World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Community of metazoan parasites in a commercial fish *Mugil curema* Cuvier and Valenciennes, 1836 in Tuxpan, Veracruz México.

Margarita-Fuentes Olivares [1, 2, *], María Amparo-Rodríguez Santiago [3, 4, 5, 6], Karla Cirila-Garcés García [1] and Enrique-Ávila Torres [3]

[1] *University Veracruzana., Faculty of Biological and Agricultural Sciences, Túxpan Veracruz, México.*
[2] *Higher Tecchnological Institute of Álamo Temapache Veracruz, México.*
[3] *Institute of Marine Sciences and Limnology, Station "The Carmen", University National Autonomous of México. City of the Carmen, Campeche, México.*
[4] *National Council of Humanities, Sciences and Technologies (CONAHCyT), México.*
[5] *One Health-Research Network One Health University Ricardo Palma, Lima-Perú.*
[6] *Environmental Sustainability Research Group (GISA), Graduate University School. Federico Villarreal National University, Lima, Perú.*

World Journal of Advanced Research and Reviews, 2024, 24(03), 233–245

Publication history: Received on 15 October 2024; revised on 30 November 2024; accepted on 02 December 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.3.3636

Abstract

The purpose of this study was to identify the component of the community of metazoan parasites in *Mugil curema* representative for its commercial value for the zone of Túxpan, Veracruz, Mexico. The analysis was carried out in the collection of 131 individuals between April 2022 and May 2023, of which 59.54% were females and 40.45% were males and with a sex ratio of 0.679:1. The most significant stage was the immature stage for the drought/season with 6 parasitized hosts, for the cold wind season 15 fish infected with some type of parasite and for the rainy season 9 infected. The average total length (TL) for males was of 31. 65 ± 8.08 cm, and the average weight of 315.86 ± 202.81 g and for females the LT was of 34.32 ± 6.56 cm and the weight of 373.20 ± 213.93 g. A richness of 6 parasite species was recorded, of which 4 were ectoparasites (*Dicrogaster* sp., *Caligus* sp., *Ergasilus* sp. and *Benedenia* sp.) and 2 endoparasites (*Floridosentis mugilis* and *Contracaecum* sp.).

Keywords: Ectoparasites; Endoparasites; *Mugil curema*; Marine biology; Infra-community

1. Introduction

In Mexico, the study of the structure of parasite communities in marine and estuarine fish has recently gained greater attention because knowledge of the ecological patterns and processes in host-parasite relationships has still been poorly described [1]. Currently, the few studies addressed have considered metazoan parasites as independent communities and not as members of a complete parasitic community [2]. It has also been found that most studies present only taxonomic records, others have focused on a single taxon of parasites (e.g. monogeneans, copepods, nematodes, cestodes, trematodes, etc.), or only host fish of economic and fishery importance have been considered [3].

A fundamental factor in the analysis of parasites is that they must be carried out based on community-level studies since they are representative and very useful for making comparisons between host species through their parasitological descriptors, for the purposes of evaluating biodiversity loss or as indicators of contamination and ecosystem health [4]. Particularly, in the Port of Tuxpan, Veracruz, where commercial species such as the lebrancha, *Mulgil curema,* represent one of the species of greatest economic importance for the Gulf of Mexico region, there are few studies in marine fish on parasites [5, 6, 7, 8]. *M. curema* is captured throughout the year and according to data from the National Commission of

*Corresponding author: Fuentes Olivares Margarita

Aquaculture and Fisheries of Mexico, in 2018 the capture volumes were 21,089 tons [9, 10]. This species represents a traditional consumption resource, both on the coasts of the Gulf of Mexico and the Pacific, recording significant capture data. Regarding the region of Tuxpan, Veracruz, few studies have been conducted regarding parasitological analysis and identification in fish; highlighting that *M. curema* has representativeness as a food source, as well as commercial importance.

Due to the few studies on parasite ecology of estuarine fish, it is important, on the one hand, to identify the parasite species that they host, on the other hand, to describe the structure of the parasite communities especially when dealing with commercially important fish that represent one of the main food sources in this region of Mexico [11]. *Mugil curema* has a wide geographic distribution in the Gulf of Mexico, mainly living in coastal systems and estuaries. Juveniles of these fish species enter coastal lagoon systems and estuaries as a means to achieve their development and then migrate to coastal pelagic zones to spawn [12, 13, 14].

Given the above, the present project contemplates a parasitological study in a species of fish of commercial importance in the region of the Port of Tuxpan, Veracruz Mexico. Particularly, it focused on *M. curema* Cuvier and Valenciennes, 1836 (21,089 tons), which stand out for their capture volumes [10]. This species is part of the group called commercial fishing and is captured by artisanal fishing as an essential part of the food and recreation that takes place on the coast and throughout its distribution [13]. In Mexico there is a large number of commercial species of ichthyofauna that can act as vehicles of transmission to human of parasitic agents of the metazoan type, which representatively implies a health problem for the consumer when ingesting species of fish with parasitic load that can compromise the health of the population when ingesting poorly cooked or raw fish. In this context, possible emerging pathologies are identified that condition the health of consumers and where it is necessary to carry out research in aspects such as the identification of the parasites involved, new host species, structure and richness of the parasitic load in species of fish intended for human consumption as a source of poorly cooked or raw nutrition [14].

The present proposal aims to: 1) identify the parasitic fauna (ecto- and endo-metazoan parasites) that this fish species host, 2) to describe the structure of the parasite communities, and 3) to evaluate the intra-annual variability in the abundance and richness of parasite species and their relationship with the size and weight of the host fish. This study contributes to the knowledge of the biodiversity of metazoan parasites in estuarine fish in the Gulf of Mexico and allows the evaluation of the possible presence of parasite species that are potentially zoonotic for humans.

2. Material and methods

A total of 131 individuals of *M. curema* were collected between April 2022 and May 2023 in the Tampamachoco commercial area of Túxpan, Veracruz, Mexico (between 20 ° 58' 93 '' and 21 ° 02' 28 '' north and 97 ° 19' 99 '' and 97 ° 23' 10 '' west). External cavities such as nasal cavities, oral cavity, eyes, fins, opercula, gills, cloaca and scales and internal organs such as the bladder, brain, kidney, liver, spleen, esophagus, heart, mesentery, intestines, stomach and coelomic cavity were examined for the extraction of parasites. Once the metazoan parasites were extracted, they were collected in vials to later be mounted, fixed, preserved and stained [15]. The species accumulation curve established by Colwell [16, 17] was determined, the sex ratio and sexual maturity of *M. curema* were analyzed with the analysis of the gonads according to Nicolsky's criteria [18]. The total length (in cm) and weight (in grams) of the total number of hosts were also determined, as well as the variances and averages with respect to $P(T \leq t)$ [19].

