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Factors determining parasite community richness and species composition in black snook *Centropomus nigrescens* (Centropomidae) from coastal lagoons in Guerrero, Mexico

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Abstract Species richness and composition were determined for parasite communities in the black snook *Centropomus nigrescens* collected from five coastal lagoons in the Guerrero state, Mexico. A total of 354 fish were collected between December 2007 and November 2008. Twenty-four species of parasite were identified: 2 monogeneans, 12 digeneans, 4 acanthocephalans, 1 cestode, 4 nematodes, and 1 pentastomid. The communities consisted mainly of autogenic parasites, and all were dominated by the digenean *Paracrytogonimus yamagutii*. Community species composition was similar among lagoons, although the influence of local conditions prevented them from being identical. Host traits such as predator feeding habits, body size, and vagility contributed to parasite community structure and species composition.

Introduction

Very few data exist on the factors determining species composition and richness in the parasite communities of fish from tropical environments in Mexico. Available data cover mainly brackish environments from southeastern Mexico (Salgado-Maldonado and Kennedy 1997; Vidal-Martinez and Poulin, 2003; Aguirre-Macedo et al. 2007). Host-related factors such as diet, body size, reproductive behavior, vagility, and migratory habits may influence parasite community structure and species composition (Sasal et al. 1997; Bush et al. 2003; Vidal-Martinez and Poulin 2003; Luque et al. 2004; Poulin 2003; Violante-González et al. 2008; Tavares and Luque 2008). Factors linked to habitat environmental and biological aspects can also affect structure and species composition (Machado et al. 1995; Salgado-Maldonado and Kennedy 1997; Vidal-Martinez and Poulin 2003; Aguirre-Macedo et al. 2007; Mwita and Nkwengulila 2008; Tavares and Luque 2008).

Tropical coastal lagoons are generally brackish environments with specific characteristics determined by environmental dynamics such as the dry/rainy season cycle and the extent and frequency of their connection to the ocean (Yáñez-Arancibia 1978). Black snook *Centropomus nigrescens* is one of the most commercially important fish species in the costal lagoons of Guerrero state, Mexico. This demersal marine fish enters coastal lagoons in search of refuge and food, reproduces in the ocean, and then remains near the coast (Yáñez-Arancibia 1978; Bussing 1995). Parasite taxonomic records exist for *C. nigrescens* from two coastal lagoons in Guerrero (Violante-González and Aguirre-Macedo 2007; Violante-González et al. 2007), although its parasite community has not been analyzed in any other lagoons in the region.

The objective of the present study was to identify the factors determining parasite community species richness and composition in *C. nigrescens* collected from five coastal lagoons in Guerrero, Mexico.

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Materials and methods

Between December 2007 and November 2008, gill nets were used to collect black snook *C. nigrescens* from five coastal lagoons in Guerrero state, Mexico: Chautengo (16°36′ N; 99°09′ W, n=115), Coyuca (16º57′ N; 100º02′ W, n=49), Mitla (16°59′ N; 100°14′ W, n=12), Tecomate (16°41′ N; 99°19′ W, n=72), and Tres Palos (16°48′ N; 99°47′ W, n=49). A sample of *C. nigrescens* (n=49) collected from Tres Palos Lagoon in 2004 was included for temporal comparative analysis, producing a total sample size of 354 individuals. Total length of fish specimens ranged from 21.7±2.3 (Tres Palos, 2008) to 37.3±11.8 cm (Chautengo) and varied significantly between lagoons (analysis of variance (ANOVA) F=36.49, P<0.0001).

A complete necropsy was done on all fish specimens, and the parasites were collected from their internal and external organs according to Vidal-Martínez et al. (2001). Voucher specimens of most parasite taxa were deposited in the National Helminth Collection, Institute of Biology, National Autonomous University of Mexico, Mexico City (CNHE).

Autogenic parasite species were defined as those which reach maturity in aquatic hosts and thus have a limited ability to colonize new locations. Allogenic species were those with birds or mammals as definitive hosts, the natural migration patterns of which favor parasite dispersion and produce a wider geographic distribution (Esch et al. 1988). Based on review of published records for Mexico and other countries, a conservative approach to parasite species distribution was applied using the general categories of freshwater, brackish water, and marine water.

Interlagoon differences in parasite community composition were described using prevalence (percent of hosts infected), mean abundance (mean number of parasites per examined fish), and intensity range for each parasite species per lagoon (Bush et al. 1997). Possible differences in infection parameters for parasite species recorded in all or most of the studied lagoons were evaluated using G tests (Sokal and Rohlf 1998) for prevalence, and a χ^2 test for abundance. Significance for all the statistical analyses was established at P=0.05, unless stated otherwise.

