracommunities, which that include all individuals of different species of parasites within a single host. (b) component communities formed by all infracommunities within a population or host and (c) composite communities, that include all parasite communities in various hosts within an ecosystem (Bush *et al.*, 1997, 2001).

Community studies form the basis of any parasitological study and are useful for making comparisons between host species by their parasitological descriptors for evaluation of biodiversity loss or as indicators of pollution (Lafferty, 2012; Madanire-Moyo *et al.*, 2012; Madhavi & Lakshmi, 2012). Most studies of these biological systems consist of interpreting patterns of distribution and abundance of parasitic taxa as hosts themselves of variables such as their ontogenetic stage with samples usually taken in a lifetime opportunity (Ferrer-Castelló *et al.*, 2007).

One of the most suitable models to study ecological aspects of parasites is the aquatic system of metazoan parasites of marine fish (Luque & Poulin, 2007). For ease of collection of hosts and

for the possibility of obtaining a large number of replicas, parasites of fish are the most studied compared to any other group of vertebrates (Luque, 2008; Luque *et al.*, 2016). Many variables of fish hosts (intrinsic characteristics) and environmental (extrinsic) influence parasitic communities (Cruces *et al.*, 2014, 2015; Chero *et al.*, 2016). The latter have been used as tools to discriminate host populations, trophic interactions and to identify contaminated environments (Muñoz & Cribb, 2006; Pulido & Monks, 2008). The length and sex of the fish host are considered important ecological variables that relate to fluctuations in parasitic communities (Luque & Poulin, 2008; Iannacone & Alvarino, 2009ab).

In the present study, we report the community ecology of the metazoan parasites of three benthopelagic fish species at the component and infracommunity level from Callao, Peru.

## MATERIAL AND METHODS

Thirty eight specimens of *Cheilodactylus variegatus* Valenciennes, 1833 (Cheilodactylidae), 66 of *Mugil cephalus* Linnaeus, 1758 (Mugilidae) and 14 of *Paralabrax humeralis* (Valenciennes,

1828) (Serranidae) were necropsied between May 2015 and January 2016 from the coast of Callao, Peru (12° 4'S, 77°10'W) to study their community of metazoan parasites (Eiras *et al.*, 2006). Fishes were identified according to Chirichigno & Cornejo (2001). The average total lengths of the fishes were: *Ch. variegatus* 23 ± 4.61 (13–33) cm; *M. cephalus* 20.85 ± 5.31 (13–37) cm and *P. humeralis* 16.86 ± 0.84 (15–18) cm.

The ecological approximation of the metazoan parasite community was made to component and infracommunity levels (Esch *et al.*, 1990). The analyses included only parasite species with prevalence higher than 10% (Bush *et al.*, 2001).

The variance-to-mean ratio of parasite abundance (index of dispersion), computed using the program Quantitative Parasitology 3.0 (Rózsa *et al.*, 2000), was used to detect distribution patterns of the infrapopulations (Poulin, 1993; Amarante *et al.*, 2015). The dominance frequency and the relative dominance (number of specimens of one species/total number of specimens of all species in the infracommunity) of each parasite species were calculated according to Rohde *et al.* (1995). The parasite species diversity was calculated using the Brillouin index (*H*), because each fish analyzed corresponded to a fully censused community (Zar, 1996). For dominance, the Berger-Parker index (Bautista-Hernández *et al.*, 2013) was used. The Pearson's correlation coefficient *r<sub>p</sub>* was used to indicate the relationship between the host's total length and parasite abundance. Spearman's rank correlation coefficient *r<sub>s</sub>* was calculated to determine possible correlation between the total length of host and parasite prevalence, with previous arcsine transformation of the prevalence data (Zar, 1996; Bautista-Hernández *et al.*, 2013). The possible influence of host sex on abundance and prevalence of parasites was tested using the t-Student test and the chi-square test, respectively. Parasite species diversity was calculated using the Brillouin's index (*H*) (Zar, 1996). The probable variation of diversity in relation to host sex (Mann-Whitney test) and to host total length (Spearman's rank correlation coefficient) was tested.

The ecological terminology used follows Bush *et al.* (1997). Statistical significance level was evaluated at  $p \leq 0.05$ . Voucher specimens of metazoan parasites were deposited in the

Helminthological Collection and Related Invertebrates of the Museum of Natural History at the San Marcos University (MUSM), 3570-3590, Lima, Peru.

#### Ethic aspects

The authors point out that they fulfilled all national and international ethical aspects.

## RESULTS

### Component community

Nineteen different species of metazoan parasites were collected: 2 monogeneans, 4 digeneans, 1 cestode, 3 nematodes, 7 copepods and 2 acanthocephalans. Two species of metazoan parasites were common in at least two communities.

***Cheilodactylus variegatus*.** Ten species of metazoan parasites were collected (1 monogenean, 2 digeneans, 1 cestode, 2 nematodes, 2 acanthocephalans and 2 copepods) (Table 1). *Cheilodactylus variegatus* is a new host record for many of these species except the monogenean *Microcotyle nemadactylus* Dillon & Hargis, 1965, and the copepods *Caligus cheilodactyli* Krøyer, 1863 and *Clavellotis dilatata* (Krøyer, 1863). The monogenean *M. nemadactylus* was the most prevalent species and Opecoelidae gen. sp. the most abundant parasite collected 323 individuals (37.16% of all parasites). *Gonocercella* aff. *pacifica* was the species with the highest average value of relative dominance (0.37 ± 0.19), followed by *M. nemadactylus* (0.34 ± 0.17) and *Corynosoma* sp. (0.14 ± 0.03). Ectoparasite adults account for 42.58% of all collected parasites, endoparasite adults around 38.78% and larval endoparasites just 18.64%. The dispersion index (ID) showed five parasites found in *Ch. variegatus* the typical aggregation distribution pattern with the following sequence from highest to lowest: *M. nemadactylus* (12.40) > *Corynosoma* sp. (7.89) > *C. dilatata* (3.08) > *C. cheilodactyli* (2.86) > *Dichelyne* sp. (2.60). The type of distribution was not determined in 5 parasites due to lower prevalence (Table 1). The total length of the host showed no correlation with the prevalence and abundance of any parasite. Sex of host did not influence the prevalence and abundance of species of parasites.

