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Composition and spatio-temporal variation of the fish community in the Chacmochuch Lagoon system, Quintana Roo, Mexico

Composición y variación espacio-temporal de la comunidad de peces en el Sistema Lagunar Chacmochuch, Quintana Roo, México

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ABSTRACT

The composition, distribution and abundance of fishes were determined in the Chacmochuch Lagoon System, a natural protected area located on the north coast of Quintana Roo. Monthly diurnal sampling was carried out at 10 sampling stations in March, June and September, 2002. During each field trip, bottom type, submerged and surrounding vegetation, salinity, temperature, dissolved oxygen and other variables were measured. Distribution and abundance of fishes were examined by means of a principal component analysis. Fifty species were recorded; *Gerres cinereus, Floridichthys polyommus, Eugerres plumieri, Harengula jaguana, Sphyraena barracuda, and Archosargus rhomboidalis* were dominant, and no significant difference in species composition was found between seasons. Apart from a single site where turbidity and nutrient concentration were particularly high, the other sites could be classified mainly according to salinity. Fish composition changed along this gradient.

Key words: Ichthyofauna, distribution, abundance, natural protected area, Caribbean.

RESUMEN

Se determinó la composición, distribución y abundancia de los peces en el Sistema Lagunar Chacmochuch, un área natural protegida en la costa norte de Quintana Roo. El trabajo se realizó durante un ciclo anual (marzo, junio y septiembre de 2002). Las 10 estaciones representaron los diversos hábitats del ecosistema. Los muestreos fueron diurnos. Se tomó nota del tipo de fondo, la vegetación circundante y sumergida, así como la salinidad, temperatura y oxígeno disuelto, entre otras variables ambientales. La distribución y abundancia de los peces se examinaron mediante un análisis de componentes principales. Se registraron 50 especies, siendo *Gerres cinereus, Floridichthys polyommus, Eugerres plumieri, Harengula jaguana, Sphyraena barracuda y Archosargus rhomboidalis* las dominantes. No hubo diferencia significativa en composición entre temporadas. Aparte de un sitio de turbidez y concentración de nutrientes particularmente alta, el resto de las estaciones de muestreo fue clasificable en función de la salinidad, principalmente. La composición íctica varió a lo largo de dicho gradiente.

Palabras clave: Ictiofauna, distribución, abundancia, área natural protegida, Caribe.

INTRODUCTION

The coastal zone is the most productive area of the oceans, both in terms of primary productivity and fisheries production (Holt, 1975). Coastal lagoons and estuarine environments are ecotones between the mainland and the sea, and are connected to the sea in a permanent or ephemeral manner. These ecosystems are shallow water bodies, semiclosed, with variable volumes of water, depending on the local climate and hydrology.

The life cycle of many fishes takes place partially or wholly within lagoons or estuaries (Castro-Aguirre *et al*., 1999). These sites are complex and variable biotopes, with an intricate web of trophic interactions and changing biogeochemical cycles (Toledo, 1991; Benedetti-Cecchi *et al*., 2001).

Fishes are the most diverse group of vertebrates, with more than 24,600 species known (Nelson, 1994). Mexico has about 2,800 described species, 14% of the World total (Lara-Domínguez *et al*., 1993). Many fishes use lagoon systems for feeding, breeding, or as shelter and recruiting areas.

The Chacmochuch lagoon system has many different habitats, where more than 194 species of Yucatan Peninsula flora and fauna can be found. There are subsistence fisheries, mainly mojarra, tarpon, snook, chihua, and barracuda. Local government and entrepreneurs plan to increase tourist activity in the system, which is a Natural Protected Area, established in 1999.

Because of these development plans, we felt it was important to carry out ichthyological studies, which can help set a baseline to monitor man-made changes in Chacmochuch. It is known, for example, that selective fishing for large piscivores such as snappers, with high demand in tourism-oriented restaurants, may bias the trophic structure of the fish community (cf. Loreto *et al*., 2003). Several attributes of fish communities have been proven as useful indicators of biotic integrity in other aquatic systems in Mexico (e.g. Lyons *et al*., 1995).