Analyses were made at the levels of component community (i.e., total parasites in all collected hosts per lagoon) and infracommunity (i.e., total parasites in each individual host; Holmes and Price 1986). Component community parameters included total number of parasite species, total number of individual parasites, the Shannon–Wiener Index (H) as a measure of diversity, species evenness (equitability; Krebs 1999), and the Berger–Parker Index (BPI) as a measure of numerical dominance (Magurran 1991). The qualitative Jaccard similarity index was used to evaluate similarity or difference in parasite community species composition between lagoons at this level. Student and χ^2 tests were applied to identify differences between component community parameters, and correlations were calculated using the Spearman range coefficient (r_s; Krebs 1999).

Infracommunities were described in terms of mean number of parasite species per host, mean number of parasite individuals, and mean Brillouin Diversity Index (H') value per host. A one-way analysis of covariance (ANCOVA) was used to identify differences in infracommunity parameters between lagoons. Normality was calculated with the Kolmogorov–Smirnov test following Lilliefors' approach (Sokal and Rohlf 1998). Data were log-transformed when significant deviations from normality were identified.

A multiple regression analysis was applied to relate the infracommunity parameters (dependent variables) with host vagility, body size, and lagoon salinity (independent variables). Host vagility was expressed in terms of greater or lesser facility of movement between lagoon and marine environments, which is largely dependent on the length of the lagoon inlet channel. Google Earth® was used to measure inlet channel length and the lagoons pooled into three categories: channel length ≤1 km, ≥2 and ≤5 km, and ≥6 and ≤10 km. They were also classified according to average annual salinity (Yáñez-Arancibia 1978) as oligohaline (mean salinity ≤6 ppt; Coyuca, Mitla, and Tres Palos) and polyhaline (mean salinity≥15 ppt; Chautengo and Tecomate).

The best regression model was determined by running multiple regressions using a forward stepwise selection technique with F values of 1 and 0 chosen a priori for the entry and removal variables, respectively. Each independent variable's contribution to prediction of each infracommunity parameter (dependent variables) was analyzed using partial correlations. Independent variable redundancy was evaluated with a tolerance model, defined for each variable as $(1-R^2)$, with all other variables included in the model.

Results

Species composition

Twenty-four parasite species were identified in 354 *C. nigrescens* specimens collected between December 2007 and November 2008 from five coastal lagoons in Guerrero, Mexico: 2 monogeneans, 12 digeneans (eight adults, four larvae), 4 acanthocephalans (three intestinal forms, one cystacanth), 1 adult cestode, 4 nematodes (one adult, three larvae), and 1 pentastomid larva (Table 1). Of these, 17 species were classified as autogenic and seven as allogenic.

Table 1 Parasite infection parameters for black snook *Centropomus nigrescens* from five coastal lagoons in Guerrero, Mexico