***Mugil cephalus***. Four species of metazoan parasites were collected (Table 2). The monogenean *Metamicrocotyla macracantha* (Alexander, 1954) was the most abundant and prevalent and 82 specimens (59.94% of all parasites) were collected. *Metamicrocotyla macracantha* had the highest value of mean relative dominance ( $0.57 \pm 0.23$ ), followed by *Contracaecum* sp. ( $0.22 \pm 0.02$ ) and *Bomolochus nitidus* Wilson, 1911 ( $0.17 \pm 0.05$ ). All parasites of *M. cephalus* showed the typical pattern of aggregated distribution observed in many parasites systems: *M. macracantha* (4.21) > *B. nitidus* (3.97) > *Contracaecum* sp. (3.01) > *N. lizae* (1.56). Specimens of *Contracaecum* sp. ( $r_s = -1.00$ ;  $p = 0.000$ ) and *B. nitidus* ( $r_s = 1.00$ ;  $p = 0.000$ ) showed correlation between the total length of *M. cephalus* and prevalence. The total length of the host showed no correlation with the abundance of any parasites. Host sex did not influence the prevalence and abundance of any species of parasite.

***Paralabrax humeralis***. Seven species of metazoan parasites were collected (3 digeneans, 1 acanthocephalan and 7 copepods) (Table 3). *Paralabrax humeralis* is a new host record for the digeneans *Macvicaria* sp. and *Opecoelidae* gen. sp. The copepod *Hatschekia amphiprocesa* Castro-Romero & Baeza-Kuroki, 1986 was the most prevalent and abundant parasite with 169 individuals (52.81% of all parasites) collected. The copepod *H. amphiprocesa* was the species that had the highest frequency value of relative dominance ( $0.53 \pm 0.27$ ), followed by *Helicometra fasciata* (Rudolphi, 1819) Odhner, 1902 ( $0.33 \pm 0.14$ ) and *Hamaticolax paralabraxis* (Luque & Bruno, 1990) ( $0.07 \pm 0.05$ ) (Table 2). Adult ectoparasites represented 63.43% of all collected parasites, adult endoparasites around 35.31%, and endoparasitic larvae just 1.25%. The dispersion index (ID) showed five parasites of *P. humeralis* with the typical aggregated distribution pattern followed by *H. fasciata* (67.64) > *H. paralabraxis* (3.99) > *H. amphiprocesa* (7.84) > *C. quadratus* (2.81) > *Corynosoma* sp. (2.06). The distribution of 2 parasites was not determined due to lower prevalence of less of 10% (Table 3). The total length of the host showed no correlation with the prevalence and abundance of any parasite. The sex of *P. humeralis* was positively correlated with the prevalence of the copepod *H. paralabraxis* ( $X^2 = 4.66$ ;  $p = 0.03$ ). However, the abundance of the

remaining parasites was not correlated with the sex of the host ( $p > 0.05$ ).

#### **Infracommunities**

***Cheilodactylus variegatus***. Thirty-six (94.73%) specimens were parasitized by at least one parasite species. A total of 869 individual parasites were collected averaging  $22.86 \pm 35.04$  per host. The total length of the host was positively correlated with the abundance ( $r = 0.42$ ;  $p = 0.008$ ) and with the richness of parasites ( $r_s = 0.48$ ,  $p = 0.002$ ). Infections with 1 parasite species were found in five hosts (13.16%), biparasitism in 17 hosts (44.74%), triparasitism in 11 hosts (28.95%), tetraparasitism two hosts (5.26%) and pentaparasitism in a host (2.63%). The dominance index of Berger-Parker for infracommunities was  $0.45 \pm 0.19$ . The average value of Brillouin diversity index (H) was  $1.31 \pm 0.27$ . The average diversity of parasite species did not correlate with the total length of the host ( $r_s = 0.21$ ;  $p = 0.19$ ) and no significant differences between the diversity of parasites between male ( $H = 1.32 \pm 0.29$ ) and female hosts were observed ( $H = 1.26 \pm 0.22$ ) ( $Z_c = 102.5$ ;  $p = 0.13$ ).

***Mugil cephalus***. Fifty-eight (80.55%) specimens were parasitized by at least one parasite species. A total of 144 individual parasites were collected averaging  $2.83 \pm 2.71$  parasite / host. Host length did not correlate with the abundance ( $r = 0.15$ ;  $p = 0.22$ ) or with the richness of parasites ( $r_s = 0.12$ ,  $p = 0.30$ ). Infections with 1 species of parasite were found in 33 hosts (46%), double infections in 17 (24%) and triple infections in 8 hosts (11%). The dominance index of Berger-Parker for infracommunities was  $0.44 \pm 0.14$ . The average value of Brillouin diversity index (H) was  $0.80 \pm 0.07$ . The average diversity of parasite species did not correlate with the total length of the host ( $r_s = 0.05$ ;  $p = 0.65$ ) and no significant differences between the diversity of parasites of male ( $H = 0.80 \pm 0.06$ ) and female hosts were observed ( $H = 0.79 \pm 0.02$ ) ( $Z_c = 95$ ;  $p = 0.45$ ).

