Communities of Helminth Parasites in Sciaenid Fish From the Alvarado Coast, Veracruz, Mexico, Southern Gulf of Mexico

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Abstract

A helminthological examination was performed on 114 specimens of sciaenids that were captured on the Alvarado coast, Veracruz, Mexico, between August 2004 and July 2006. *Bairdiella chrysoura* (n = 15); *Cynoscion arenarius* (n = 31); *Menticirrhus americanus* (n = 16); *Menticirrhus littoralis* (n = 33) and *Umbrina coroides* (n = 19). 26 parasites were identified at the species, 12 genus and 5 family levels, as follows: 21 digeneans (14 adults and 7 metacercariae), 9 monogeneans, 7 nematodes (4 adults and 3 larvae), 2 cestodes (larvae), and 4 acanthocephalans (adults). Digeneans and monogeneans were the most abundant. Helminths with the highest prevalence in all five communities were *Pseudorhamnocercoides stichospinus* and Tetraphyllidae. The species with highest mean intensity were *Diplomonorchis leiostomi* and Tetraphyllidae, and *Hysterothylacium* sp., were registered in the five communities. Significant correlations between the host total length and species richness, *U. coroides* (r = 0.54), and total length and abundance, *M. americanus* (r = 0.63), were found. The highest similarity was recorded among communities of *M. americanus* and *M. littoralis*. The infracommunities and component communities in species richness and diversity, in all cases, were within ranges observed in most marine fish helminth communities.

Keywords: infracommunity, component community, helminths, parasite, Mexico

1. Introduction

Communities of parasitic helminths in marine fish are as rich and abundant as those found in birds and mammals (Holmes, 1990), particularly in hosts from tropical latitudes (Rohde & Heap, 1998). The helminth richness and abundance, *e.g.*, *Acanthopagrus australis*, *Lethrinus miniatus* and *Plectropomus leopardus*, can be explained by the continuity and stability of the marine environment (Rohde & Heap, 1998; Madhavi & Sai-Ram, 2000), the gregarious habits and vagility of hosts (Sasal et al., 1997), the diversity of their feeding habits with diet changes according to their growth and length (Marcogliese & Cone, 1997; Lo et al., 1998; Muñoz et al., 2006; Lagrue et al., 2011), as well as, the phylogenetic relations and environmental factors (Morand et al., 2000). On the other hand, communities of parasitic fish helminths in the southeastern Gulf of Mexico and the Caribbean Sea are as rich and abundant as those from other latitudes (Sánchez-Ramírez & Vidal-Martínez 2002; Aguirre-Macedo et al., 2007; Montoya-Mendoza et al., 2014, 2016, 2017), as it has been registered in some sciaenids from the US Atlantic Coast, such as *Leiostomus xanthurus* and *Micropogonias undulatus* (Thoney, 1991, 1993), and from Brazil, *Menticirrhus americanus* (Chaves & Luque 1999), *Micropogonias furnieri* (Alves & Luque, 2001), *Cynoscion guatucupa* and *Macrodon ancylodon* (Sabas & Luque, 2003), *Paralonchurus brasiliensis* (Luque et al., 2003), *Menticirrhus ophicephalus*, *Paralonchurus peruanus*, *Sciaena deliciosa*, *Sciaena fasciata,* and *Stellifer minor* (Oliva & Luque, 1998), and *Sciaena deliciosa* (Iannacone et al., 2010). Here, we describe the helminth community found in *Bairdiella chrysoura* (Lacepède), *Cynoscion arenarius* (Ginsburg), *Menticirrhus americanus* (Linnaeus), *Menticirrhus littoralis* (Holbrook), and *Umbrina coroides* (Cuvier), in terms of species composition, richness, diversity, and similarity.

2. Method

2.1 Sampling Procedures

A total of 114 organisms from five species of Sciaenidae were examined between August, 2004 and February, 2007. Specimens were caught in Playa Las Barrancas (18º59′31″ N, 95º57′83″ W), Municipality of Alvarado, Veracruz, Mexico, using a beach seine net (500 m L × 4 m H; ¼ mesh). All collected fish were transported alive to the laboratory, and placed in 1,000 L seawater tanks. Dead organisms were kept in plastic containers with ice and transported to the lab for examination within 24 h post-capture. Taxonomic Identifications of fish were made according to Froese and Pauly (2018). Tissues and organs were reviewed using a stereomicroscope. The external examination included skin, scales, fins, gills, eyes, nostrils, mouth, and anus. Gills were removed and analyzed separately in Petri dishes with seawater. The internal examination included mesenteries, liver, kidney, and gonads. The whole digestive system was placed in Petri dishes with 0.75% saline for examination. Helminths were fixed with hot formalin 4%, and preserved in ethanol 70%. For taxa identification, monogeneans, digeneans, cestodes, and acanthocephalans were stained using either Mayer's paracarmine, Gomori's triple stain or Erlich's hematoxylin, and then dehydrated in a graded alcohol series, cleared with clove oil, and mounted whole in Canada balsam. Nematodes were studied on temporary slides and cleared in glycerin, and then preserved in alcohol 70%. To study sclerotized structures, some monogenean specimens were fixed with ammonium picrate (Vidal-Martínez et al., 2001). Voucher specimens were deposited at the National Helminths Collection *(Colección Nacional de Helmintos)* (CNHE), Institute of Biology of the National Autonomous University, Mexico City.