Parasite	Site	CNHE	*N*/Lagoon	P(%)	Total	Mean abundance	Range of intensity
Monogenea							
Cornutohaptor nigrescensi (Mw, Au) Mendoza-Franco, Violante-González, Vidal-Martínez, 2006	Gills	6,771	115/Ch	81.74	6,637	57.7±87.1	1–466
		6,770	49/Co	85.71	503	10.27±10.2	1–45
Rhabdosynochus alterinstitus (Mw, Au) Mendoza-Franco, Violante-González, Vidal-Martínez, 2008	Gills		115/Ch	39.1	1,441	12.5±37.5	1–160
			72/Te	88.89	20.68	28.72±32.5	2–215
			57/3P04	14.04	81	1.42±11.9	2–37
Digenea (adult)							
Bucephalus margaritae (Mw, Au)[a] Ozaqui *et* Ishibashi, 1934	Intestine	6,805	115/Ch	9.6	205	1.8±22.9	1–60
Neoapocreadium marina (Mw, Au) Manter, 1947	Intestine	6,777	115/Ch	0.87	3	0.03	3
Paracryptogonimus yamagutii (Mw, Au) Lamothe, 1969	Intestine	6,809	115/Ch	*93.0*	11,745	*102.1±152.5*	2–948
		6,811	49/Co	61.22	1,165	23.78±75.4	1–278
		6,813	12/Mi	75	83	6.92±2.7	5–12
		6,812	72/Te	*84.72*	4,353	*60.46±121.2*	1–619
		6,810	57/3P04	50.88	411	7.21±20.7	1–92
			49/3P08	42.86	257	5.24±32.9	1–50
Paropecoelus parupenei (Mw, Au)[a] Yamaguti, 1970	Intestine	6,804	72/Te	1.39	6	0.08	6
Plagiocirrus cf. *primus* (Mw, Au)[a] Van Cleave and Mueller, 1932	Intestine	6,778	115/Ch	1.74	7	0.06±3.5	1–6
		6,779	72/Te	1.39	2	0.03	2
			49/3P08	2.04	1	0.02	1
Pseudacaenodera cristata (Mw, Au) Yamaguti, 1965	Intestine	6,776	115/Ch	0.87	1	0.01	1
Stephanostomum baccatum (Mw, Au)[a] Nicoll, 1907	Intestine	6,806	115/Ch	0.87	1	0.04	1
		6,807	72/Te	1.39	5	0.07	5
Stephanostomum ditrematis (Mw, Au)[a] Yamaguti, 1939	Intestine	6,775	72/Te	1.39	8	0.11	8
Digenea (larvae)							
Ascocotye (*Phagicola*) *longa* (Bw, Al) Ransom, 1920	Heart, mesentery, liver		57/3P04	5.26	12	0.21±2.6	2–7
Diplostomum (*Austrodiplostomum*) *compactum* (Fw, Al) Lutz, 1928	Eyes	6,772	49/Co	6.12	5	0.10±0.6	1–2
		6,774	12/Mi	16.67	2	0.17	1
		6,773	57/3P04	3.51	2	0.04	1
			49/3P08	2.04	1	0.02	1
Posthodiplostomum minimum (Fw, Al) MacCallum, 1921	Muscle		49/Co	2.04	1	0.02	1
			57/3P04	3.51	12	0.21±4.2	1–3
Pseudoacanthostomum panamense (Bw, Au) Caballero, Bravo-Hollis and Grocott, 1953	Mesentery, inside intestine wall	6,813	12/Mi	16.67	3	0.25	1–2
		6,814	57/3P04	10.53	11	0.19±0.7	2–7
Acanthocephala (adult)							
Floridosentis mugilis (Mw, Au) Bullock, 1962	Intestine	6,822	115/Ch	1.74	3	0.03±0.7	1–2
Neoechinorhynchus cf. *golvani* (Fw, Au) Salgado-Maldonado, 1978	Intestine	6,819	115/Ch	0.87	3	0.03	3
		6,818	49/Co	2.04	2	0.04	2
		6,817	72/Te	4.17	10	0.14±2.1	1–5
		6,816	57/3P04	38.60	153	2.68±13.1	1–56
			49/3P08	53.06	110	2.24±5.1	1–22
Pseudoleptorhynchoides lamothei (Bw, Au) Salgado-Maldonado 1976	Intestine	6,815	12/Mi	66.67	27	2.25±2.1	2–7
Southwellina hispida (Fw, Al) Van Cleave, 1916	Liver, mesentery	6,821	115/Ch	0.87	1	0.01	1
			49/Co	2.04	1	0.02	1
			12/Mi	16.67	2	0.17	1
		6,820	72/Te	2.78	2	0.03	1

Table 1 (continued)

Parasite	Site	CNHE	*N*/Lagoon	P(%)	Total	Mean abundance	Range of intensity
			57/3P04	3.51	3	0.05±0.7	1–2
			49/3P08	2.04	1	0.02	1
Cestoda (adult)							
Proteocephalus sp. (Mw, Au)	Intestine	6,832	115/Ch	23.48	102	0.89±4.6	1–23
			49/Co	20.41	35	0.71±4.7	1–16
		6,830	12/Mi	25.00	6	0.50	2
		6,831	72/Te	12.50	21	0.29±2.2	1–7
			57/3P04	*40.35*	72	1.26±2.4	1–9
			49/3P08	4.08	3	0.06±0.7	1–2
Nematoda (adult)							
Hysterothylacium perezi (Bw, Au) Gopar-Merino, Osorio-Sarabia, and García-Prieto, 2005.	Intestine	6,827	115/Ch	2.61	14	0.12±4.73	1–10
Nematoda (larvae)							
Contracaecum sp. (Fw, Al)	Mesentery	6,826	115/Ch	*53.91*	337	2.93±8.6	1–62
		6,824	49/Co	38.78	59	1.20±2.6	1–9
		6,823	12/Mi	*50.00*	16	1.33±2.0	1–5
		6,825	72/Te	44.44	91	1.26±3.6	1–18
			57/3P04	17.54	17	0.30±1.6	1–6
			49/3P08	22.45	63	1.29±13.7	1–47
Eustrongylides sp. (Fw, Al)[a]	Intestine	6,828	115/Ch	1.74	2	0.02	1
Echinocephalus sp. (Mw, Au)[a]	Mesentery	6,829	115/Ch	1.74	3	0.03±0.71	1–2
Pentastomida (larvae)							
Sebekia sp. (Fw, Al)[a]	Liver, stomach, mesentery		115/Ch	10.43	20	0.17±1.15	1–4
			72/Te	4.17	3	0.04	1