***Paralabrax humeralis***. All specimens of hosts were parasitized by at least one parasite species. A total of 320 individual parasites were collected averaging  $3.26 \pm 7.19$ . The length of the host did not correlate with the abundance ( $r = 0.13$ ;  $p = 0.64$ ) or with the richness of parasites ( $r_s = 0.35$ ,  $p = 0.21$ ). One host (7.14%) showed infection with one

parasite species and 7 (50%) with 3 (21.43%) and 2 (14.29%), and 1 (7.14%) with multiple infections of 2, 3, 4 and 5 species, respectively. The dominance index of Berger-Parker for infracommunities was  $0.52 \pm 0.14$ . The average value of Brillouin diversity index (H) was  $1.09 \pm$

0.15. The average diversity of parasite species did not correlate with the total length of the host ( $r_s = 0.32$ ;  $p = 0.26$ ) and no significant differences between the diversity of parasites of male ( $H = 0.83 \pm 0.46$ ) and female hosts were observed ( $H = 0.91 \pm 0.43$ ) ( $Z_c = -0.19$ ;  $p = 0.84$ ).

**Table 1.** Prevalence, intensity range, mean intensity, mean abundance, and site of infection of metazoan parasites found in *Cheilodactylus variegatus* from the coastal zone of Callao, Peru.

Parasites	Prevalence (%)	Intensity range	Mean intensity $\pm$ SD	Mean abundance $\pm$ SD	Site of infection
<b>Monogenea</b>					
<i>Microcotyle nemadactylus</i>	76.32	2–57	10.28 $\pm$ 2.80	7.84 $\pm$ 3.98	Gills
<b>Digenea</b>					
<i>Gonocercella aff. pacifica</i> †*	5.26	1–5	3 $\pm$ 7.95	0.16 $\pm$ 1.46	Intestine
Opecoelidae gen. sp. †*	7.89	57–203	107.67 $\pm$ 66.06	8.50 $\pm$ 4.44	Intestine
<b>Cestoda</b>					
<i>Adenocephalus pacificus</i> (larvae)*	2.63	1	1 $\pm$ 9.36	0.03 $\pm$ 1.55	Mesenteries
<b>Acantocephala</b>					
<i>Corynosoma</i> sp. (larvae)*	50	1–22	6.79 $\pm$ 5.27	3.39 $\pm$ 0.83	Mesenteries
<i>Proflicollis altmani</i> (larvae)*	2.63	27	27 $\pm$ 9.36	0.03 $\pm$ 1.55	Intestine
<b>Nematoda</b>					
<i>Dichelyne</i> sp.*	10.53	1–4	2 $\pm$ 8.66	0.21 $\pm$ 1.42	Intestine
<i>Proleptus carvajali</i> (larvae)*	2.63	5	5 $\pm$ 6.54	0.13 $\pm$ 1.48	Intestine
<b>Copepoda</b>					
<i>Caligus cheilodactyli</i>	21.05	1–5	2.75 $\pm$ 8.13	0.58 $\pm$ 1.16	Gills Operculum
<i>Clavellotis dilatata</i>	44.74	1–7	2.94 $\pm$ 7.99	1.32 $\pm$ 0.64	Gills

† New geographical record. \*New host record.

**Table 2.** Prevalence, intensity range, mean intensity, mean abundance, and site of infection of metazoan parasites found in *Mugil cephalus* from the coastal zone of Callao, Peru.

Parasites	Prevalence (%)	Intensity range	Mean intensity $\pm$ SD	Mean abundance $\pm$ SD	Site of infection
<b>Monogenea</b>					
<i>Metamicrocotyla macracantha</i>	51.39	1–7	2.22 $\pm$ 0.29	1.14 $\pm$ 0.45	Gills
<b>Nematoda</b>					
<i>Contraecum</i> sp. (larvae)	34.72	1–4	1.28 $\pm$ 0.38	0.44 $\pm$ 0.04	Kidney
<b>Copepoda</b>					
<i>Bomolochus nitidus</i>	11.11	1–5	3.125 $\pm$ 0.93	0.35 $\pm$ 0.11	Gills Operculum
<i>Naobranchia lizae</i>	11.11	1	0.63 $\pm$ 0.84	0.07 $\pm$ 0.30	Gills

**Table 3.** Prevalence, intensity range, mean intensity, mean abundance, and site of infection of metazoan parasites found in *Paralabrax humeralis* from the coastal zone of Callao, Peru.

Parasites	Prevalence (%)	Intensity range	Mean intensity $\pm$ SD	Mean abundance $\pm$ SD	Site of infection
<b>Digenea</b>					
<i>Helicometra fasciata</i>	78.57	1–37	9.73 $\pm$ 2.96	7.64 $\pm$ 3.10	Intestine
<i>Macvicaria</i> sp. †	7.14	1	1 $\pm$ 3.21	0.07 $\pm$ 2.26	Intestine
Opecoelidae gen. sp. †	7.14	5	5 $\pm$ 0.38	0.36 $\pm$ 2.06	Intestine
<b>Acantocephala</b>					
<i>Corynosoma</i> sp. (larvae)	14.28	2	2 $\pm$ 2.50	0.29 $\pm$ 2.11	Mesenteries
<b>Copepoda</b>					
<i>Caligus quadratus</i>	21.42	1–8	3.67 $\pm$ 1.32	0.79 $\pm$ 1.75	Gills Operculum
<i>Hamaticolax paralabracis</i>	50	1–8	3.29 $\pm$ 1.59	1.64 $\pm$ 1.15	Gills Operculum
<i>Hatschekia amphiprocesa</i>	85.71	3–37	14.08 $\pm$ 6.04	12.07 $\pm$ 6.23	Gills

†New geographical record.