The structure and richness of parasitic metazoans was determined with the identification of parasitic populations using the quantitative prevalence parameters for the parasitic fauna component of *M. curema*, in relation to the average intensity for the species with the greatest dominance [12-14]. The data of abundance, prevalence and intensity and dominance of Berger-Parker allowed us to identify the proportion of the most abundant species with respect to the total number of parasites. It was calculated the abundance, intensity and prevalence of parasitic species according the criteria of Bush [20]. The Shannon-Wiener index (H') was used to describe the community composition in terms of the richness and relative evenness of the distribution of the species [21]. The non-parametric Berger-Parker index was used to identify the proportion of the most abundant species in relation to the total number of parasites in the samples obtained. The degree of contagion of a parasitic species in the host population was evaluated; with the support of the aggregation index, the degree of contagion of a parasitic species in the host population was determined [22].

The gonasomatic index (IGS) was related to the weight of the gonads, expressing it as a percentage of the total weight of the fish. With this index, the cyclical variation of the reproductive activity was graphically observed with respect to time [23]. With the hepatosomatic index (IHS) the value of the participation of the hepatic reserves in the production of eggs was determined, which was related to the liver, since it is a storage organ for fats and glycogen that participates directly in the formation of exogenous vitellogenin as the maturation of the ovaries progresses. It was calculated by establishing the relationship between the weight of the liver and the eviscerated weight of the fish, expressed as a percentage [24, 32]. The somatic index of the spleen was determined, which corresponds to an immune indicator as a host defense response against parasites [25]. The spleen is a lymphatic organ and its importance lies in the process of hematopoiesis and in the immunological activity of teleost fish; reacting with the production of antibodies. This index has been used as a method of evaluation of immunological response in fish as a product of parasitism [26].

Fish that have a smaller spleen in relation with a larger liver corresponds to an indicator of greater immunological stress, that is, it represents the relationship of the activation of the immune system. Thus we have that a large spleen is an indicator of some long-term infectious process or an environmental alteration [27]. Fulton's condition factor (K) was estimated to determine the degree of well-being or robustness of the species under study, considering that it allowed us to compare fish with similar length and weight [28].

3. Results and discussion

3.1. Collections

Sampling collections were carried out with a total of 131 individuals of *M. curema* as hosts during the months of June 2022 to August 2023. The sampling coverage obtained for the months of September 2022 and April 2023 was of 88.10% and 92.42% respectively, compared to the month of January 2023 where a coverage of 100% was obtained [29, 31].

3.2. Sex ratio and stages

Regarding the sexual proportion of the 131 individuals that were collected, 59.54% were females and 40.46% were males, with a sexual proportion of 0.679:1. For *M. curema* we have a proportion with a bias towards females as dominant compared to males, which is an indicator that the reproduction of offspring is ensured. Regarding the phases of sexual maturity for stages, we have that the mature state was represented by 6.03%, maturing 9.48%, immature 70.69%, declining 6.03% and spawned 1.72% and undefined 6.03%, with the immature state registering a higher proportion and the spawned type to a lesser extent. The most significant stage was for the immature; for the dry season, as there were 6 parasitized hosts, of which 3 were females and 3 males, and 18 were not parasitized, 13 females and 5 males; and for the northern season, 15 fish were recorded infected with some type of parasite, of which 11 were females and 4 males in an immature stage, and for the rainy season, 9 were infected by some type of endo and/or ectoparasite, of which 6 were females and 3 males. It is important to mention that for *M. curema*, 14 hosts had more than one parasite and 48 had some type of parasite.

3.3. Total length and weight of hosts

The length and weight of fish were initially used to obtain information on the growth status of the fish and to determine whether somatic growth was of the isometric type (i.e. when the weight increases proportionally to the length), or otherwise, that condition of growth in allometric type fish where the weight does not increase proportionally to the length [27, 30]. However, it was recorded that the total length for *M. curema* for males ranged between 25 cm and 65 cm for total length, average LT of 31.65 ± 8.08 cm and for females it ranged between 26 cm and 62 cm with average LT of 34.32 ± 6.56. Regarding the weight of *M. curema* males, it ranged between 109 g and 820 g, with an average weight of 315.86 ± 202.81, and for females between 921 g and 113 g, with an average weight of 373.20 ± 213.93 g. The relationship of the weights with respect to P ($T \leq t$) of 0.124 indicates a significant difference with respect to weights of males with females, presenting the same case for the length with a value of 0.049, and with respect to the weight-length analysis, males present a smaller significant difference compared to females (Figure 1). For the isometric test analysis, two hypotheses were formulated regarding the length and weight relationship, the first is if in the case that "there is no difference between the length and weight relationship, therefore, it is said that the difference is isometric" and second hypothesis "if there is a difference between the length and weight relationship, then it is established that the relationship is of the allometric type" [26]. Thus, we have that our p value (1.9E-16) for *M. curema* evaluates the hypothesis of a p value < 0.05 was significantly different from 3 to which tells us that our hypothesis that for *M. curema* there is a difference and, therefore, our fish grow disproportionately, so the relationship tells us that there is no isometry but a negative allometry. In other words, it is that our predictor that has a value ofet (9.45) calculated greater than at tables (1.96) and a p of 1.9E-16, therefore, the existence of isometry is rejected, a larger p value (insignificant) suggests that changes in the predictor are not associated with changes in the response as shown in this case presenting allometric growth.

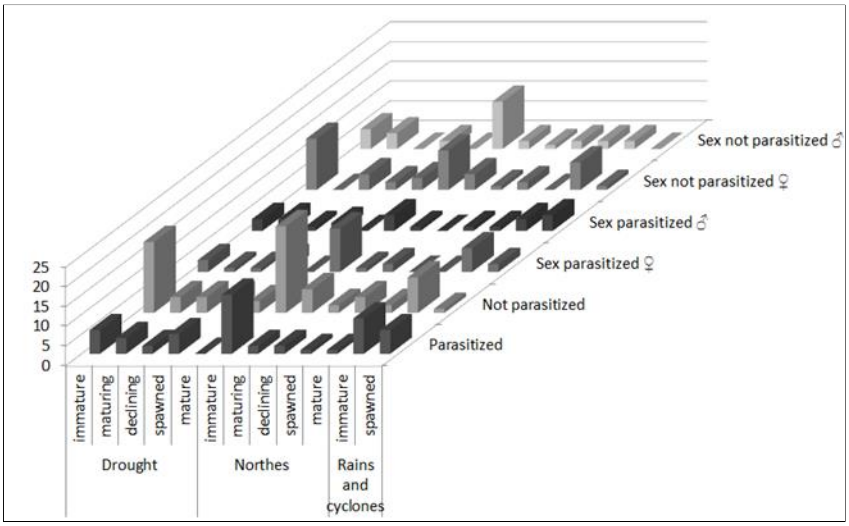


Figure 1 Graphical representation of stages for *M. curema*

For the adjusted regression curve it is observed that adjusted R^2 was of 0.401 (Figura 2), which represents a change with respect to length and weight and the adjustment line increases or falls by 88.82 g. Likewise, we observed a flat adjustment line of the length variable that indicates that a determination coefficient of 0.405 was obtained and with respect to the confidence interval values with a lower limit of 0.0081 and an upper limit of 0.00529, therefore it is concluded that there is no isometry for *M. curema* and a small probability and the existence of isometry between the variables of length and total weight is rejected.