Fw freshwater, *Bw* brackish water, *Mw* marine water, *Au* autogenic species, *Al* allogenic species, *CNHE* National Helminth Collection, *N* number of fish examined, *Ch* Chautengo, *Co* Coyuca, *Mi* Mitla, *Te* Tecomate, *3P* Tres Palos, *P(%)* prevalence of infection (percent infected), *Total* total number of individual parasites, *Abundance* mean number of parasites per examined fish±standard deviation, *Intensity* range (i.e., min–max). Higher significance values of prevalence (*G* test), and abundance (χ^2 test), are in italics ($P<0.05$)

[a] New geographical record

Based on parasite species distribution, 13 were classified as marine, 7 as freshwater, and 4 as brackish water (Table 1).

The number of marine species ranged from 2 (Mitla) to 11 (Chautengo) and varied significantly between lagoons (χ^2= 10.92, $P<0.05$). The number of freshwater species ranged from three to five with no differences between lagoons (χ^2= 0.73, $P>0.05$; Fig. 1). Four species (*P. yamagutii*, *Contracaecum* sp., *Proteocephalus* sp., and *Southwellina hispida*)

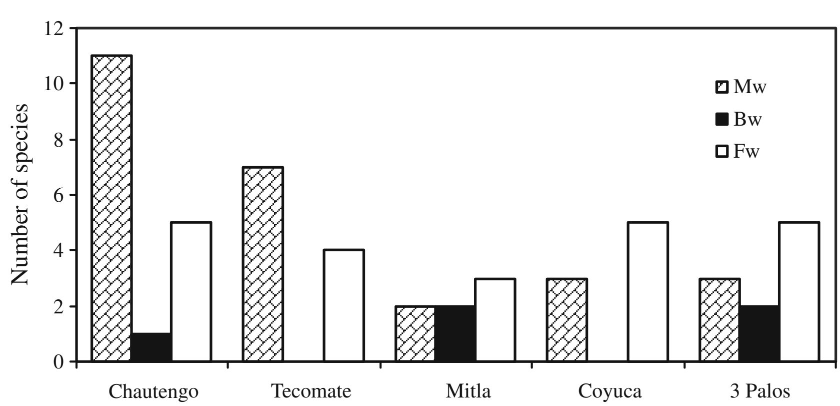

Fig. 1 Parasite species distribution in *C. nigrescens* from five coastal lagoons in Guerrero, Mexico, by environment: freshwater (*Fw*), brackish water (*Bw*), marine water (*Mw*)

were widely distributed and occurred in the parasite communities of all the collected hosts. The acanthocephalan *Neoechinorhynchus* cf. *golvani* was identified in four of the lagoons. The prevalence values of four of these five widespread species varied significantly between lagoons (*P. yamagutii*, G=28.32, P<0.05; *Contracaecum* sp., G=29.05, P<0.05; *Proteocephalus* sp., G=36.03, P<0.05; *N.* cf. *golvani*, G=129.39, P<0.05). In contrast, mean abundance between lagoons only varied significantly for *P. yamagutii* (χ^2=225.13, P<0.05; Table 1). Overall, prevalence values correlated positively with mean abundance values in all the communities, indicating that the most prevalent species were also the most abundant (P<0.01).

Component community

The number of species collected by lagoon ranged from 7 (Mitla, Tres Palos 08) to 17 (Chautengo) and varied significantly between lagoons (t=6.45, P<0.01). Total number of individual parasites ranged from 132 (Mitla) to 20,529 (Chautengo) and also varied significantly between lagoons (χ^2=62813.28, P<0.05; Table 2). The digenean *P. yamagutii* was numerically dominant in all component communities. Shannon–Wiener diversity index values ranged from 1.09 (Tecomate) to 2.06 (Tres Palos 04) and varied between lagoons (t=10.60, P<0.01). Evenness was positively correlated with diversity values in all five lagoons (r_s=0.87, P<0.05). Qualitative similarity between the component communities of different lagoons ranged from 1.03% (Chautengo–Mitla) to 43.7% (Chautengo–Tecomate; Fig. 2) and varied significantly between pairs of communities (χ^2= 114.08, P<0.05). The highest similarity (63.9%) was between the samples taken in 2004 and 2008 from Tres Palos Lagoon (Fig. 2). Similarity between component communities generally decreased with distance between lagoons, although the correlation between these variables was weak and not significant (r_s=−0.524, P>0.05).