2.2 Sample Size

Helminth communities in the five sciaenid species were analyzed at the component community (all helminths in all individuals per species examined), and infracommunity (helminths in each fish examined) levels (Holmes & Price, 1986). Helminth species richness observed was one measure of the adopted community structure. Sampling adequacy for the component community was assessed with a procedure similar to the one used for helminth parasites communities of *L. campechanus* (Montoya-Mendoza et al., 2014) and *L. synagris* (Montoya-Mendoza et al., 2016), using a randomized (100×) sample-based species accumulation curve computed in EstimateS (version 8.5 RK Colwell, http://viceroy.eeb.unconn.edu/estimates) (Moreno & Halffter, 2001). For the component community, we examined the asymptotic richness based on the Clench's model equation (Soberon & Llorente, 1993), along with the final slope of the randomized species accumulation curve (Jiménez-Valverde & Hortal, 2003). Clench's model is described by the following function:

$$V2 = (a \times V1)/[1 + (b \times V1)] \tag{1}$$

where, $V2$ is the observed richness, $V1$ is the number of hosts examined, and a and b are curve parameters; a equals the new species adding rate, and b is a parameter related to the curve shape. These values were calculated using the EstimateS and Statistica softwares (StatSoft, Inc., Tulsa, Oklahoma) as in Jiménez-Valverde and Hortal (2003). The slope of the cumulative species curve was calculated as $a/(1 + b \times n)^2$, where a and b are parameters cited above, and n is the number of hosts examined for a given component. The Clench's model equation allows estimating the total number of species in a component as a/b. To calculate the number of rare species missing at the component community level, the nonparametric species-richness estimator bootstrap was calculated from data observed, as recommended by Poulin (1998).

2.3 Data Analysis

Prevalence (percentage of infected hosts) and mean intensity (mean number of parasites per infected fish), were calculated following Bush et al. (1997); as well as the correlation between the total number of species with the total number of helminths, and compared with the host size and diversity. We analyzed the distribution of helminth species, and abundance for component community, using rank-abundance curves. Data was adjusted with predictive distribution models (x^2, $p = 0.05$), recording the dominant species in each community. These values were calculated using PAST version 3.14 (Hammer et al., 2001). The Shannon diversity index (H'), was calculated for the component community as in Magurran (2004). Infracommunity descriptors included the mean number of helminth species per fish, the mean number of helminth individuals per fish, and the mean value of the Brillouin's diversity index per fish (H). Similarity among all five parasites communities from *Bairdiella chrysoura*, *Cynoscion arenarius*, *Menticirrhus americanus*, *Menticirrhus littoralis*, and *Umbrina coroides,* was estimated with a cluster analysis using the Bray Curtis similarity index (Magurran, 2004).

3. Results

A total of 114 fish of 5 sciaenid species: silver perch, *B. chrysoura* (n = 15), sand weakfish, *C. arenarius* (n = 31), southern kingcroaker, *M. americanus* (n = 16); gulf kingcroaker, *M. littoralis* (n = 33), and sand drum, *U. coroides* (n = 19). Mean (±SD) length (cm) and weight (g) of specimens were: *B. chrysoura* (16.2±1.3, 48.4±17.7); *C. arenarius* (18.9±2.7, 68.4±26.7); *M. americanus* (25.1±4.6, 181.9±77.2); *M. littoralis* (24.6±3.8, 141.8±65.6); and *U. coroides* (17.4±3.12, 73.9±31.7).

Table 1. Infection parameters and site of infection of the helminth parasites of five species of sciaenids from Alvarado, Veracruz, Mexico

Species	Site	*Bairdiella chrysoura* (n = 15)			*Cynoscion arenarius* (n = 31)			*Menticirrhus americanus* (n = 16)			*Menticirrhus littoralis* (n = 33)			*Umbrina coroides* (n = 19)		
		nhp (% prev)	tnhl (Pi)	Int (range)	nhp (% prev)	tnhl (Pi)	mnt (range)	nhp (% prev)	tnhl (Pi)	mnt (range)	nhp (% prev)	tnhl (Pi)	mnt (range)	nhp (% prev)	tnhl (Pi)	mnt (range)
TREMATODA																
Adults																
Bucephalus cynoscion Hopkins, 1956	i				11* (16.1)	23 (0.06)	4.6±4.1 (2-12)									
*Diplomonorchis leiostomi*** Hopkins, 1941	i										6* (18.2)	1214 (0.289)	202±220 (7-554)	15 (78.9)	1257 (0.52)	83.8±121 (1-421)
*Glaucivermis spinosus*** Overstreet, 1971	i							4 (25)	418 (0.41)	105±97 (11-196)	13* (39.4)	338 (0.081)	104±97 (3-83)	8* (42.1)	364 (0.15)	45.5±43.7 (1-137)
Hurleytrema catarinensis Amato, 1982	i										3 (9)	26 (0.006)	86±6.5 (2-15)			
*Lecithaster confusus*** Odhner, 1905	i										1* (3)	9 (0.002)	9±- (3)	1 (5.2)	3 (0.001)	3±- (3)
Lecithochirium musculus (Looss, 1907)	i							1* (6.2)	2 (0.002)	2±- (2)						
Opecoeloides fimbriatus (Linton, 1934)	i							9* (56.3)	28 (0.027)	3.1±2.1 (1-8)	3 (9)	5 (0.001)	1.6±1.2 (1-3)			
Pleorchis americanus Lühe, 1906	i				14 (19.3)	12 (0.03)	2±0.9 (1-3)							1* (5.2)	3 (0.001)	3±- (3)
*Pseudopecoelus manteri*** Sogandares & Hutton, 1958	i	2* (13.3)	3 (0.007)	1.5±0.7 (1-3)												
Siphodera vinaledwardsii (Linton, 1901)	i	6 (40)	30 (0.07)	5±3.1 (1-10)												
Stephanostomum interruptum Spark & Thatcher, 1958	i	4* (26.7)	22 (0.05)	5.5±6.4 (1-15)	13* (42)	45 (0.117)	3.5±2.8 (1-9)									
*Stephanostomum sentum*** (Linton, 1910)	i							6* (37.5)	34 (0.033)	5.7±5.1 (3-16)	8* (24.2)	21 (0.005)	2.6±1.7 (1-6)			
Stephanostomum sp.	i				3 (9.7)	4 (0.005)	1.3±0.6 (1-2)	3 (18.8)	4 (0.004)	1.3±0.6 (1-2)						
Metacercariae																
Bucephalus sp.	f				1* (3.2)	1 (0.01)	1±0.0 (1)									
Cardiocephaloides sp.	b				11* (35.5)	31 (0.08)	2.8±2.6 (1-8)				1* (3)	17 (0.004)	17±- (17)	3* (15.7)	9 (0.004)	3±3.4 (1-7)
Diplostomum sp.	e	1* (6.6)	1 (0.002	1±- (1)												
Lepocreadium sp.	i	4* (26.7)	8 (0.02)	2±2 (1-5)												
Rhipidocotyle sp.**	f				14* (19.3)	12 (0.031)	2±0.9 (1-4)									
Stephanostomum sp.	i, f				2* (6.5)	2 (0.01)	1±0 (1)				1 (3)	1 (0.001)	1±- (1)	3 (15.8)	4 (0.002)	1.3±0.6 (1-2)
Didymozoidae gen. sp.	i	1* (6.7)	1 (0.002)	1±- (1)												
Trematoda gen. sp.	h,g	1 (6.7)	66 (0.16)	66±- (66)				1 (6.2)	2 (0.002)	2±- (2)				1 (5.2)	3 (0.001)	3±- (3)
MONOGENEA																
Hargicotyle louisianensis (Hargis, 1955)	g							2 (12.5)	2 (0.002)	1±0 (1)	10 (30.3)	11 (0.003)	1.1±0.3 (1-2)			
Cynoscionicola pseudoheteracantha (Hargis, 1957)	g				6 (19.4)	14 (0.036)	2.3±3.3 (1-9)							11 (57.9)	18 (0.008)	1.6±0.9 (1-3)
Neoheterobothrium cynoscioni (MacCallum, 1917)	g				1 (3.2)	1 (0.03)	1±0 (1)									
Pedocotyle minima Hargis, 1955	g	3 (20)	9 (0.022)	3±2 (1-5)												
Rhamnocercus bairdiella Hargis, 1955	g	8 (53.5)	203 (0.49)	25.4±28 (2-84)												