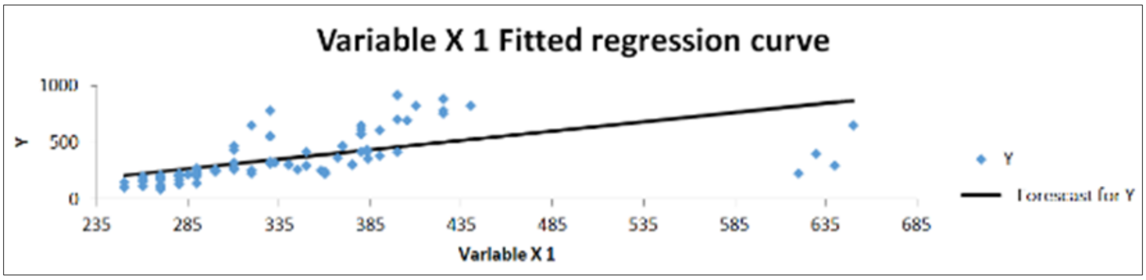


Figure 2 Graphical representation of weights-lengths for *M. curema*

Is observed that higher frequencies for length were of 286.36 cm, followed by 322.72 cm and 395.45 cm, and those of lower frequency of 613.63 cm, 468.18 cm and 250 cm (fig. 3 and 4). Regarding weights, values that ranged between 242.72 g and 318.09 g are frequently presented and less frequently between 92.54 g, 694.90 g and 770.27 g.

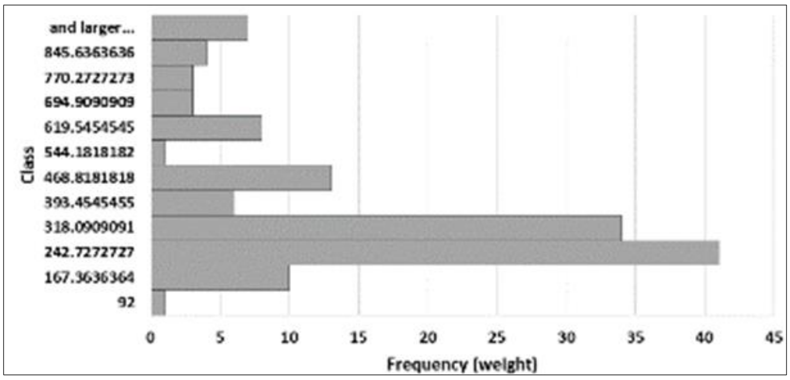


Figure 3 Graphical representation of weight frequencies for *M. curema*

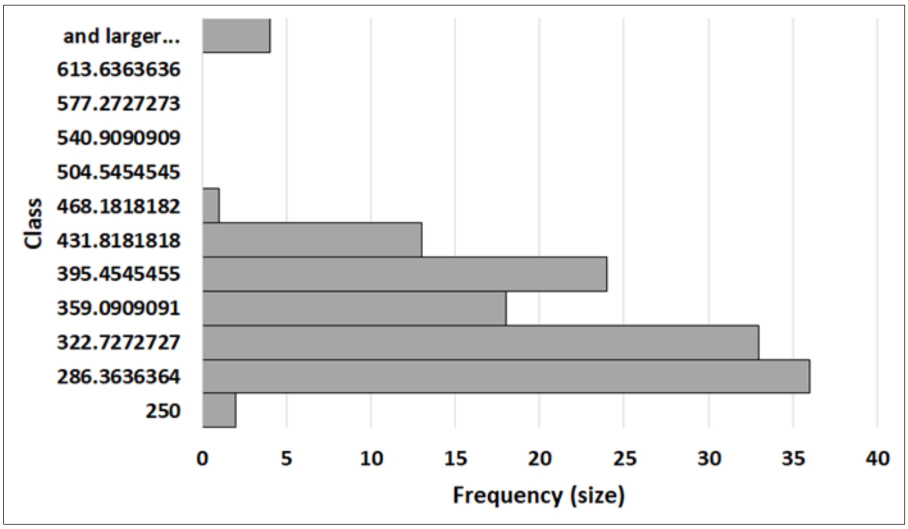


Figure 4 Graphical representation of length frequencies for *M. curema*

3.4. Component community

The parasitic structure present in *M. curema* presented four different phylum of parasitic metazoans (platyhelminthes, nematodes, arthropods and rotifers) and four classes of Monogenean represented by *Benedenia* sp. (47%), *Caligus* sp. (63%), and *Ergasilus* sp. (20.74%), the nematode *Contracaecum* sp. (17.01%), the Acanthocephala *Floridosentis mugilis* 23.23% and the digenean *Dicrogaster* sp. 0.42%. It is important to mention that the species with the highest presence was *Caligus* sp. (63%) followed by *Floridosentis mugulis* (56%) and *Ergasilus* sp. (50%).

In figures 5 and 6, as can be seen, there was a greater presence of ectoparasites with 60% compared to endoparasites (40%). It is also important to mention that the female hosts (30%) had a greater presence of parasites compared to the males (20%). Based on the records presented in Table 2, the organs with the highest parasitic load for *M. curema* were the gills and body surface. It is important to mention that with respect to the number of infected hosts, the acanthocephala class was present in 15 hosts, its habitats were the intestines, mesentery and liver, a similar case for *Ergasilus* sp. (11 infected) and *Benedenia* sp. (10 infected) which were in the gills and body surface.