Infracommunities

Host body size differed significantly between lagoons (one-way ANOVA; F=34.69, P<0.05), with the largest fish (37.3±11.8 cm) collected from Chautengo Lagoon and the smallest (21.7±2.3 cm) from Tres Palos Lagoon (2008). Body size (length) was positively correlated with all infracommunity parameters: mean number of parasites (r_s= 0.506, P<0.01), mean richness (r_s=0.398, P<0.01), and mean diversity (r_s=0.351, P<0.01). Within infracommunities, body size correlated positively with all parameters in Tres Palos Lagoon, while in Tecomate and Coyuca lagoons, the only correlation was between body size and mean number of parasites.

Mean number of species ranged from 1.50±0.7 (Tres Palos 08) to 3.25±1.0 (Chautengo) and mean number of parasites from 10.38±24.7 to 178.5±173.5 (Table 2). Brillouin diversity index values varied from 0.50±0.13 to 0.89±0.36. Mean values for all infracommunity parameters were highest in Chautengo Lagoon (one-way ANCOVA, P<0.001; Table 2). The multiple regression analysis showed that host vagility, that is, ease of movement between brackish and marine water environments, was the only predictor variable accepted in all three models. Host vagility and body size explained approximately 53% of variance in the mean number of parasites of the studied infracommunities (Table 3). Host body size was accepted in one model, and salinity was rejected in all models (Table 3).

Discussion

Environmental and biological characteristics in the five studied coastal lagoons influenced the species composition of each component community. In lagoons with greater marine influence, communities had higher numbers of

Table 2 Characteristics of the parasite component communities and infracommunities in black snook *Centropomus nigrescens* from five coastal lagoons

Lagoon	Component communities							Infracommunities		
	No. of hosts	No. of species	No. of parasites	BPI	Dominant species	H	Evenness	Mean number of species	Mean number of individuals	Mean value of Brillouin Index
Chautengo	115	17	20,529	0.57	Para	1.49	0.37	3.25±1.02	178.5±173.5	0.89±0.36
Coyuca	49	8	1,771	0.66	Para	1.24	0.41	2.23±0.9	36.14±63.7	0.79±0.34
Mitla	12	7	139	0.60	Para	1.75	0.63	2.67±.0.6	11.58±4.1	0.77±0.22
Tecomate	72	11	6,569	0.66	Para	1.09	0.31	2.47±0.8	91.24±123.1	0.68±0.3
3 Palos 04	57	10	774	0.53	Para	2.06	0.62	2.02±0.9	13.58±22.4	0.78±0.27
3 Palos 08	49	7	436	0.59	Para	1.46	0.52	1.50±0.7	10.38±24.7	0.50±0.13

BPI Berger–Parker Index, *H* Shannon–Wiener diversity index, *Para Paracryptogonimus yamagutii*

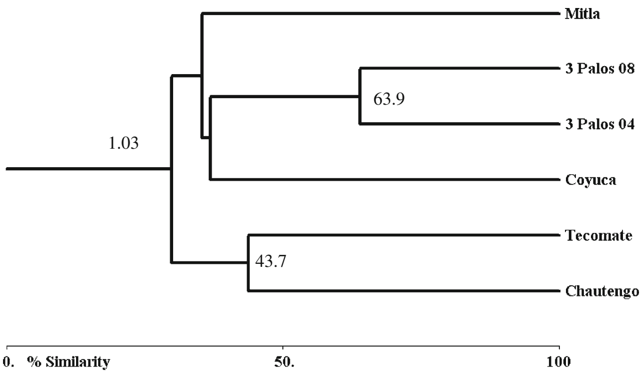

Fig. 2 Jaccard Index similarity percentages for parasite communities in *C. nigrescens* from five coastal lagoons in Guerrero, Mexico. A sample collected from Tres Palos Lagoon in 2004 is included for temporal comparison

marine parasite species, while in those with less marine influence, freshwater and brackish water species were more prominent. Host vagility and body size were the main factors determining species richness and diversity in the parasite infracommunities of *C. nigrescens*.