## DISCUSSION

Findings indicate that the ectoparasites are the main components of parasite community of *M. cephalus*, where monogeneans dominance was observed, and *P. humeralis* dominance was with copepods. In the parasitic community of *C. variegatus*, digeneans endoparasites were the dominant.

Parasite community of *M. cephalus* is dominated by ectoparasites (copepods and monogeneans), that has previously been reported by Luque (1985) and by Iannacone & Alvarino (2009a) on the marine coast of Lima, Peru. However, the dominance of endoparasites in *M. cephalus* has been reported by Özer & Kurca (2015) off the coast of Turkey. These differences in the dominance of a particular group of parasites (ectoparasites and endoparasites) may be influenced by the hydrobiological conditions or regional

environmental or ecological conditions where the fish were caught (Ibáñez & Sinque, 1995). The dominance of ectoparasites has been reported for other parasitic communities in marine fish from the South Pacific Coast (Luque, 1994; Oliva & Luque, 1998).

Iannacone & Alvarino (2009a) indicated that the monogenean parasite *M. macracantha* and copepod *N. lizae* were the most prevalent species with prevalences of 36.4% and 22.9%, respectively. However, in the present research the monogenean *M. macracantha* and the nematode *Contracaecum* sp. were the most common species with prevalences of 51.39% and 34.72%, respectively. However, the copepods *B. nitidus* and *N. lizae* presented prevalence lower than 12%. The behavior of forming schools in the flathead grey mullet would probably facilitate the transmission of *M. macracantha*, since this species of parasite has a direct life cycle. The foraging habits would favor the transmission of the nematode

*Contracaecum* sp. when consuming infected free living copepods.

No correlation between the abundance of each parasite species and the length in the composition of the parasite community of *M. cephalus* was found. In contrast, only a correlation was found between the prevalence of *Bomolochus* sp. and *Contracaecum* sp. with the size of the hosts. Luque (1994) found that both the prevalence and mean infection intensity of *M. macracantha* were positively correlated with host length. However, Iannacone & Alvarino (2009a) did not find correlation between the prevalence and the abundance of each species of parasite with the length of flathead grey mullet. These differences may be caused by the influence of regional ecological disturbances. Poulin & Morand (2004) mention that larger body size host fish could provide more space, more nutrients, and possibly a wider variety of niches for parasitic species.

Our results indicate that there is no effect of host sex on parasite prevalence and abundance. These same results were found by Iannacone & Alvarino (2009a). Iannacone (2004) points out that the selection of parasites for one of the two sexes of host fish could be attributed to differences in the ecological relationships (habitat, behavior and feeding) of males and females. In this work, the same pattern was observed in other marine fishes of the Peruvian coast, where fish showed no difference in parasite prevalence and abundance in relation to host sex (Iannacone, 2003, 2004; Iannacone & Alvarino, 2008).

The parasites *B. nitidus* and *N. lizae* showed low prevalence values (11.11%). In contrast, Iannacone & Alvarino (2009a) observed low prevalence values (4.1%) for *B. nitidus* and relatively higher values (22.9%) for *N. lizae*. In a congeneric species of Brazil *Mugil platanus* (Günther, 1880), a prevalence of 30.6% was observed for *B. nitidus* (Knoff *et al.*, 1997).

The most prevalent taxa for *M. cephalus* were not the same in different years. During 1983-1986, the most prevalent taxa were *N. lizae*, *M. macracantha* and *Contracaecum* sp. (Luque, 1994). During 2008, *M. macracantha*, *N. lizae* and *H. manteni* were more prevalent (Iannacone & Alvarino, 2009a). In contrast, during 2015-2016 (present

study), *M. macracantha* and *Contracaecum* sp. were more prevalent. Also, species richness was not the same in different years: during 1983-1986, we recorded a total of 6 parasite taxa, 5 species in 2008, and 4 taxa in the present study (2015-2016). This could be the result of changes in the environmental conditions of the collection area, mainly the abiotic environmental factors of the Peruvian Fauna Province, the El Niño event and the upwelling phenomenon in the marine environment. Iannacone & Alvarino (2009a) indicate that variation in composition between years, involving trophic transmission of taxa, could be explained by the types of prey available and seasonal fluctuations of the intermediate hosts (Iannacone *et al.*, 2007). In addition, these authors point out that another factor that could explain the results obtained is the sampling period, which would cause seasonal variations in the parasites of *M. cephalus*; as well as in those that present intermediate hosts (Ñahui, 2006).

With the exception of ectoparasites that have been previously reported in *C. variegatus* in Peru by Oliva & Luque (1998) and Iannacone *et al.* (2003), all other species of parasites constitute new records for this host. On the other hand, most of the species of parasites that are in the Peruvian morwong have been previously reported in other hosts that inhabit the Peruvian sea (Luque *et al.*, 2016).