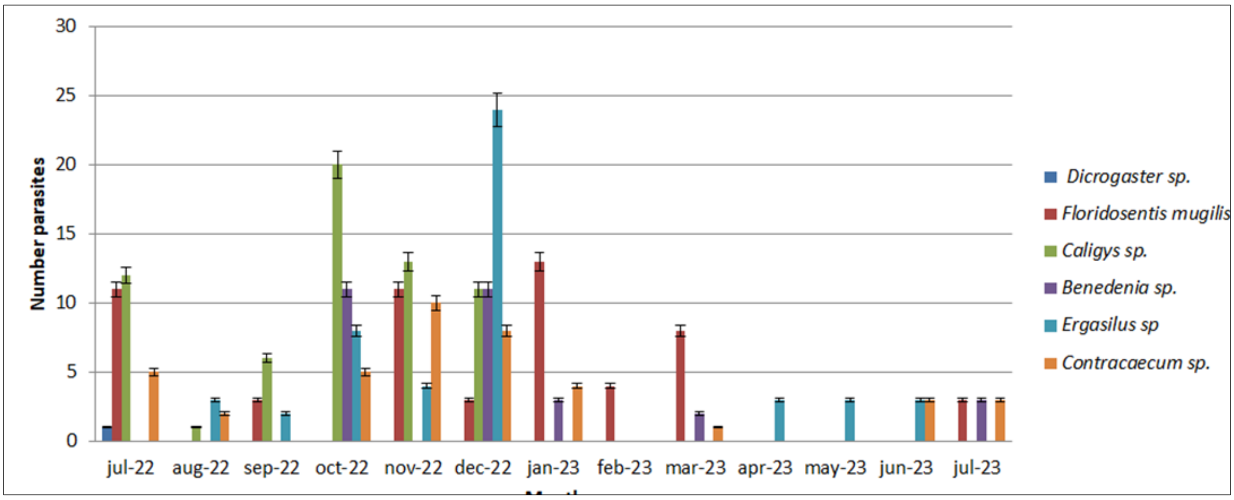


Figure 5 Parasitic component community for *Mugil curema* per month

.

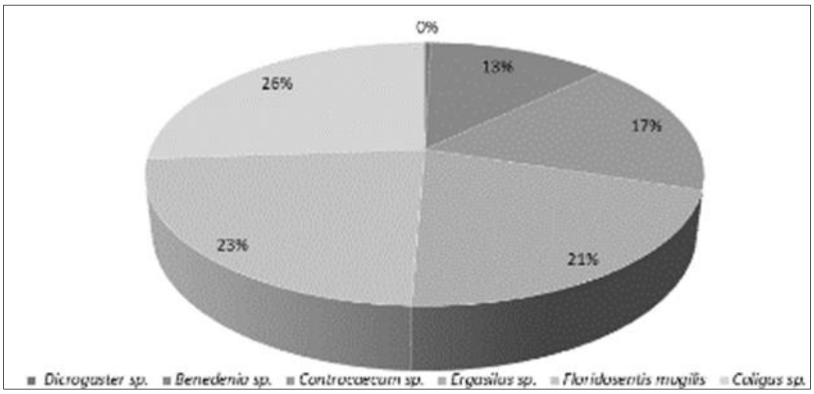


Figure 6 Parasitic component community for *Mugil curema*

3.5. Average prevalence, intensity, abundance and distribution

A 56.48% of the host individuals presented some type of parasitic metazoan and in relation to the ecological descriptors six types of metazoans were recorded: ascarid (*Contracaecum* sp.), Acanthocephalan (*Floridosentis mugilis),* digenean (*Dicrogaster* sp.), monogenean (*Benedenia* sp.) and two copepods (*Caligus* sp. and *Ergasilus* sp.). In parasitological terminology, we have that prevalence corresponds to the number of hosts infected by a certain parasitic species identified in its host divided by the total number of hosts examined and is expressed as a percentage; thus, we have that both, the acanthocephalan *Floridosentis mugilis* and the nematode *Contracaecum* sp., have a prevalence of 14.5%, followed by the ectoparasitic copepods *Caligus* sp. (13.7%), *Ergasilus* sp. (7.6%), the monogenean *Benedenia* sp. (5.343%) and the digenean *Dicrogaster* sp. (0.76%). It can be noted that the prevalence of this ectoparasite in our parasitic community was very low. Let us remember that intensity refers to the number of a particular parasitic species in a sample of infected hosts and the abundance refers to the number of parasites of a particular species in a sample of hosts without considering whether the host are infected or not [25, 30]. Of the 131 individuals collected, 81 of them did not present any type of ecto or endoparasite and 50 presented some type of metazoan parasite. In the dry season, a total of 33 hosts were recorded with some type of metazoan parasite, of which 22 were females and 11 males. In the rainy season, a total of 12 hosts were parasitized, of which eight were females and four were males. In the north-winds season, 36 hosts had some type of parasite, of which 17 were females and 19 were males. This represents a total of 81 hosts that presented some type of metazoan parasite and 50 were free of ecto or endoparasites. For the rainy season, the parasite with the highest prevalence was *Floridosentis mugilis* and *Caligus* sp. with 4.5% and with less significance the Digenean with 0.7%, for north the most prevalent was identified again as *Floridosentis mugilis* with 9.1% and the least significant is the monogenean (*Benedenia* sp.) (Fig.78) with 2.2% and finally for rains the most prevalent is the copepod *Caligus* sp. with 4.5% also the nematode (*Contracaecum* sp.) and the least representative the acanthocephalan *Floridosentis Mugilis* with a prevalence of 0.7%; very similar behavior for intensity and abundance. It should be noted that for *M. curema* the organ most infected by some type of parasite was recorded the body surface and soft organs were those that did not present significant parasitic load.

Table 1 Infection parameters in *M. curema*

Parasite		**P (%)**	**I**	**A**	**D**
Digenea	*Dicrogaster* sp.	0.763	1	0.007	satellite
Acanthocephalan	*Floridosentis mugilis*	14.503	2.947	0.427	secondary
Arthropod	*Caligus* sp.	13.740	3.5	0.480	secondary
Nematode	*Contracaecum* sp.	14.503	2.157	0.312	secondary
Monogenea	*Benedenia* sp.	5.343	4.285	0.229	satellite
Arthropod	*Ergasillus*sp	7.633	5	0.381	satellite

*P: prevalence, I: intensity, A: abundance, D: distribution

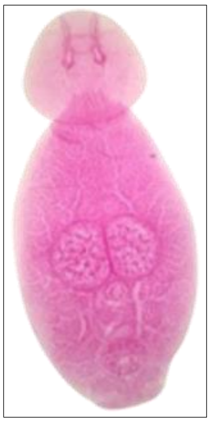


Figure 7 Monogenean specimen belonging to the Genus *Benedenia* sp.

Table 2 Prevalence records in *M. curema*.