Species	Hab	nhp (prev)	tnhl (Pi)	Int (range)	nhp (prev)	tnhl (Pi)	Int (range)	nhp (prev)	tnhl (Pi)	Int (range)	nhp (prev)	tnhl (Pi)	Int (range)	nhp (prev)	tnhl (Pi)	Int (range)
Rhamnocercus margaritae Fuentes-Zambrano, 1997	g	3 (20)	9 (0.022)	5±3.6 (1-9)												
Rhamnocercus rhamnocercus Monaco, Wood & Mizelle, 1954	g													9 (47.3)	549 (0.226)	61±34.5 (12-111)
Pseudorhamnocercoides stichospinus (Seamster & Monaco, 1956)	g							16 (100)	509 (0.497)	31.8±34.1 (5-128)	29 (87.9)	2418 (0.58)	83.3±91.8 (10-353)			
Encotyllabe sp.	g							3 (18.8)	3 (0.003)	3±0 (1)	2 (6)	2 (0.001)	1±0 (1)			
CESTODA																
Larvae																
Calitetrarhynchus sp.	i	1 (6.7)	10 (0.02)	10±- (1)												
Tetraphyllidae gen. sp.	i	6* (40)	40 (0.09)	6.7±6 (1-14)	20* (64.5)	103 (0.267)	5.2±8.9 (1-42)	5* (31.3)	12 (0.012)	1.7±1.1 (1-4)	10* (33.3)	63 (0.015)	5.7±4.4 (1-15)	10* (52.6)	76 (0.03)	7.6±4.6 (1-13)
NEMATODA																
Adults																
Hysterothylacium fortalezae Deardoff & Overstreet, 1980	i				16* (51.6)	104 (0.269)	6.5±6.4 (1-23)									
Hysterothylacium reliquens Norris & Overstreet, 1975	i, m				9 (29)	18 (0.047)	2±2 (1-8)	3 (18.8)	5 (0.005)	1.7±1.1 (1- 3)	1* (3)	1 (0.001)	1±- (1)	1* (8.3)	3 (0.0012)	3±- (1)
*Spirocamallanus cricotus*** Fusco & Overstreet, 1978	i										1* (3)	2 (0.001)	2±- (2)			
Capillaridae gen. sp.	i							1 (6.2)	1 (0.0002)	1±- (1)	1* (3)	1 (0.001)	1±- (1)			
Larvae																
Contracaecum sp.	i				1 (3.2)	1 (0.003)	1± (1)							1 (5.2)	1 (0.001)	1± (1)
Cucullanus sp.	i													1* (5.2)	5 (0.002)	5±- (5)
Hysterothylacium sp.	i	3 (20)	6 (0.014)	2±1.7 (1-4)	11 (35.5)	15 (0.039)	1.4±0.5 (1-2)	1 (6.2)	1 (0.0002)	1±- (1)	6* (18.2)	8 (0.002)	1.3±0.5 (1-2)	12* (63.1)	29 (0.01)	2.4±1.3 (1-5)
ACANTHOCEPHALA																
Dollfusentis chandleri Golvan, 1969	i							3 (18.8)	3 (0.003)	1±0 (1)				10* (52.6)	87 (0.036)	8.7±10 (2-35)
Tegorhynchus furcatus Van Cleave & Lincicome, 1939	i										18 (54.5)	585 (0.04)	3.2±2.4 (1-9)	1* (5.2)	1 (0.001)	1±- (1)
Serrasentis sagittifer (Linton, 1889)	i													1* (5.2)	1 (0.001)	1±- (1)
Acanthocephala gen. sp.**	i													2* (10.5)	7 (0.003)	3.5±0.7 (3-4)

Note. *, new host record; **, new record for Mexico; nhp, number of hosts parasitized; tnhl, total number of helminthes; Int, mean intensity; Pi, proportional abundance; prev (%), prevalence. i, intestine; m, mesentery; g, gill; b, brain; h, heart; f, fin; e, eye.

3.1 Prevalence

The parasites identified (26 at species level, 12 at genus and 5 at family) 21 belong to trematodes (14 adults and 7 metacercariae), 9 monogeneans, 2 cestodes (larvae), 7 nematodes (4 adults and 3 larvae), and 4 acanthocephalans (adults) (see Table 1). By group of parasites for each host species, the host with the highest proportion of trematode species corresponded to *C. arenarius* with 8 sp. (53.3%), followed by *M. littoralis* (8 sp., 47%), *U. coroides* (7 sp., 38.8%) and *B. chrysoura* (7 sp., 53.8%). For the nematode species the proportions were 26.6%, 23.5% and 22.2%, in *C. arenarius*, *M. littoralis* and *U. coroides*, respectively, and the host with the highest proportion of acantocephalans species was for *U. coroides* (4 sp., 22.2%).