The results obtained in the present study show the predominance in numerical abundance and endoparasite taxa richness over ectoparasites (copepods and monogeneans) for the parasite community of *C. variegatus*. However, Oliva & Luque (1998) and Iannacone *et al.* (2003) reported the dominance of ectoparasites in *C. variegatus* off the coast of Chorrillos, Lima, Peru. For other communities of parasites in fish of the family Cheilodactylidae, the dominance of endoparasites has been well documented. Thus, Vooren & Tracey (2010) reported the dominance of endoparasites in the coastal zone of New Zealand in *Nemadactylus macropterus* (Forster, 1801). Rossin & Timi (2010) point to *Nemadactylus bergi* (Norman, 1937) from the coast of Mar de Plata (Argentina) dominance of endoparasites. According to Tam *et al.* (2008) dominance of endoparasites in the parasitic community component of marine fish can be attributed to the trophic behavior of hosts because they are mainly omnivorous fish, which include a

wide range of aquatic invertebrates that can act as intermediate hosts in the life cycle of several endohelminths. Alves & Luque (2006) attributed the dominance of endoparasites to the food habit, the trophic level and the geographical distribution of fish hosts (Gomez del Prado-Rosas *et al.*, 2017). Most studies of parasite communities in marine fishes on the Peruvian coast show a dominance pattern of endoparasites (Iannacone & Alvarino, 2008; Iannacone *et al.*, 2010; Iannacone *et al.*, 2012; Ñacari & Sánchez, 2014; Chero *et al.*, 2014abcd; Iannacone *et al.*, 2015).

Oliva & Luque (1998) and Iannacone *et al.* (2003) indicated a low parasite richness in the community of *C. variegatus*, registering 4 and 3 species of ectoparasites, respectively. However, our data show intermediate parasite richness, registering 10 species (three ectoparasites and seven endoparasites). These differences in parasite richness in *C. variegatus* could be attributed to the sampling period that may be related to seasonal variations in species richness. Intermediate richness of parasitic species have been reported for other fish communities in the Cheilodactylidae family (Marcogliese, 2002; Vooren & Tracey, 2010; Rossin & Timi, 2010).

The parasites *M. nemadactylus*, *Corynosoma* sp. and *C. dilatata* were the most prevalent species, with prevalences of 76.32%, 50% and 44.74%; respectively. In this study, these parasites are considered core species. These results are consistent with those obtained by Oliva & Luque (1998) and Iannacone *et al.* (2003) who point to *M. nemadactylus* as the most prevalent species. Rossin & Timi (2010) found a prevalence of 21%, for *M. nemadactylus* while *Corynosoma australe* was the most prevalent species.

The digenean Hemiuridae gen. sp., the tapeworm *A. pacificus*, the acantocephalan *P. altmani* and the nematode *Proleptus* sp. presented low values of prevalence (<6%) and are considered accidental species. Iannacone *et al.* (2009ab) assign the low prevalence of marine fish macro-parasite communities to the environmental conditions of the collection area, mainly to the abiotic environmental factors of the Peruvian Fauna, to the El Niño event, and to the upwelling phenomenon. They can be attributed to the low number of hosts analyzed or the narrow range of sizes analyzed

(Oliva & Luque, 1998).

A characteristic found during the sampling period (May 2015 to January 2016) indicates that 4 larval forms of endohelminths (*A. pacificus*, *Corynosoma* sp., *P. altmani* and *Proleptus* sp.) are part of the parasite community of *C. variegatus*. The presence of endohelminth larvae in the present study can be considered a reflection of the trophic level of *C. variegatus* that would act on an intermediate scale in the marine food chain, a consequence of a benthopelagic habitat.

All the parasites showed an aggregated or contagious distribution. This pattern is common in most host-parasite systems (Poulin, 2007). This fact seems to be related to the benthopelagic fish, because of the three fish species studied, 2 of them: *M. cephalus* and *P. humeralis* have an aggregate pattern and form large schools with a dominance of ectoparasites. This pattern of aggregate distribution (ID > 1) is typical for parasitic marine fish fauna on the Peruvian coast (Chero *et al.*, 2014abc). This type of pattern is common in most host-parasite systems (Poulin, 2007; Amarante *et al.*, 2015). According to Von Zuben (1997), 3 factors can lead to an aggregated pattern of distribution: (1) heterogeneity in host susceptibility to infection; (2) direct playback of the parasite within the host and (3) heterogeneity in the ability of the host to eliminate the parasites by immune response or other response (Amarante *et al.*, 2015).

In the present study, the total length of the Peruvian morwong correlated with the abundance and richness of parasites. According to Poulin & Moran (2004), larger fish hosts harbor greater parasite richness because they provide a wide variety of niches and can sustain a greater number of parasites. In fact, ontogenic changes in the composition of parasite communities in fish hosts are commonly reported in the literature (Rossin & Timi, 2010). Henríquez & González (2012) point out that another factor that could explain the results is the sampling period, which would cause seasonal variations in *M. cephalus* parasites; as well as those presenting intermediate hosts (Gomez del Prado-Rosas *et al.*, 2017).

The fact that copepods were the most abundant group in *P. humeralis* clearly shows that having a

direct life cycle, which does not involve more than one host, is an attribute that favors the dispersion and persistence of this group of parasites (Salgado-Maldonado & Rubio-Godoy, 2014).

Three species of digeneans, *Helicometra fasciata* (Rudolphi, 1819) Odhner, 1902, *Macvicaria* sp. and Opecoelidae gen. sp. have been recorded in *P. humeralis*. Of these species, *H. fasciata* presented high prevalence values in comparison with the other 2 species. This high prevalence could be related to fish diet and the availability of infective stages which depend mainly on the presence of appropriate mollusk first intermediate hosts and the crustaceans second intermediate hosts (Keeney *et al.*, 2008). *Helicometra fasciata* is a general species that has been recorded along the coast of the South Pacific (Peru and Chile) in 11 species of carnivorous fish hosts (Kohn *et al.*, 2007, Chero *et al.*, 2014ad; Luque *et al.*, 2016).

*Paralabrax humeralis* sex was positively correlated with the prevalence of *H. paralabracis* copepod. Iannacone *et al.* (2012) points out that the selection of parasites to one of the two sexes of host fish could be attributed to differences in ecological relationships (habitat, behavior and feeding) of males and females.