Eight of the 24 parasite species identified in *C. nigrescens* are new geographical records for Guerrero, Mexico (Table 1), and the remaining sixteen have been previously reported in this host species and/or others (Mendoza-Franco and Violante-González 2006; Violante-González and Aguirre-Macedo 2007; Violante-González et al. 2007; Mendoza-Franco et al. 2008).

Fourteen of the identified species were recovered from the intestine (Table 1), meaning that diet is important in structuring this host's parasite community in the studied coastal lagoons (Sasal et al. 1997; Luque et al., 2004; Tavares and Luque 2004; Mwita and Nkwengulila 2008). Black snook is considered a tertiary predator since it feeds on several fish species in juvenile stages, crustaceans such as shrimp and crab, and mollusks such as clams, mussels, and snails (Yáñez-Arancibia 1978; Bussing 1995). This predatory behavior exposes this host to the infective stages of a large variety of tropically transmitted parasites. Presence of the nematode *Echinocephalus* sp., which matures in elasmobranch fish (Moravec 1998), and the pentastomid *Sebekia* sp., which matures in aquatic reptiles such as crocodiles (Hoffman 1999), in *C. nigrescens* from Chautengo and Tecomate lagoons indicates that it can also serve as a prey species.

Marine species accounted for over 60% of the species in the parasite communities of hosts from Chautengo and Tecomate, but only 30% in the other studied lagoons (Fig. 1). This difference can be attributed to the environmental and biological conditions of each lagoon. For instance, Chautengo and Tecomate have a greater marine influence (salinity>15 ppt) because their inlet channels are relatively short, providing ready communication with the ocean, and they are connected to the ocean either year round (Chautengo) or for several months a year (Tecomate). The ichthyofauna of these lagoons includes over 80% marine species (Yáñez-Arancibia 1978), and therefore, the parasite species exchanged between fish species are mainly of marine origin. By contrast, Tres Palos, Mitla, and Coyuca have long, sinuous inlet channels which restrict marine influence, resulting in an ichthyofauna with over 60% freshwater or brackish species (Yáñez-Arancibia 1978). This agrees with previous studies indicating that local environmental conditions can substantially affect

Table 3 Multiple regression models predicting richness and diversity in parasite infracommunities of *Centropomus nigrescens* from five coastal lagoons from Guerrero, Mexico. (mean (±SE) of the intercept and regression coefficients for each predictor variable

	Mean number of parasites	Infracommunity parameters	
		Mean richness	Mean diversity (*H*′)
Intercept	0.22 (0.14)	0.37 (0.03)	0.33 (0.11)
Total length	0.11 (0.01)	NS	NS
PC	0.13		
T	0.62		
Vagility	0.56 (0.11)	0.57 (0.14)	0.60 (0.15)
PC	0.26	0.21	0.21
T	0.11	0.11	0.11
Salinity	NS	NS	NS
PC			
T			
R^2 adj	0.5302	0.2722	0.1802
F	127.20	42.15	25.99
P	<0.0001	<0.0001	<0.0001
SE of estimate	0.47	0.11	0.39
N	338	338	338

Predictor variables: total body size (length), vagility, salinity

PC partial correlation, *T* tolerance, *NS* not significant (variable removed), R^2 *adj* adjusted determination coefficient, *F* ANOVA, *P* significance level, *N* number of data parasite community structure (Machado et al. 1995; Salgado-Maldonado and Kennedy 1997; Valtonen et al. 2001; Vidal-Martínez and Poulin 2003; Aguirre-Macedo et al. 2007).

The parasite component communities and infracommunities of *C. nigrescens* exhibited the same pattern, i.e., low number of species, low diversity, and dominated by a single species (*P. yamagutii*; see Table 2). However, richness in the parasite community of *C. nigrescens* from Chautengo (17 species) was higher than those reported for *Centropomus undecimalis* (nine specie; Tavares and Luque 2004) and *Centropomus robalito* (nine species; Violante-González et al. 2007).