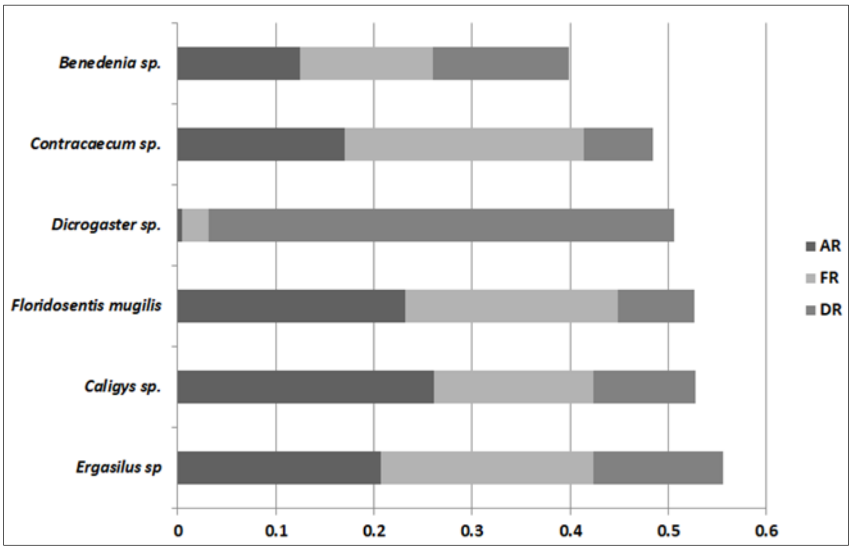
Season	Parasite		Location place
Drought/low water	Digenea	*Dicrogaster* sp.	SP
	Acanthocephalan	*Floridosentis mugilis*	CE, M, H
	Arthropod	*Caligus* sp.	SP, B
	Nematode	*Contracaecum* sp.	I, M
	Monogenea	*Benedenia* sp.	B
	Arthropod	*Ergasilus* sp.	SP, B
Norths	Acanthocephalan	*Floridosentis mugilis*	M, H, I
	Arthropod	*Caligys* sp.	SP, B
	Arthropod	*Ergasilus* sp.	SP, B
	Nematode	*Contracaecum* sp.	I, M, H
	Monogenea	*Benedenia* sp.	B
Rains and cyclones	*Arthropod*	*Caligus* sp.	SP, B
	Nematode	*Contracaecum* sp.	H, I
	Acanthocephalan	*Floridosentis mugilis*	H
	Arthropod	*Ergasilus* sp.	SP
	Monogenea	*Benedenia* sp.	SP

*SP: body surface, *CE: gastric caeca, *M: mesentery, *H: liver, *B: gills and *I: intestines.

3.6. Abundance, frequency, dominance, richness and diversity-evenness

The relative abundance was higher in the copepod *Caligus* sp. (26%) and lower in the digenean *Dicrogaster* sp. with 0%. The parasite with the highest frequency was the nematode *Contracaecum* sp. (24%) followed by the acanthocephalan *Floridosentis mugilis* and the copepod *Ergasilus* sp. with a frequency of 22% (Fig. 8).

Regarding dominance, which allows us to know the proportion of the most abundant species with respect to the total number of parasites, the digenean had a higher dominance of 47%. The infestation by parasites was demonstrated by the highest presence of ectoparasites such as the copepod *Caligus* sp. The endoparasites with the highest frequency was *Benedenia* sp. (47%) (Fig. 8).



*AR: Relative abundance, FR: Relative frequency and DR: relative dominance

Figure 8 Graph of relative abundance, frequency and dominance of *M. curema* parasites.

3.7. Wealth (S), Diversity and Equity

Biological communities composed of organisms with a parasitic lifestyle consider three levels of study, in increasing order of inclusiveness: the infracommunity, the component community and the composite community [22]. Regarding the ecological terms currently used in parasitology, there are two types of concepts: first, at the population level, which includes the terms infrapopulation, which includes all individuals of a parasite species that have their microhabitats in a host individual at a given time; another concept is the population component, which includes the parasites of a population of the same species in a host population [27], the population guild, which includes the parasites of a population of the same species in a host community [28] and the overpopulation, defined as all individuals of a parasite species at all stages of development within all hosts in their environment [17, 27]; and second, at the community level, it includes the concept of infracommunity, defined as all parasite species infecting a single host; a community component where all parasite species parasitize an entire host population at a given time [14, 27] 23], the community guild refers to the entire community of parasites, in a guild of specific hosts [24] and finally the supracommunity which is defined as that which includes an entire community of parasites; in an ecosystem [14, 23].