## ACKNOWLEDGEMENTS

The Authors would like to thank the Programa Nacional de Innovación para la competitividad y Productividad (Innovate Perú) for the financial support provided.

## BIBLIOGRAPHIC REFERENCES

- Alves, DR & Luque, JL. 2006. [Community ecology of the metazoan parasites of five Scombrid species (Perciformes: Scombridae), from the coastal zone of the State of Rio de Janeiro, Brazil]. Brazilian Journal of Veterinary Parasitology, vol. 15, pp. 167–181.
- Amarante, CF, Tassinari, WS, Luque, JL, Pereira, MJS. 2015. Factors associated with parasite aggregation levels in fishes from Brazil. Brazilian Journal of Veterinary Parasitology, vol.24, pp. 174–182.
- Bautista-Hernández, CE, Monks, S & Pulido, G. 2013. [Los parásitos y el estudio de su biodiversidad: un enfoque sobre los estimadores de la riqueza de especies]. Estudios científicos en el estado de Hidalgo y zonas aledañas, vol. 2, pp.3–17.
- Bush, AO, Lafferty, KD, Lotz, JL & Shostak, AW. 1997. Parasitology meets ecology on its own terms: Margolis *et al.* revisited. Journal of Parasitology, vol. 83, pp. 575–583.
- Bush, AO, Fernandez, J, Esch, G & Seed, JR. 2001. *Parasitism: The diversity and ecology of animal parasites*. Cambridge University Press. 566 p.
- Chero, J, Sáez, G, Iannacone, J & Aquino, W. 2014a. [Ecological aspects of parasites helminths of lorna drum *Sciaena deliciosa* (Tschudi, 1846) (Perciformes: Sciaenidae) acquired at the fishing terminal of Ventanilla, Callao, Peru]. Neotropical Helminthology, vol. 8, pp. 59–76.
- Chero, J, Cruces, C, Iannacone, J, Sáez, G, Alvariano, L, Rodríguez, C, Rodríguez, H, Tuesta, E, Pacheco, A & Huamani, N. 2014b. [Parasitological indexes of Peruvian Hake *Merluccius gayi peruanus* Ginsburg, 1954 (Perciformes: Merlucciidae) acquired at the fishing terminal of Ventanilla, Callao, Peru]. Neotropical Helminthology, vol. 8, pp. 141–162.
- Chero, J, Cruces, C, Iannacone, J, Saez, G & Alvariano, L. 2014c. [Helminth parasites of *Anisotremus scapularis* (Tschudi, 1846) (Perciformes: Haemulidae) "Peruvian grunt" acquired at the Fishing Terminal of Villa Maria del Triunfo, Lima, Peru]. Neotropical Helminthology, vol. 8, pp. 411–428.
- Chero, J, Iannacone, J, Cruces, C, Sáez, G & Alvariano, L. 2014d. [Community of metazoan parasites of corvina drum *Cilus gilberti* (Abbott, 1899) (Perciformes: Sciaenidae) in the coastal zone of Chorrillos, Lima, Peru.]. Neotropical Helminthology, vol. 8, pp.163–182.
- Chero, J, Sáez, G, Iannacone, J, Cruces, C, Alvariano, L & Luque, J. 2016. [Community