On the other hand, it is considered that distance between sampling localities is one of the best predictors of the similarity among communities of parasite. Hosts in locations closer to each other are exposed to local parasite pools which are more similar than those in locations further away (Poulin and Morand 1999; Poulin 2003; Vidal-Martínez and Poulin 2003). This is supported by the present results in that parasite communities from Chautengo and Tecomate (separated by a distance of 18.8 km) had high similarity (43.7%) of species composition, whereas similarity between Mitla and Chautengo (distance of 126.2 km) was much lower (1.03%; Fig. 2). Nonetheless, no clear pattern was observed since only a weak and not significant correlation was found among the distance between lagoons and their respective parasite community similarity percentages. This may be caused by other factors affecting community similarity between nearby lagoons, such as environmental and biological characteristics. For example, Chautengo and Tecomate are closer to each other than to the other studied lagoons, have greater marine influence and consequently more similar ichthyofauna than the other studied lagoons (Yáñez-Arancibia 1978). In contrast, Tres Palos and Tecomate are relatively near each other (distance to 36.2 km), but similarity between them (9.48%) was notably much lower than that between Tres Palos and Coyuca (36.8%, distance= 60.2 km), both of which have a lesser marine influence and predominantly freshwater ichthyofauna (Yáñez-Arancibia 1978). The present results therefore support the hypothesis that in tropical coastal lagoons, the parasite communities of a single host species may share some parasite species but will vary in composition due to each lagoon's specific environmental and biological characteristics (Salgado-Maldonado and Kennedy 1997; Valtonen et al. 2001; Vidal-Martínez and Poulin 2003).

Host feeding behavior, body size, vagility, and migratory habits contribute most to parasite community richness and diversity (Sasal et al. 1997; Bush et al. 2003; Tavares and Luque 2008; Mwita and Nkwengulila 2008). The present results suggest that infracommunity richness and diversity were most affected by host vagility and body size, while salinity had no significant effect (Table 3). In lagoons such as Chautengo, *C. nigrescens* can easily move between brackish and marine water, coming into contact with parasite species from both environments. This consequently increases parasite fauna richness and diversity in hosts from this lagoon. In addition, larger hosts harbor more individual and parasite species and individual parasites than those smaller hosts because larger (presumably older) fish have had more time to accumulate parasites than smaller (presumably younger) fish (Bush et al. 2003; Zander 2004). Despite the significant effect that the host body size may have on infracommunity structuring, this variable was rejected in two of the three multiple regression models (Table 3). This occurred because body size had no correlation to parasite richness and diversity in some of the studied lagoons, probably due to the minimal variation in body size at these locations. Salinity was rejected as a predictive variable in all the models, most likely because this environmental parameter is not highly variable in many of the studied lagoons and, therefore, cannot be an important factor in structuring parasite communities (Violante-González et al. 2008). This coincides with the results of Zander and Kesting (1998), who reported that salinity had no significant effect on the presence of parasites in fish from the brackish Baltic Sea.

In conclusion, the parasite communities on the black snook *C. nigrescens* from five coastal lagoons in Guerrero, Mexico, showed similar species composition. However, local environmental and biological conditions suggest an effect on the parasite community structure, meaning that it was not identical in different lagoons. This suggests that each community is assembled from a characteristic pool of parasite species available in each lagoon (Valtonen et al. 2001). Host traits such as feeding behavior, body size, and vagility also affect parasite community structure and composition in *C. nigrescens* from the studied coastal lagoons.

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References

Aguirre-Macedo ML, Vidal-Martínez VM, González-Solís D, Caballero PI (2007) Helminth communities of four commercially important fish species from Chetumal Bay, Mexico. J Helminthol 80:1–14

Bush AO, Lafferty KD, Lotz JM, Shostak AW (1997) Parasitology meets ecology on its own terms: Margolis et al. revisited. J Parasitol 83:575–583

Bush AO, Fernandez J, Esch GW, Seed JR (2003) Parasitism: The diversity and ecology of animal parasites. Cambridge University Press, Cambridge, UK, 566 p

Bussing WA (1995) Centropomidae. Robalos. In: Fischer W, Krupp F, Schneider W, Sommer C, Carpenter KE, Niem V (eds) Guía FAO para Identificación de Especies para los Fines de la Pesca, 3. FAO, Roma, pp 987–995

Esch GW, Kennedy CR, Bush AO, Aho JM (1988) Patterns in helminth communities in freshwater fish in Great Britain: alternative strategies for colonization. Parasitology 96:519–532

Hoffman LG (1999) Parasites of North American freshwater fishes. Comstock Publishing associates a division of Cornell University Press 539 p

Holmes JC, Price PW (1986) Communities of parasites. In: Anderson DJ, Kikkawa J (eds) Community ecology: Patterns and processes. Blackwell Scientific Publications, Oxford, UK, pp 187–213

Krebs CJ (1999) Ecological methodology. Addison-Welsey Educational Publishers Inc, Boston, Massachusetts, 654 p