Within the parasitic load for each host species, in *M. littoralis*, the monogenean *R. stichospinus* and the trematode *D. leiostomi*, recorded the highest relative abundance with 2418 helminthes (Pi = 0.58) and 1257 helminthes (Pi = 0.52) respectively, as well as the highest prevalence 88% and 79%, respectively, followed by larvae of Tetraphyllidae (64%) in *C. arenarius* and the nematode *Hysterothylacium* sp. (63%) in *U. coroides*. On the other hand, the larvae of *Hysterothylacium* sp., were recorded in the five hosts species, and *Hysterothylacium reliquens* recorded in four host species and *Cardiocephaloides* sp., in three. This study reports 8 new locality records and 38 new host records (Table 1).

3.2 Sample Size

Analysis of cumulative species curves for component community suggested that the inventory of helminth species was almost complete, and slope of the cumulative species curve was at or near 0.1 ($bxi \leq 0.1$) for *C. arenarius* and *M. littoralis*, but not for *B. chrysoura* (0.21), *M. americanus* (0.19), and *U. coroides* (0.18).

However, we collected from 74-90% of species for each community. Clench's model showed that there are some missing species (Table 2).

Table 2. Component community parameters of helminth parasites in five species of sciaenids from Alvarado, Veracruz, Mexico

Host	n	#th	So	Se	R^2	b_{xi}	% sp Cle	S_{Boot}
B. chrysoura	15	408	13	17	0.9999	0.21	74	15
C. arenarius	31	386	15	17	0.9987	0.05	89	16
M. americanus	16	1024	14	18	0.9992	0.19	77	16
M. littoralis	33	4195	16	20	0.9918	0.08	85	19
U. coroides	19	2420	18	21	0.9897	0.18	81	20

Note. n, number of hosts examined; #th, total number of helminths; So, number of observed helminth species; Se, number of helminth species estimated with Clench model; R^2, correlation coefficient between date and Clench model; b_{xi}, date of the condition species curve as calculated from Clench model; % sp. Cle, proportion of species by the Clench model; S_{Boot}, richness estimated by Bootstrap.

3.3 Richness and Abundance Correlation

Significant correlations ($\alpha = 0.05*$) between the total number of species (S) and total number of helminths (N) with total host length in *U. coroides* ($r = 0.54$) and *M. americanus* ($r = 0.63$), respectively, were found. No other correlations were significant, excepting that between richness and diversity (Table 3).

Table 3. Correlation coefficient between helminth parasitic and community parameters in five sciaenids species from Alvarado, Veracruz, Mexico

Host	n	S	L vs S	L vs N	L vs H'	% pre vs mean int	N vs H'	S vs H'
C. arenarius	19	13	0.15	0.24	0.34	0.37	0.0006	0.69*
B. chrysourus	15	15	0.21	0.48	0.001	0.005	0.1	0.63*
M. americanus	16	14	0.31	0.63*	0.03	0.06	0.005	0.57*
M. littoralis	33	16	0.06	0.35	0.02	0.08	0.0003	0.59*
U. coroides	19	18	0.54*	0.08	0.34	0.37	0.0006	0.69*

Note. n, number of hosts examined; S, number of observed helminth species; L, total length of the host; N, number of helminths; H', Shannon-Wiener diversity index; *, significant correlations.

3.4 Abundance Distribution

The abundance distribution of helminth parasites for each of the component communities was analyzed through rank-abundance curves, and it was pointed out to the parasite species with the highest proportional abundance. Three component communities were adjusted to the *log-normal* predictive distribution, y and two were adjusted to the *broken-stick* predictive distribution; in four of the communities the dominant species showed a proportional abundance near or greater than *Pi = 0.5*, except for *H. fortalezae* (hf, pi = 0.27) in *C. arenarius* (Table 1, Figure 1).
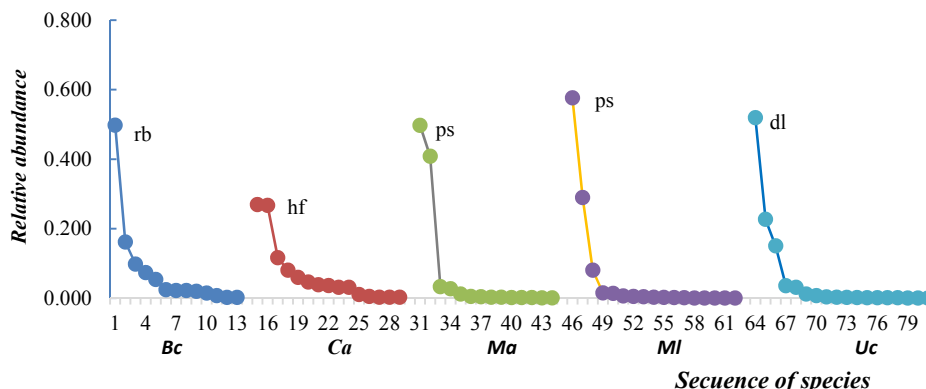
Figure 1. Dominant species of the parasite component communities of five species of sciaenids from Alvarado, Veracruz, Mexico

Note. Hosts: Ba, *B. chrysoura*; Ca, *C. arenarius*; Ma, *M. americanus*; Ml, *M. littoralis*; Uc, *U. coroides*. Parasites: rb, *R. bairdiella*; hf, *H. fortalezae*; ps, *P. stichospinus*; dl, *D. leiostomi*.

3.5 Component Communities and Infracommunities

In the component communities, the highest number of helminths (4195 and 2420) and the highest species richness (17 and 18) were recorded for the community of *M. littoralis* and *U. coroides*, respectively, while for the other communities the records were well below these. Meanwhile, diversity indexes < 2.0 were observed, except for the community of parasites in *C. arenarius* (H' = 2.05), even though this community was one of the least rich and least abundant (Table 4).