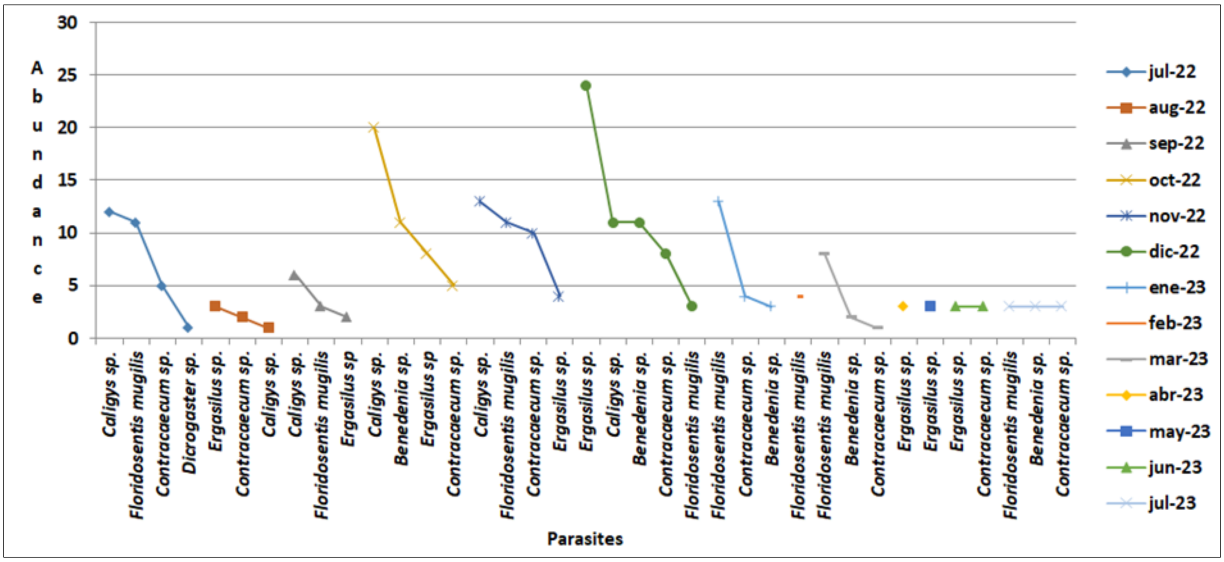


Figure 9 Range-abundance curves by month for *Mugil curema*

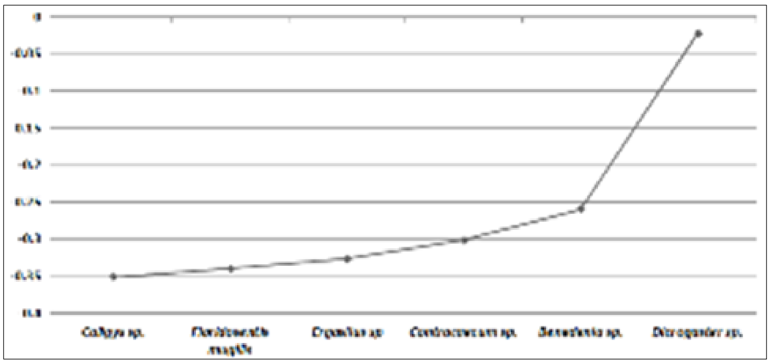


Figure 10 Diversity curves of *Mugil curema* parasites

A monthly analysis of the collection of 131 hosts was carried out, managing to isolate 241 metazoan parasites of the ecto- and endoparasite type from the hosts produced by the collection; thus, we have that the months that presented the greatest abundance of parasitic species were December 2022, highlighting the copepod represented by *Ergasilus* sp. A second aspect for the month of December is also the copepod *Caligus* sp. representing within the classification for the component community of *M. curema*; However, by applying a comparative analysis we can see that the community structure with the lowest dominance is represented by the digenean for the month of July 2022, a similar case to the visual one that for the months of February, April and May 2023 a species richness of the community component was recorded only a richness of 1, registering for those months one species of which the acanthocephalan was recorded with *Floridosentis mugilis* and the copepod *Ergasilus* sp. With a richness of two species were for the month of June with *Ergasilus* sp. and the nematode *Contracaecum* sp. (Fig. 9 and 10).

With a richness of 3 species they were the community component for five months of August and September 2022 and for the year 2023 January, February and July, that is, per month a richness of 3 species was presented and among them those recorded were the copepods *Caligus* sp., *Ergasilus* sp., *Contracaecum* sp., *Floridosentis mugilis* and *Benedenia* sp. The months of July, October and November 2022 presented each month a richness of 4 species among them Digeneo *Dicrogaster* sp., acanthocephalan with *Floridosentis mugilis*, *Caligus* sp, *Benedenia* sp., *Ergasilus* sp., and the nematode *Contracaecum* sp., for the month of December 2022 only a richness of 5 species was recorded. It is important to mention that in none of the collection months was the richness of our community component of 6 species recorded. Regarding the evenness for *M. curema* (table 3), the acanthocephalan *Floridosentis mugilis* had a value of 0.921 and the copepod *Ergasilus* sp. had a value of 0.9211. As their values are very close to 1, it represents total evenness in the representation of individuals of each species detected in the collection. For the acanthocephalan *Floridosentis mugilis* (0.921), *Contracaaecum* sp. (0.855) and *Benedenia* sp. (0.794), it can be inferred that based on the values they present, we can conclude that their parasitic community structures are equally represented by presenting a value very close to 1. It is also highlighted that the digenean presented a value of 0, which presents zero evenness; therefore, the null uniformity of parasitic populations for the distribution of digenean individuals is evident.

Table 3 Comparison at the community component level of helmites recorded in *M. curema*

Estimator	***TO***	***B***	***C***	***D***	***AND***	***F***
Wealth (S)	1	8	6	5	8	9
Number of helminths	1	56	63	41	30	50
Dominance	1	0.165	0.219	0.2933	0.278	0.150
Shannon-Wiener diversity	0	1.915	1.6	1.377	1.652	2.024
Berger-Parker dominance	1	0.232	0.317	0.3667	0.48	0.243
Equitability	0	0.921	0.893	0.8555	0.794	0.921

*TO: Dicrogaster sp., **B**: Floridosentis mugilis, **C**: Caligys Sp., **D**: Contracaecum sp., **AND**: Benedenia sp. , **F:** Ergasilus sp.

Regarding diversity, the digenean is also the least diverse in relation to the richness and relative equality of the distribution of species, however for the copepod *Ergasilus* sp. with 2,024 diversity it shows that there are more possibilities of diversity between the microhabitats housed. In this context, the parasites of greatest specific importance for *M. curema* are represented firstly by ectoparasites and to a lesser extent by Acanthocephalans and nematodes, highlighting an invasion of the body of fish, scales and gills for ectoparasites and for endoparasites the intestines, mesentery and liver.

3.8. Coefficient of aggregation (k)

Most parasitic metazoans have the characteristic of increasing their populations and forming parasitic aggregations of the host population and being able to reproduce and ensure that their species survives; in this context, the importance of the degree of contagion of a parasitic species with respect to the host population can be determined, as can be seen in Table 4, where the distribution types with respect to CD and K were identified. Thus, the spatial arrangement that we recorded for the structure of the component community for *M. curema* we have that for the copepods *Caligus* sp. (-4,347), *Ergasilus* sp. (-3,493), the digenean (0.00), *Benedenia* sp. (-1,979), the acanthocephalan *Floridosentis mugilis*, (-3,503) and the nematode *Contracaecium* sp. (-2.188) *Caligus* sp., copepods present aggregated distribution when values below 8 are presented, an indicator that, like all parasitism, it indicates an ecological association of the parasitic type, where in the case of this study we see its microhabitats defined mainly in gills and body surface for *M. curema*.

Table 4 Community component of parasites in *M. curema*

Parasite	**Coefficient of aggregation**	**Distribution coefficient**	**Morisita dispersion index**	**Negative binomial distribution**	**Degree of contagion**
Dicrogaster sp.	0.00000	0.07692	0.00000	0.00039	*
Floridosentis mugilis	-3.50314	123.48905	-342958.00000	0.00241	Normal
Caligys sp.	-4.34796	458.56495	-405838.00000	0.00499	Normal
Benedenia sp.	-1.97958	114.15641	-83316.00000	0.00241	Normal
Ergasilus sp.	-3.49373	458.08017	-236324.00000	0.09433	Normal
Contracaecum sp.	-2.18886	33.68856	-187068.00000	0.12995	Normal

Where the distribution pattern of the aggregate type is recorded in all species of parasites, representing the common pattern. This distribution behavior tends to expand the stability in relation to the parasitic host, increasing the reproductive efficiency of adult parasites (Iannacone and Alvariño 2008). A negative binomial distribution model was obtained from the hosts (*M. curema*) due to the type of aggregation that occurs where a large number of hosts harbor a small number of parasites; while most parasites focus on few hosts.

3.9. Condition factor and IES

The indicators to evaluate the physical condition of fish correspond to the parameters of their health status and the energy reserves available in their bodies to carry out their biological functions such as growth and reproduction. Obviously, a better health condition of individuals ensures a higher performance and a high survival rate. For parasitology, the condition of the fish under study is considered an influencing factor in order to compare the parasitic load with the welfare indices; since one of the factors that can be an indicator of the welfare status of fish is the parasite load that they present either in microhabitats such as the surface of the body and gills or in internal organs and striated and/or smooth muscle; since these parasites can obviously undermine to a greater or lesser extent the stability and balance of their vital functions.