Luque JL, Mouillot D, Poulin R (2004) Parasite biodiversity and its determinants in coastal marine teleost fishes of Brazil. Parasitology 128:671–682

Machado MH, Pavanelli GC, Takemoto RM (1995) Influence of the type of environment and of the hydrological level variation in endoparasitic infrapopulations of *Pseudoplatystoma corruscans* (Agassiz) and *Schizodon borelli* (Boulenger) (Osteichthyes) of the high Paraná River, Brazil. Rev Bras Zool 12:961–976

Magurran A (1991) Ecological diversity and its measurement. Princeton University Press, Princeton, New Jersey, 178 p

Mendoza-Franco EF, Violante-González J (2006) A new diplectanid (Monogenea) genus and species from the gills of the black snook, *Centropomus nigrescens* (Perciformes: Centropomidae) of the pacific coast of Mexico. J Parasitol 92:481–485

Mendoza-Franco EF, Violante-González J, Vidal-Martínez VM (2008) New species of *Rhabdosynochus* Mizelle and Blatz 1941 (Monogenoidea: Diplectanidae) from the gills of centropomid fishes (Teleostei) off the Pacific coast of Mexico. J Parasitol 94:28–35

Moravec F (1998) Nematodes of freshwater fishes of the neotropical region. Academia, Praha, 464 p

Mwita C, Nkwengulila G (2008) Determinants of the parasite community of clariid fishes from Lake Victoria, Tanzania. J Helminthol 82:7–16

Poulin R (2003) The decay of similarity with geographical distance in parasite communities of vertebrate hosts. J Biogeo 30:1609–1615

Poulin R, Morand S (1999) Geographical distances and the similarity among parasite communities of conspecific host population. Parasitology 119:369–374

Salgado-Maldonado G, Kennedy CR (1997) Richness and similarity of helminth communities in the tropical cichlid fish *Cichlasoma urophthalmus* from the Yucatan Peninsula, Mexico. Parasitology 114:581–590

Sasal P, Morand S, Guegan JF (1997) Determinants of parasite species richness in Mediterranean marine fishes. Mar Ecol Prog Ser 149:61–71

Sokal RR, Rohlf FJ (1998) Biometry, 2nd edn. W. H. Freeman and Company, San Francisco, California, 859 p

Tavares LER, Luque JL (2004) Community ecology of the metazoan parasites of the later juvenile common snook *Centropomus undecimalis* (Osteichthyes: Centropomidae) from the coastal zone of the State of Rio de Janeiro, Brazil. Braz J Biol 64:523–529

Tavares LER, Luque JL (2008) Similarity between metazoan parasite communities of two sympatric brackish fish species from Brazil. J Parasitol 94:985–989

Valtonen ET, Pulkinen K, Poulin R, Julkunen M (2001) The structure of parasite component communities in brackish water fishes of the northeastern Baltic Sea. Parasitology 122:471–481

Vidal-Martinez VM, Poulin R (2003) Spatial and temporal repeatability in parasite community structure of tropical fish hosts. Parasitology 127:387–398

Vidal-Martínez VM, Aguirre-Macedo L, Scholz T, González-Solís D, Mendoza-Franco EF (2001) Atlas of helminth parasites of Cichlid fish of Mexico. Academy of Sciences of the Czech Republic 165 p

Violante-González J, Aguirre-Macedo ML (2007) Metazoan parasites of fishes from Coyuca Lagoon, Guerrero, Mexico. Zootaxa 1531:39–48

Violante-González J, Aguirre-Macedo ML, Mendoza-Franco EF (2007) A checklist of metazoan parasites of fish from Tres Palos lagoon, Guerrero, Mexico. Parasitol Res 102:151–161

Violante-González J, Aguirre-Macedo ML, Vidal-Martínez VM (2008) The temporal variation in the helminth parasite communities of pacific fat sleeper *Dormitator latifrons* from Tres Palos lagoon, Guerrero, Mexico. J Parasitol 94:326–334

Yáñez-Arancibia A (1978) Taxonomía, ecología y estructura de las comunidades de peces en lagunas costeras con bocas efímeras del Pacífico de México. Centro de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México Publicaciones Especiales 2: 1−306

Zander CD (2004) Four-year monitoring of parasite communities in gobiid fishes of the south-western Baltic II. Infracommunity. Parasitol Res 93:17–29

Zander CD, Kesting V (1998) Colonization and seasonality of goby (Gobiidae, Teleostei) parasites from the southwestern Baltic Sea. Parasitol Res 84:459–466