Table 4. Descriptive parameters of the component communities of five sciaenids species from Alvarado, Veracruz, Mexico

Host	n	#th	S	H'	J'	I_{B-P}	spd
B. chrysoura	15	408	13	1.7	0.7	0.3	*R. bairdiella*
C. arenarius	31	386	15	2.05	0.75	0.26	*H. fortalezae*
M. americanus	16	1024	14	1.1	0.4	0.4	*P. stichospinus*
M. littoralis	33	4195	17	1.14	0.4	0.57	*P. stichospinus*
U. coroides	19	2420	18	1.38	0.47	0.50	*D. leistomi*

Note. #th, No. total helminths; S, richness; H', Shannon-Wiener diversity index; J', Evenness index; I_{B-P}, Berger-Parker dominance index; spd, dominant species.

On the other hand, we recorded that one of the 114 hosts examined had no parasites, but all the others had from 1 to 9 species of parasites. Usually the record was between two and four, and up to six species, as observed in the community of *U. coroides* (Table 5). The most frequent co-occurrences were: Tetraphyllidae and *H. fortalezae* in *C. arenarius* (11/31 hosts), *P. stichospinus* and *Choricotyle louisianensis* in *M. littoralis* (9/33 hosts), *D. leiostomi* and *Hysterothylacium* sp., in *U. coroides* (11/19 hosts), and *R. bairdiella* and *R. margaritae* in *B. chrysoura* (4/15 hosts).

Table 5. Frequency of parasite species per host in five species of sciaenids from Alvarado, Veracruz, Mexico

Host	Number of parasite species per host									
	0	1	2	3	4	5	6	7	8	9
B. chrysoura		3	3	3	4	2				
C. arenarius		4	5	4	13	1	2	1		1
M. americanus			6	3	1	3	3			
M. littoralis		6	8	4	4	4	5	1	1	
U. coroides	1	1		2	1	5	8			1

Regarding infracommunities, the averages of species richness were < 5, even when we registered 8 and 9 species in some hosts; the averages of the number of helminths were > 100, only in two communities with many helminths. But in the diversity index (H) in all the infracommunities, they were < 1.0, and consequently, low indexes of equity and dominance indexes > 0.7 were observed (Table 6).

Table 6. Infracommunities of five species of sciaenids from Alvarado, Veracruz, Mexico

	B. chrysoura	C. arenarius	M. americanus	M. littoralis	U. coroides
S	13	15	14	17	18
$\overline{X}S\pm ES$	2.9±1.4	3.6±1.8	3.6±1.6	3.5±2	5.1±1.7
Range	1-5	1-9	2-6	1-8	1-9
N	408	386	1024	4195	2420
$\overline{X}n\pm ES$	28±34.3	12.4±12.1	64±94.5	127±161	134±155
Range	2-124	1-56	6-324	2-672	7-573
$\overline{X}H\pm ES$	0.5±0.4	0.79±0.32	0.6±0.3	0.61±0.34	0.93±0.25
Range	0-1.3	0.23-1.48	0.1-1	0.08-1.24	0.54-1.4
$\overline{X}J'\pm ES$	0.7±0.2	0.75±0.2	0.6±0.2	0.5±0.25	0.64±0.14
Range	0.2-1	0.27-1	0.2-1	0.14-0.92	0.43-0.91
$\overline{X}I_{B-P}\pm ES$	0.7±0.2	0.82±0.15	0.7±0.2	0.8±0.2	0.6±0.2
Range	0.3-1	0.3-1	0.4-1	0.4-1	0.3-1

Note. Data include. S, Richness helminth species; $\overline{X}S$, average helminth species; $\overline{X}n$, average number of helminth; $\overline{X}H$, average Brillouin index; $\overline{X}J'$, average evenness index; $\overline{X}I_{B-P}$, average Berger-Parker index.

3.6 Similarity Among Component Communities

Among component communities, similarity was < 50%, as they share only a few parasite species, excepting those for *M. americanus* and *M. littoralis* sharing 10 species. *C. arenarius* and *U. coroides* shared 7 species. *B. chrysoura*, only shares three parasite species (Table 1, Figure 2).
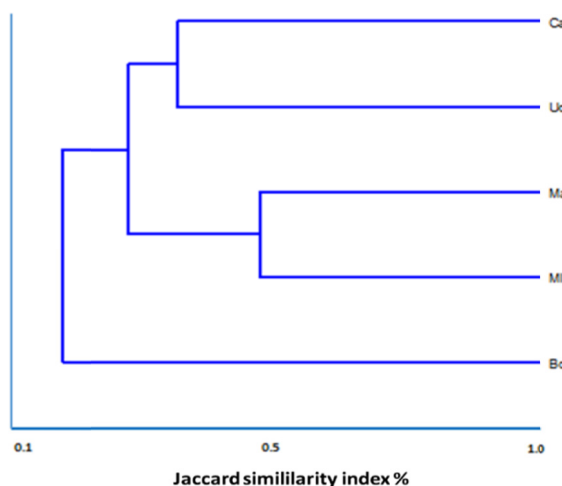

Figure 2. Cluster of similarity between the communities of parasites of five sciaenids species from Veracruz

Note. Hosts: Ba, *B. chrysoura*; Ca, *C. arenarius*; Ma, *M. americanus*; Ml, *M. littoralis*; Uc, *U. coroides*.

4. Discussion

Parasitic helminths in sciaenid fish have been widely studied in the Gulf of Mexico and the Caribbean Sea (Nahhas & Powell, 1971, Hendrix, 1994, Kohn et al., 2006, Pérez-Ponce de León et al., 2007, Overstreet et al., 2009), despite having extensive studies, our work adds new records of hosts as well as locality, with records of parasites of the five groups of helminths, both in *M. americanus* and *M. littoralis* and in *U. coroides*, and only of four groups in *C. arenarius*, for not having monogeneous records.