- ecology of metazoan parasites of Pacific Bonito *Sarda chiliensis* Cuvier, 1832 (Perciformes: Scombridae) de la Costa Peruana]. *Revista de Investigaciones Veterinarias del Perú*, vol. 27, pp. 539-555.
- Chirichigno, NF & Cornejo, RM. 2001. [Commented catalog of the marine fishes of Peru]. Instituto del mar del Perú. 314p.
- Cruces, C, Chero, J, Iannacone, J, Diestro, A, Sáez, G & Alvariano, L. 2014. [Metazoans parasites of "chub mackerel" *Scomber japonicus* Houttuyn, 1782 (Perciformes: Scombridae) at the port of Chicama, La Libertad, Peru]. *Neotropical Helminthology*, vol. 8, pp. 357-381.
- Cruces, C, Chero, J, Iannacone, J, Sáez, G & Alvariano, L. 2015. [Community of endohelminth parasites of yellowmouth blenny *Labrisomus philippii* (Steindachner, 1866) (Perciformes: Labrisomidae) from the central coast of Peru]. *The Biologist (Lima)*, vol. 13, pp. 91-109.
- Eiras, JC, Takemoto, RM & Pavanelli, GC. 2006. [Methods of study and laboratory techniques in fish parasitology]. Universidade Estadual de Maringá, Maringá. 199p.
- Esch, GW, Shostak, AW, Marcogliese, DJ & Goater, TM. 1990. *Patterns and process in helminth parasite communities: an overview*. In: Esch, G, Bush, AC & Aho, J. (Eds) *Parasite Communities: Patterns and processes*. New York. Chapman and Hall. pp. 1-19.
- Ferrer-Castelló, E, Raga, JA & Aznar, FJ. 2007. *Parasites as fish population tags and pseudoreplication problems: the case of striped red mullet *Mullus surmuletus* in the Spanish Mediterranean*. *Journal of Helminthology*, vol. 81, pp. 169-178.
- Gómez del Prado-Rosas, MC, Lozano-Cobo, H, Alvariano, L & Iannacone, J. 2017. *Comparison of biodiversity parasitic of *Paralabrax clathratus* (Girard, 1854) and *P. humeralis* (Valenciennes, 1828) (Pisces: Serranidae) from the eastern pacific*. *Neotropical Helminthology*, vol. 11, pp. 167-186.
- Henríquez, V & González, M.T. 2012. *Patterns of variation in parasite component communities and infracommunities of a littoral fish species from the northern coast of Chile*. *Journal of Helminthology*, vol. 88, pp. 89-96.
- Iannacone, J. 2003. [Three metazoan parasites of palm ruff *Serirolella violacea* Guichenot (Pisces, Centrolophidae), Callao, Peru]. *Revista Brasileira de Zoologia*, vol. 20, pp. 257-260.
- Iannacone, J, Alvariano, L, Guabloche, A, Alayo, M, Sánchez, J, Arrascue, A & Abanto, M. (2003). [Comunidades ectoparasitarias branquiales de la pintadilla *Cheilodactylus variegatus* Valenciennes 1833 (Pisces: Cheilodactylidae)]. *Parasitología latinoamericana*, vol. 58, pp. 59-67.
- Iannacone, J. 2004. [Metazoos parásitos de la mojarrilla *Stellifer minor* (Tschudi) (Osteichthyes, Sciaenidae) capturados por pesquería artesanal en Chorrillos, Lima, Perú]. *Revista Brasileira de Zoologia*, vol. 21, pp. 815-820.
- Iannacone, J, Alvariano, L & Bolognesi, B. 2007. [Aspectos cuantitativos de los metazoos parásitos del muy muy *Emerita analoga* Stimpson (Decapoda: Hippidae) en Chorrillos, Lima, Perú]. *Neotropical Helminthology*, vol. 1, pp. 59-67.
- Iannacone, J. & Alvariano, L. 2008. [Influencia del tamaño y sexo de *Peprilus medius* (Peters) (Stromateidae: Perciformes) capturados en Chorrillos, Lima, Perú, sobre su comunidad parasitaria]. *Neotropical Helminthology*, vol. 2, pp. 62-70.
- Iannacone, J. & Alvariano, L. 2009a. [Metazoos parásitos de *Mugil cephalus* Linnaeus, 1758 (Mugilidae: Perciformes) procedentes del Terminal Pesquero de Chorrillos, Lima, Perú]. *Neotropical Helminthology*, vol. 3: pp.15-28.
- Iannacone, J & Alvariano, L. 2009b. [Population dynamic of parasite diversity of the Peruvian Rock Seabass, *Paralabrax humeralis* (Teleostei: Serranidae) on Chorrillos, Lima, Peru]. *Neotropical Helminthology*, vol. 3, pp. 73-88.
- Iannacone, J, Morón, L & Guizado, S. 2010. [Variación entre años de la fauna de parásitos metazoos de *Sciaena deliciosa* (Tschudi, 1846) (Perciformes: Sciaenidae) en Lima, Perú]. *Latin American Journal of Aquatic Research*, vol. 38, pp. 218-226.
- Iannacone, J, Sánchez, V, Olazábal, N, Salvador, C, Alvariano, L & Molano, J. 2012. [Ecological

- indices of parasites of Scartichthys gigas (Steindachner, 1876) (Perciformes: Blenniidae) of the coasts of Lima, Peru*. Neotropical Helminthology, vol. 6, pp. 191-203.
- Iannacone, J, Alvarino, L, Chero, J & Sáez, G. 2015. [Parasite community of cabinza grunt *Isacia conceptionis (Cuvier & Valenciennes, 1830) (Perciformes: Haemulidae) in the area of Chorrillos, Lima, Peru*]. Revista de Investigaciones Veterinarias del Perú, vol. 26, pp. 96-110.
- Ibagy, AS & Sinque, C. 1995. [Distribution of eggs and larvae of (Teleostei, Perciformes, Sciaenidae) in the coastal region of Rio Grande do Sul, Brazil]. Arquivos de Biologia e Tecnologia, vol. 38, pp. 249-270.
- Keeney, DB, Boessenkool, S, King, TM, Leung, TL & Poulin, R. 2008. Effects of interspecific competition on asexual proliferation and clonal genetic diversity in larval trematode infections of snails. Parasitology, vol. 135, pp. 741-747.
- Knoff, M, Luque, JL & Amato, JF. 1997. Community ecology of the metazoan parasites of grey mullets, *Mugil platanus (Osteichthyes: Mugilidae) from the littoral of the state of Rio de Janeiro, Brazil*. Revista Brasileira de Biologia, vol. 57, pp. 441-454.
- Kohn, A, Fernandes, BMM & Cohen, SC. 2007. South American trematodes parasites of fishes. Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). Sao Paulo. pp.318.
- Lafferty, KD. 2012. Biodiversity loss decreases parasite diversity: theory and patterns. Philosophical Transactions of the Royal Society B: Biological Sciences, vol. 367, pp. 2814-2827.
- Luque, JL. 1985. [Parasitic helminths of *Mugil cephalus Linnaeus, 1758 (Osteichthyes: Mugilidae) of Lima, Peru*]. Lic. Biology Thesis. Lima, Peru. Ricardo Palma University.
- Luque, JL. 1994. [Population dynamics of *Metamicrocotyla macracantha (Monogenea: Microcotylidae) parasite of Mugil cephalus (Pisces: Mugilidae) in the central Peruvian coast*]. Revista de Biología Tropical, vol. 42, pp. 733-735.
- Luque, JL. 2008. [Parasites: A hidden component of the Biodiversity?]. The Biologist (Lima), vol. 6, pp. 5-7.
- Luque, JL & Poulin, R. 2007. Metazoan parasite species richness in Neotropical fishes: hotspots and the geography of biodiversity. Parasitology, 134: 865–878.
- Luque, J.L., Poulin, R. 2008). Linking ecology with parasites diversity in Neotropical fishes. *J. Fish Biol.*, 72: 189-204.
- Luque, JL, Cruces, C, Chero, J, Paschoal, F, Alves, PV, Da Silva, AC, Sánchez, L, Iannacone, J. 2016. Checklist of metazoan parasites of fishes from Peru. Neotropical Helminthology, vol.10, pp. 301-375.
- Madanire-Moyo, GN, Luus-Powell, WJ & Olivier, PA. 2012. Diversity of metazoan parasites of the Mozambique tilapia, *Oreochromis mossambicus (Peters, 1852)*, as indicators of pollution in the Limpopo and olifanta river systems. Journal of Veterinary Research, vol. 79, pp. 1-9.
- Madhavi, R & Lakshmi, TT. 2012. Community ecology of the metazoan parasites of the Indian mackerel *Rastrelliger kanagurta (Scombridae) from the coast of Visakhapatnam, Bay of Bengal*. The Journal of Parasitic Diseases, vol. 36, pp. 165-170.
- Marcogliese, D. 2002. Food webs and the transmission of parasites to marine fish. Parasitology, vol. 124, pp. 83-99.
- Muñoz, G & Cribb, TH. 2006. Parasite communities and diet of *Coris batuensis (Pisces: Labridae) from Lizard Island, Great Barrier Reef*. Memoirs of the Queensland Museum, vol. 52, pp. 191-198.
- Ñacari, L & Sánchez, L. 2014. [Helminth fauna of *Peprilus snyderi Gilbert & Starks, 1904 (Stromateidae) of Chorrillos fishmarket, Lima, Peru*]. Neotropical Helminthology, vol. 8, pp. 1-17.
- Ñahui, RED. 2006. [Spatio-temporal variability of sea surface temperature (SST) off the coast of Peru, using the TSM-Reynolds data]. Compendio de Trabajos de Investigación IGP, vol. 7, pp. 9-26.
- Oliva, ME & Luque, JL. 1998. Distribution Patterns of *Microcotyle nemadactylus (Monogenea) on Gill Filaments of Cheilodactylus variegatus (Teleostei)*. Memórias do Instituto Oswaldo Cruz, Rio de Janeiro, vol. 93, pp. 477-478.
- Oliva, M & Luque, JL. 2010. [Marine ichthyoparasitology in the up-welling