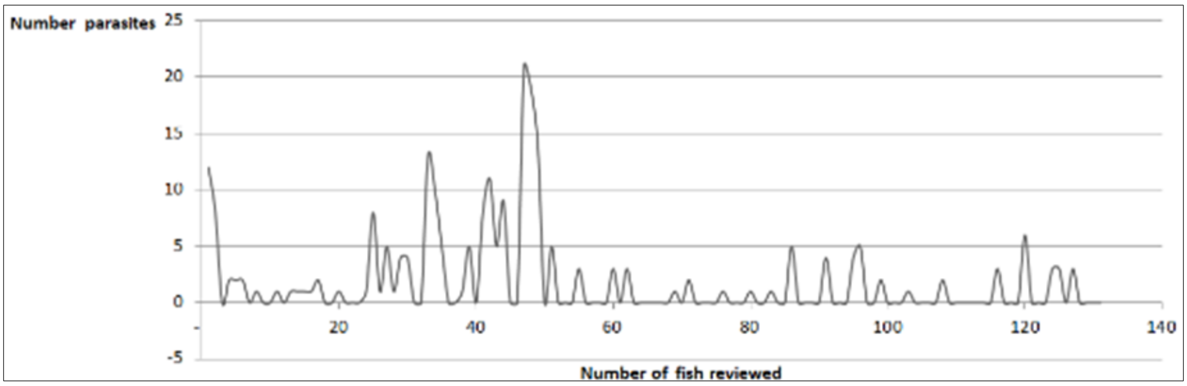


Figure 11 Chart of parasites and fish reviewed for *Mugil curema.*

Figure 11 shows that the negative binomial distribution dynamics represents a parasite load for *M. curema* in which few individuals of the population of our hosts harbor a significant number of parasites and many infected hosts with very few parasites are present; it is important to mention this pattern of microhabitat structure for our hosts for the reason that the gonasomatic index (IGS) and the hepatosomatic index are indicators of mobilization of energy reserves from the liver and pancreas towards the gonads, which represents an estimate of the product of reproductive activity [29]. Parasitized and non-parasitized individuals, thus we have that for *M. curema* a min K of 960.98±462.76 was recorded for parasitized males and with the maximum value representatively also recorded for parasitized males with a value of 1094±607.22, we can observe that the average K does not present large fluctuations so we can observe that for males most likely the parasites lodged in their body did not represent alterations for their condition; similar case observed in females; This index as an immune indicator represents the defense mechanism of organisms infected by parasitic agents, so we have that for *M. curema* there are low average values for females parasitized by some type of endo or ectoparasitic helminth since they show in table 21 values of 0.07 ± 0.07 and the males also represent relatively low values (0.11 ± 0.11) than fish not parasitized by any type of parasite, likewise it should be noted that the females had a slightly smaller spleen in correlation with the liver, which indicates that the immune system of the parasitized females was activated and on alert.

4. Conclusion

The parasitic community for the hosts of *M. curema* was composed of 6 taxa corresponding to Digeneo (0.42%), Acanthocephalus (23%), nematode (17%), arthropods (47%) monogenean (13%), the predominant group were the arthropods (*Ergasilus* sp. (21%) and *Caligus* sp. (26%); it is important to mention that the nematodes were found in larval stages L3. The richness of the infracommunities was varied from 1 to 3 and with richnesses of 2 were the most frequent (6.11%), the months that presented the highest abundance of parasitic species were December 2022 highlighting the copepod represented by *Ergasilus* sp. a second aspect for the month of December is also the copepod *Caligus* sp. it was recorded that the total length for *M. curema* for males ranged from 25 cm to 65 cm for total length, average (LT) 31.65 ± 8.08 a mean of 31.65 and a variance of 65.34; and for females with respect to total length ranged from 26 cm to 62 cm with average (LT) 34.32 ± 6.56 a mean of 34.32 and a variance of 43.05. Regarding the weight of *M. curema* of males the values ranged from 109 g to 820 g, the average weight of 315.86 ± 202.81, a mean of 315.86 and variance of 4132.63; the females of *M. curema* values fluctuated for weight between 921 g to 113 g, with an average weight of 373.20 ± 213.93, a mean of 373. 20 and variance of 45766.83. Regarding prevalence in records, we have that both the Acanthocephalus (*Floridosentis mugilis*) and the nematode *Contracaecum* sp. both have a prevalence record of 14.503%; followed by the The copepod ectoparasite *Caligus* sp. with 13.740%, different from *Ergasilus* sp. with 7.633% and in the fourth place is the monogenean (Benedenia sp.) with a prevalence of 5.343% and the Digeneo (*Dicrogaster* sp.) with 0.763%, it can be noted that the prevalence of this ectoparasite in our parasitic community is significantly very low; which can be an indicator of alterations in the ecosystem under study. The majority of parasitic metazoans have the characteristic of increasing their populations and forming parasitic aggregations of the host population, and being able to determine the degree of contagion of a parasitic species of the host population, as can be appreciated by the aggregation coefficient for *M. curema* of 0.530, we have a representative parasitic aggregation as a type of aggregated populations. We can infer that the presence of immunological stress was registered and therefore the activation of the immune system as a consequence of the homeostasis of the hosts due to the parasitic load presented by the hosts of *M. curema*.

Compliance with ethical standards

Disclosure of conflicts of interest

The authors declare that they have no conflict of interest, financial or otherwise, of their knowledge.

Declaration of ethical approval

Ethical approval is duly obtained from the Code of Ethics Approved at the session of the H. General University Council held on December 14, 2016.

Declaration of informed consent

Informed consent was obtained from all participants in this study before starting

References

[1] Love MS, Yoklavich M., Thorsteinson L. 2002. The rockfishes of the Northeast Pacific. University of California Press, Los Angeles, 405 p.

[2] Oliva, ME & JL Luque. 1998. Metazoan parasites infracommunities in five sciaenids from the Central Peruvian Coast. Memórias do Instituto Oswaldo Cruz, Rio de Janeiro, 93: 175-180.

[3] Holmes, JC 1990. Helminth communities in marine fishes. Pages 101–130 in G. Esch, A. Bush, and J. Aho, eds. Parasite communities: patterns and processes. Chapman and Hall, London.

[4] Iannacone, J., L. Alvariño & M. Alayo. 2008. Ecological aspects of the metazoan parasites of Callichirus seilacheri (Bott 1955) (Decapoda: Callianassidae) in Lima, Peru. Neotrop. Helminthol., 2: 9-17.

[5] Lafferty, KD 2012. “Biodiversity Loss Decreases Parasite Diversity: Theory and Patterns.”Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 367(1604): 2814–27

[6] Madanire GN Moyo, MM Matía, PAS Olivier and WJ Luus-Powell (2010). Population dynamics and spatial distribution of monogeneans on the gills of Oreochromis mossambicus (Peters, 1852) from two lakes of the Limpopo River System, South Africa Published online by Cambridge University.