In general, trematodes and nematodes are the most numerous parasities species in marine fish, among them the sciaenids (Rohde & Heap, 1998; Zander et al., 1999), including those from tropical (Moravec et al., 1997; Sabas & Luque, 2003; Luque & Poulin, 2007), and temperate latitudes (Zander et al., 1999; Madhavi & Sai-Ram, 2000), and Our results also showed this condition, these results are similar to records in other sciaenids from the USA (Thoney, 1991, 1993), Peru (Oliva & Luque, 1998), and Brazil (Chaves & Luque, 1999; Alves & Luque, 2001; Sabas & Luque, 2003), adding that in our records of the parasites of *U. coroides*, the number of acanthocephalans (4 sp.) is high with respect to the registry for other scianids.

Records of larval stage parasites, such as *Callitetrarhynchus* sp., *Contracaecum* sp., *Cardiocephaloides* sp. And *Rhipidocotyle* sp., suggest the importance of sciaenids as intermediate hosts for completing life-cycles of parasites (Overstreet, 1978; Deardorff & Overstreet, 1981; Sánchez-Ramírez & Vidal-Martínez, 2002; Aguirre-Macedo et al., 2007), the importance is also highlighted of sciaenids in the food chain in the area (Chaves & Luque; 1999; Sánchez-Ramírez & Vidal-Martínez, 2002; Luque & Poulin, 2004). On the other hand, it is generally considered that the larger the host the higher richness and abundance (Holmes, 1990; Bush et al., 1990), this was confirmed, with the richness of community parasites for *U. coroides* and *M. americanus*. This greater richness of parasites in the larger fish, usually responds to greater vagility, to greater contact with infected intermediate hosts, to a higher probability of infection; and for these fish, it also responds to eating habits (Poulin & Mouillot, 2003; Poulin et al., 2003). These aspects were pointed out for the community of parasites of *Caranx hippos* from the study area (Montoya-Mendoza et al., 2017).

In relation to the abundance distribution types, our communities of parasites were adjusted to the log-normal and stick-broken models, these types of distribution are frequent for parasitic helminth communities of marine fish (Poulin & Justine, 2008), even when, two species of parasites were the most abundant (*P. stichospinus* on *M. littoralis*, *D. leiostomi* on *U. coroides*), and that exceed all others. Therefore, dominance of these species had effects on the abundance distribution type (log-normal), and in these communities is different from the broken-stick model with *C. arenarius* in *H. fortalezae* and Tetraphyllidae, as codominant species; and also in *M. americanus* with *Glaucivermis spinosu*s and *P. stichospinus* as codominant species. The different communities adapted to one type of distribution model or the other, showing that, in all community components, they have a high proportion of species of medium and low abundance. These types of species have effects on the community components richness.

The similarity analysis revealed that sciaenids have and share a helminth fauna, as the *Rhamnocerchus* sp., *Hargicotyle* sp., and *Pseudorhamnocercoides* sp., or *Glaucivermis spinosus* and *Stephanostomum sentum*. Meanwhile, the highest similitude was observed among *M. americanus* with *M. littoralis*, and between *U. coroides* with *C. arenarius*, considering that they are sympatric species living in the place. This aspect was registered for some lutjanids and carangids species in the on the site (Montoya-Mendoza et al., 2014, 2016; 2017), and for carangids from other places (Sánchez-Ramírez & Vidal-Martínez, 2002; Aguirre-Macedo et al., 2007).

On the other hand, the parasite communities in five sciaenids are as rich and diverse as those in marine hosts in temperate (Châari et al., 2015) and tropical zones (Luque & Poulin, 2007; Madhavi & Triveni-Lakshmi, 2012), both in community components and infracommunities, especially with parasitic helminth communities of sciaenids from the west coast of the Atlantic. *e.g.*, *Leiostomus xanturus* (S = 19, S = 6±1.9, H' = 1.4±0.69) and *Micropogonias undulatus* (S = 21, S = 7.3±2.3, H'= 1.8±0.63) (Thoney, 1993); *Cynoscion guatucupa* (S = 15, S = 4.6±1.8) and *Macrodon ancylodon* (S = 14, S = 2.8±1.3) (Sabas & Luque, 2003); *Menticirrhus americanus* (S = 12, S = 2.2±1.3, H = 0.56±0.28) (Chaves & Luque, 1999); *Micropogonias furnieri* (S = 20, S = 2.9±2, H = 0.49±0.41) (Alves & Luque, 2001), and *Paralonchurus brasiliensis* (S = 12, S = 2.1±0.9) (Luque et al., 2003). Finally, it has to be said that parasitic relations of hosts in wild populations, with biological, commercial and food relevance, and high farming potential, as those of sciaenids (Ohs et al., 2013), pose no zoonotic risk, and their parasitic helminth communities are rich and diverse.

References

Aguirre-Macedo, M. L., Vidal-Martínez, V. M., González-Solís, D., & Caballero, P. L. (2007). Helminth communities of four commercially important fish species from Chetumal Bay, Mexico. *Journal of Helminthology, 81*, 19-31. https://doi.org/10.1017/S0022149X0721209X

Alves, D. R., & Luque, J. L. (2001). Community ecology of the metazoan parasites of White Croaker, *Micropogonias furnieri* (Ostheichthyes: Sciaenidae), from the coastal zone of the State of Rio de Janeiro, Brazil. *Memórias do Instituto Oswaldo Cruz, 96*, 145-153. https://doi.org/10.1590/S0074-02762001000200002

Bush, A. O., Aho, J. H., & Kennedy, L. R. (1990). Ecological versus phylogenetic determinants of helminth parasites community richness, *Evolutionary Ecology, 4*, 1-20. https://doi.org/10.1007/BF02270711

Bush, A. O., Lafferty, K. D., Lotz, J. M., & Shostak, A. W. (1997). Parasitology meets ecology on its own terms: Margolis et al. revisited. *Journal of Parasitology, 83*, 575-583. https://doi.org/10.2307/3284227

Châari, M., Feki, M., & Neifar, L. (2015). Metazoan parasites of the Mediterranean garfish *Belone belone gracilis* (Teleostei: Belonidae) as a tool for stock discrimination. *Open Journal of Marine Science, 5*, 324-334. https://doi.org/10.4236/ojms.2015.53027

Chaves, N. N., & Luque, J. L. (1999). Ecology of metazoans parasites of *Menticirrhus americanus* (Osteichthyes: Sciaenidae), coast area from Rio de Janeiro State, Brazil, *Revista Brasileira de Parasitolgia Veterinária, 8*, 137-144.