- Humboldt current system: challenges for Neotropical Helminthology journal*]. Neotropical Helminthology, vol.4, pp. 99-103.
- Özer, A & Kurca, D.Y. 2015. *Parasite fauna of the grey mullet Mugil cephalus L. 1758, and its relationship with some ecological factors in Lower Kızılırmak Delta located by the Black Sea, Turkey*. Journal of Natural History, vol. 49, pp. 1-24.
- Poulin, R. 1993. *The disparity between observed and uniform distributions: a new look at parasite aggregation*. International Journal for Parasitology, vol. 23, pp. 937-944.
- Poulin, R & Morand, S. 2004. *Parasite biodiversity*. British Library Cataloging, USA. 216p.
- Poulin, R. 2007. *The structure of parasite communities in fish hosts: ecology meets geography and climate*. Parasitologia, vol. 49, pp. 169-172.
- Pulido, G & Monks, O. 2008. [*Species of helminths introduced as bioindicators of environmental quality in Laguna de Metztilán, Hidalgo*]. En: Pulido-Flores, G, López-Escamilla, AL & Pulido-Silva, MT. (Eds.). [*Biological studies in the Natural Areas of the state of Hidalgo*]. Ciencia al día 7. Universidad Autónoma del Estado de Hidalgo, 2008; pp. 97-105.
- Rohde, K, Hayward, C & Heap, M. 1995. *Aspects of the ecology of metazoan ectoparasites of marine fishes*. International Journal for Parasitology, vol. 25, pp. 945-970.
- Rózsa, L, Reiczigel, J & Majoros, G. 2000. *Quantifying parasites in samples of hosts*. The Journal of Parasitology, vol. 86, pp. 228-232.
- Rossin, MA & Timi, JT. 2010. *Parasite assemblages of Nemadactylus bergi (Pisces: Latridae): the role of larval stages in the short-scale predictability*. Parasitology Research, vol. 107, pp. 1373-1379.
- Salgado-Maldonado, G & Rubio-Godoy, M. 2014. [*Helminths parasites of freshwater fishes introduced*] In: *Invasive aquatic species in Mexico*. Mendoza, R & Koleff, P. (Eds.). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México, D.F. pp. 269-285.
- Tam, J, Marc, H, Taylor, MH, Blaskovic, V, Espinoza, P, Michael-Ballón, R, Díaz, E, Wosnitza-Mendo, C, Argüelles, J, Purca, S, Ayón, P, Quipuzcoa, L, Gutiérrez, D, Goya, E, Ochoa, N & Wolff, M. 2008. *Trophic modeling of the Northern Humboldt Current Ecosystem, Part I: Comparing trophic linkages under La Niña and El Niño conditions*. Progress in Oceanography, vol. 79, pp. 352-365.
- Von Zuben, C.J. 1997. [*Implications of spatial aggregation of parasites for the population dynamics in host-parasite interaction*]. Revista de Saúde Pública, vol. 31, pp. 523-530.
- Vooren, CM & Tracey, D. 2010. *Parasites in tarakihi (Pisces: Cheilodactylidae) from three areas around New Zealand*. New Zealand Journal of Marine and Freshwater Research, vol. 10, pp. 499-509.
- Zar, J.H. 1996. *Biostatistical Analysis*. New Jersey, Prentice-Hall, Inc. 663 p.

Received, August 11, 2019.  
Accepted, October 2, 2019.