[7] Madhavi, R., Triveni Lakshmi, T. (2012). Metazoan parasites of the Indian mackerel, Rastrelliger kanagurta (Scombridae) of Visakhapatnam coast, Bay of Bengal. J Parasit Dis 35, 66–74

[8] Lafferty, K.D. 2012. “Biodiversity Loss Decreases Parasite Diversity: Theory and Patterns.” Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 367(1604): 2814–27

[9] Morales-Serna, Francisco N., María Amparo Rodríguez-Santiago, Rolando Gelabert and Luz M. Flores-Morales. (2019). Parasites of fish Poecilia velifera and their potential as bioindicators of wetland restoration progress. Helgol Mar Res 73:1.https://doi.org/10.1186/s10152-019-0522-1

[10] Valdés, A. (2010). Parasitic helminths in wild populations of Farfantepenaus aztecus in the Estero la Mata, Veracruz Mexico. Tuxpan, Veracruz Mexico: Universidad Veracruzana.

[11] National Commission for Aquaculture and Fisheries. (November 11, 2018). Statistical Yearbook of Aquaculture and Fisheries. Mazatlán, Sinaloa, Mexico.

[12] Maria Amparo Rodriguez-Santiago, Jorge Adrian Rosales-Casian, Mayra Ixchel Grano-Maldonado, Jose Adam Vazquez-Caballero, Sandra Martha Laffon-Leal and Enrique Nunez-Lara. 2020. Parasitological records of eight rockfish species (Scorpaeniformes: Scorpaenidae) from Pacific Baja California, Mexico. Pacific Science. Pacific Science, 74(4):395-403 (2021).https://doi.org/10.2984/74.4.7

[13] Rodríguez-Santiago María Amparo, Ramos-Colorado Luisa, García-Magaña Leticia, Grano-Maldonado, José Iannacone Mayra Ixchel & Vázquez-Caballero Adán. Parasite community analysis of the gray snapper Lutjanus griseus (Perciformes, Lutjanidae) in a tropical region of the Southern Gulf of Mexico. Helminthologia. 59, 1: 94 – 103, 2022.

[14] (2023). Rodríguez Santiago M. A., Torres, E. Á., Centella, F. E. V., Canche-Tun, C. R., & Oliver, J. A. I. Fauna parasitaria de cuatro especies de peces globo (Tetraodontiformes) del sureste de México: Parasitic fauna of four species of

pufferfishes (Tetraodontidae) from southeastern México. SIBIUAS Revista de la Dirección General de Bibliotecas, 18 (1), 18-27.

[15] Crosetti, D., and Blaber, S. (2016). Biology, Ecology and cultyre of Gray Mullet (Mugilidae). New York: CRC Press Taylos and Francis Group A SCIENCE PUBLISHER BOOK.

[16] Iannacone, J., L. Alvariño & M. Alayo. 2008. Ecological aspects of the metazoan parasites of Callichirus seilacheri (Bott 1955) (Decapoda: Callianassidae) in Lima, Peru. Neotrop. Helminthol., 2: 9-17.

[17] Hiroki-Hata, Atsushi-Sogabe, Shinya-Tada, Ryohei, N., Reina-Nakano, Nobuhko-Kohya, and others. (2017). Molecular phylogeny of obligate fish parasites of the family Cymothoidae (Isopoda, Crustacea): evolution of the attachment mode to host fish and the habitat shift from saline water to freshwater. Springer Berlin Heidelberg. Berlin Heidelberg: Mar Biol.

[18] Eiras, JE, Takemoto, RM, and Pavanelli, GC (2000). Study methods and laboratory techniques in fish parasitology. Zaragoza: Acribia.

[19] Colwell, R.K., Chao-New, J.G., Lin-C.X., M.R.-Chazdon, & J.T.-Longino. (2012). Models and estimators linking rarefaction, extrapolation, and comparison of sample-based and individual-based assemblages. Journal of Plant Ecology 5, 3–21.

[20] Nikolsky, G.V. (1963). Fishes Ecology. London: London: Academic Press

[21] Bush, AO, KD Lafferty, JM Lotz, and AW Shostak. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. Journal of Parasitology 83:575-583.

[22] Vivas, LE (2002). Manual of rice pest insects. Maracay, Venezuela: first edition. INIA-SINGENTA.

[23] Rubio, R., Salahange, P., and Betancourt, M. (1985). Relationships of age with length, weight and fecundity of the smelt Lutjanus synagris from the Southeastern Shelf of Cuba. Cuba: Rev. Inv. Pesq.

[24] Cabrera-Páez, Y., Aguilar-Betancourt, C., and González-Sansón, G. (2008). Morphological and reproductive indicators of the fish Gambusia puncticulata (Poeciliidae) in highly contaminated sites of the Almendares River, Cuba. Rev. biol. Trop. (Int. J. Trop. Biol.) Vol 56, 1991-2004.

[25] Moller, AP, and Saino, N. (2004). Laboratory of evolutionary parasitology CNR UMR 7103 (Immune response and survival). St. Bernard France: Univ. Pierre et Maire Curie quai.

[26] May Hernández, E. (2015). Community of parasites of the European eel (Anguilla anguilla) from the Mar Menor and evaluation of its effects on the ecological fitness of the population. Spain: University of Murcia.

[27] Di Giulio, RT, and Hinton, DE (2008). Fish Toxicology. CRCPress. Taylor and Francis. Group, LLC.

[28] Goncalves-Nazaré, M., Reis-Dias, M., Gracas-Das, R., Marinko-Barbosa, A., & Tavares-Dias, M. (2014). Parasite diversity of Osteoglossum Bicirrhosum, an Osteoglossidae fish from the Amazon. Brazil: Peruvian Association of Helminthology and Related Invertebrates (APHIA).

[29] Cabrera-Páez, Y., Aguilar-Betancourt, C., and González-Sansón, G. (2008). Morphological and reproductive indicators of the fish Gambusia puncticulata (Poeciliidae) in highly contaminated sites of the Almendares River, Cuba. Rev. biol. Trop. (Int. J. Trop. Biol.) Vol 56, 1991-2004.

[30] Margolis, L., GW Esch, JC Holmes, AM Kuris, and GA Schad. 1982. The use of ecological terms in parasitology (Report of an ad hoc committee of The American Society of Parasitologists). Journal of Parasitology 68:131-133.

[31] Zander, CD 2001. The guild as a concept and a means in ecological parasitology. Parasitology Research 87:484-488.

[32] Rodríguez-González H, Hernández Llamas A, Villarreal H, Saucedo P, García-Ulloa M, Rodríguez-Jaramillo C. 2006. Gonadal development and biochemical composition of female crayfish Cherax quadricarinatus (Decapoda: Parastacidae) in relation to gonadosomatic index at first maturation. Aquaculture 254:637-645. doi: 10.1016/ j.aquaculture.2005.10.020.