Deardorff, T. L., & Overstreet, R. M. (1981). Larval *Hysterothylacium* (= *Thynnascaris*) (Nematoda: Anisakidae) from fishes and invertebrates in the Gulf of Mexico. *Proceedings of the Helminthological Society of Washington, 43*, 113-126.

Froese, R., & Pauly, D. Eds, (2018). *FishBase*. World Wide Web Electronic Publication.

Hammer, O., Harper, D. A. T., & Ryan, P. D. (2001). PAST, Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica, 4*, 1-9.

Hendrix, S. S. (1994). *Marine flora and fauna of the Eastern United States, Platyhelminthes: Monogenea*. NOAA Technical Report, NMFS, USA.

Holmes, J. C. (1990). Helminth communities in marine fishes. In G. W. Esch, A. O. Bush, & J. M. Aho (Eds.), *Parasite comunities: Patterns and processes* (pp. 101-130). Chapman and Hall, USA. https://doi.org/10.1007/978-94-009-0837-6_5

Holmes, J. C., & Price, P. W. (1986). Communities of parasites. In D. J. Anderson, & J. Kikkawa (Eds.), *Community biology: Pattern and processes*. (pp. 187-213). Blackwell, Oxford, UK.

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, 38*, 218-226. https://doi.org/10.3856/vol38-issue2-fulltext-6

Jiménez-Valverde, A., & Hortal, J. (2003). Las curvas de acumulación de especies y la necesidad de evaluar la calidad de los inventarios biológicos. *Revista Ibérica de Aracnología, 8*, 151-161.

Kohn, A., Cohen, S. C., & Salgado-Maldonado, G. (2006). Checklist of Monogenea parasites of freshwater and marine fishes, amphibians and reptiles from Mexico, Central America and Caribbean, *Zootaxa, 1289*, 1-114.

Lagrue, C., Kelly, D. W., Hicks, A., & Poulin, R. (2011). Factors influencing infection patterns of trophically transmitted parasites among a fish community: Host diet, host-parasite compatibility or both? *Journal of Fish Biology, 79*, 466-485. https://doi.org/10.1111/j.1095-8649.2011.03041.x

Lo, C. M., Morand, S., & Galzin, R. (1998). Parasite diversity/host age and size relationship in three coral-reef fishes from French Polynesia. *International Journal for Parasitology, 28*, 1695-1708. https://doi.org/10.1016/S0020-7519(98)00140-4

Luque, J. L., Alves, D. R., & Ribeiro, R. S. (2003). Community ecology of the metazoan parasites of Banded Croaker, *Paralonchurus brasiliensis* (Osteichthyes: Sciaenidae), from the coastal zone of the State of Rio de Janeiro, Brazil, *Acta Scientiarum. Biological Sciences, 25*, 273-278. https://doi.org/10.4025/actascibiolsci.v25i2.2009

Luque, J. L., & Poulin, R. (2004). Use of fish as intermediate hosts by helminth parasites: A comparative analysis. *Acta Parasitologica, 49*, 353-361.

Luque, J. L., & Poulin, R. (2007). Metazoan parasite species richness in Neotropical fishes: Hotspots and the geography of biodiversity. *Parasitology, 134*, 865-878. https://doi.org/10.1017/S0031182007002272

Luque, J. L., & Poulin, R. (2008). Linking ecology with parasite diversity in Neotropical fishes. *Journal of Fish Biology, 72*, 189-204. https://doi.org/10.1111/j.1095-8649.2007.01695.x

Madhavi, R., & Sai-Ram, B. K. (2000). Community structure of helminth parasites of the tuna, *Euthynnus affinis*, from the Visakhapatnam coast, Bay of Bengal. *Journal of Helminthology, 74*, 337-342. https://doi.org/10.1017/S0022149X00000494

Madhavi, R., & Triveni-Lakshmi, T. (2012). Metazoan parasites of the Indian mackerel, *Rastrelliger kanagurta* (Scombridae) of Visakhapatnam coast, Bay of Bengal. *Journal of Parasitic Diseases, 35*, 66-74. https://doi.org/10.1007/s12639-011-0028-5

Magurran, A. E. (2004). *Measuring biological diversity*. Blackwell Publishing, Oxford, U. K.

Marcogliese, D. J., & Cone, D. K. (1997). Food webs: A plea for parasites. *Trends in Ecology & Evolution, 12*, 320-325. https://doi.org/10.1016/S0169-5347(97)01080-X

Montoya-Mendoza, J., Castañeda-Chávez, M. R., Lango-Reynoso, F., & Rojas-Castañeda, S. (2016). Helminth parasites of Lane Snapper, *Lutjanus synagris* from Santiaguillo reef, Veracruz, Mexico. *Journal of Agricultural Science, 8*, 81-88.

Montoya-Mendoza, J., Jiménez-Badillo, M. L., Salgado-Maldonado, G., & Mendoza-Franco, E. F. (2014). Helminth parasites of the red snapper, *Lutjanus campechanus* (Perciformes: Lutjanidae) from the reef Santiaguillo, Veracruz, Mexico. *Journal of Parasitology, 100*, 868-872. https://doi.org/10.1645/13-429.1

Montoya-Mendoza, J., Salgado-Maldonado, G., Favila-Castillo, M. E., Vázquez-Hurtado, G., & Castañeda-Chávez, M. R. (2017). Communities of helminth parasites in five Carangidae species from the Coast of Veracruz, Mexico, Southern Gulf of Mexico. *Global Journal of Science Frontier Research: C Biological Science 17*, 7-17.

Morand, S., Cribb, T. H., Kulbicki, M., Chauvet, C., Dufour, V., Faliex, E., … Sasal, P. (2000). Determinants of endoparasite species richness of New Caledonian Chaetodontidae. *Parasitology, 121*, 65-73. https://doi.org/10.1017/S0031182099006058

Moravec, F., Vidal-Martínez, V. M., Vargas-Vázquez, J., Vivas-Rodríguez, C., González-Solís, D., Mendoza-franco, E., … Güemez-Ricalde, J. (1997). Helminth parasites of *Epinephelus morio* (Pisces: Serranidae) of the Yucatan Peninsula, southeastern Mexico. *Folia Parasitologica, 44*, 255-266. https://folia.paru.cas.cz/pdfs/fol/1997/04/03.pdf

Moreno, C. E., & Halffter, G. (2001). On the measure of sampling effort used in species accumulation curves. *Journal of Applied Ecology, 38*, 487-490. https://doi.org/10.1046/j.1365-2664.2001.00590.x

Muñoz, G., Grutter, A. S., & Cribb, T. H. (2006). Endoparasite communities of five fish species (Labridae: Cheilininae) from Lizard Island: How important is the ecology and phylogeny of the hosts? *Parasitology, 132*, 363-373. https://doi.org/10.1017/S0031182005009133

Nahhas, F. M., & Powell, E. C. (1971). Digenetic trematodes of marine fishes from the Floridian Northern Gulf of Mexico, *Tulane Studies in Zoology and Botany, 17*, 1-9.

Ohs, C. L., Creswell, R. L., & DiMaggio, M. A. (2013). Growing marine baitfish: A guide to Florida's common baitfish and their potential for aquaculture, Florida Sea Grant SGEB 69.

Oliva, M. E., & Luque, J. L. (1998). Metazoan parasites infracommunities in five sciaenids from the Central Peruvian Coast, *Memorias do Instituto Oswaldo Cruz, Rio de Janeiro, 93*, 175-180.

Overstreet, R. M. (1978). *Marine maladies? Worms, germs, and other symbionts from the Northern Gulf of Mexico*. Mississippi-Alabama Sea Grant Consortium, MASGP-78-021.

Overstreet, R. M., Cook J. O., & Heard, R. (2009). Trematoda (Platyhelminthes) of the Gulf of Mexico. In D. W. Felder, & D. K. Camp (Eds.), *Gulf of Mexico-Origins, Waters, and Biota* (Volume 1), *Biodiversity* (pp. 419-486). Texas A&M University Press, College Station, Texas, USA.

Pérez-Ponce De León, G., García-Prieto, L., & Mendoza-Garfias, B. (2007). Trematode parasites (Platyhelminthes) of wildlife vertebrates in Mexico. *Zootaxa, 1534*, 1-247. https://doi.org/10.11646/zootaxa.1534.1.1

Poulin, R. (1998). Comparison of three estimators of species richness in parasite component communities. *Journal of Parasitology, 84*, 485-490. https://doi.org/10.2307/3284710

Poulin, R., & Mouillot, D. (2003). Parasite specialization from a phylogenetic perspective: A new index of host specificity, *Parasitology, 126*, 473-480. https://doi.org/10.1017/S0031182003002993

Poulin, R., Nichol, K., & Latham, A. (2003). Host sharing and host manipulation by larval helminths in shore crabs: Cooperation or conflict? *International Journal for Parasitology, 33*, 425-433. https://doi.org/10.1016/S0020-7519(03)00002-X

Poulin, R., & Justine, J.-L. (2008). Linking species abundance distributions and body size in monogenean communities. *Parasitology Research, 103*, 187-193. https://doi.org/10.1007/s00436-008-0953-0

Rohde, K., & Heap, M. (1998). Latitudinal differences in species and community richness and in community structure of metazoan endo- and ectoparasites of marine teleost fish. *International Journal for Parasitology, 28*, 461-474. https://doi.org/10.1016/S0020-7519(97)00209-9

Sabas, C. S. S., & Luque, J. L. (2003). Metazoan parasites of weakfish, *Cynoscion guatucupa* and *Macrodon ancylodon* (Osteichthyes: Sciaenidae), from the coastal zone of the State of Rio de Janeiro, Brazil. *Revista Brasileira de Parasitologia veterinária, 12*, 171-178.

Sánchez-Ramírez, C., & Vidal-Martínez, V. M. (2002). Metazoan parasite infracommunities of Florida pampano (*Trachinotus carolinus*) from the coast of the Yucatán Peninsula, Mexico. *Journal Parasitology, 88*, 1087-1094. https://doi.org/10.2307/3285476

Sasal, P., Serge Morand, S., & Guegan, J.-F. (1997). Determinants of parasite species richness in Mediterranean marine fishes. *Marine Ecology Progress Series, 149*, 61-71. https://doi.org/10.3354/meps149061

Soberón, M. J., & Llorente, J. (1993). The use of species accumulation functions for the prediction of species richness. *Conservation Biology, 7*, 480-488. https://doi.org/10.1046/j.1523-1739.1993.07030480.x

Thoney, D. A. (1991). Population dynamics and community analysis of the parasite fauna of juvenile spot, *Leiostomus xanthurus* (Lacepede), and Atlantic croaker, *Micropogonias undulatus* (Linnaeus), (Sciaenidae) in two estuarines along the meddle Atlctic coast of the United States. *Journal of Fish Biology, 39*, 515-534. https://doi.org/10.1111/j.1095-8649.1991.tb04383.x

Thoney, D. A. (1993). Community ecology of the parasites of adult Spot, *Leiostomus xanthurus*, and Atlantic croaker, *Micropogonias undulatus* (Sciaenidae) in the Cape Hatteras region, *Journal of Fish Biology, 43*, 718-804. https://doi.org/10.1111/j.1095-8649.1993.tb01155.x

Vidal-Martínez, V. M., Aguirre-Macedo, M. L., Scholz, T., González-Solís, D., & Mendoza-Franco, E. (2001). *Atlas of the helminth parasites of cichlid fishes of Mexico*. Academia, Academy of Sciences of the Czech Republic, Prague, Czech Republic.

Zander, C. D., Reimer, L. W., & Barz, K. (1999). Parasite communities of the Salzhaff (Northwest Mecklenburg, Baltic Sea). I. Structure and dynamics of communities of littoral fish, especially small-sized fish. *Parasitology Research, 85*, 356-372. https://doi.org/10.1007/s004360050562

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