Doing this type of research is especially important in tropical regions, where understanding about the ecology and management of the natural resources may be scant, and development decisions may lack an adequate scientific background.

The objectives of the present study were to describe the composition, distribution, and abundance of fishes in the Chacmochuch lagoon system in different seasons, and to ascertain the influence of physicochemical variables.

MATERIALS AND METHODS

The Chacmochuch lagoon system is located northwest of the city of Cancún (21°10´53”N, 86°48´45”W; 21°15´14”N, 86°51´29”W), with an area of 11,527 ha. It is comprised of Chacmochuch Bay, the Ría or channel Nagigo, and nine other main water bodies (Figure 1). The climate is subhumid and warm, with a mean temperature of 26°C, and a mean annual rainfall of 1300 mm (Comisión Nacional del Agua (CNA), unpubl. data). Tides have little influence.

Field work was carried out in March 10-14, June 10-15, and September 10-15, 2002, attempting to represent climatic variability: March has been in average the driest month (32.2 mm) during the last 30 years; June has been the warmest month (27.1°C, daily mean), and September-October, the rainiest (240.2-242.5 mm) (CNA, unpubl. data). Ten stations were established in representative areas of the system, based on bottom type, depth, and distance from the Caribbean Sea at the mouth of Chacmochuch Bay (Figure 1). Quantitative sampling was done with a 2.5-m high, 70-m long, 1.5-cm mesh seine net, a sampling gear that proved to be useful at more sites than other devices (but which, however, has a bias towards small fishes). To obtain the greatest possible diversity of organisms in each site, samples were taken at different hours, and other fishing gear was also used. At the Ría Nagigo, Larga and Manatí lagoon stations, the seine net did

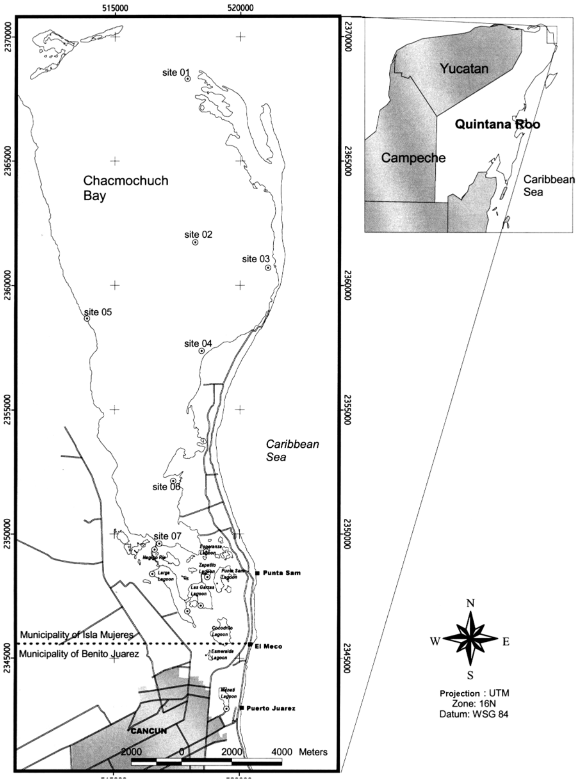

Figure 1. Study area, Chacmochuch Lagoon system.

Table 1. Spatial distribution, mean SL, and total biomass of fishes collected in the Chacmochuch Lagoon system over 3 different seasons during 2002. A= Chacmochuch Bay (sites 1, 2, 3, 4, 5, 6, and 7), B= Ría Nagigo, C= Laguna Larga, D= Laguna Zapatito, D= Laguna Garzas, E= Laguna Esperanza, F= Laguna Manatí.

Sites								Mean standard	Total
Species	A	B	C	D	E	F	G	length, mm	biomass, g
Urolophus jamaicensis	3							69	9.7
Megalops atlanticus				x				54	2.9
Anchoa parva	1 2 3 4 5 7							48	112.9
Harengula clupeola		x						46	4.7
Harengula jaguana	1 2 3 4 5 6							43	1065.9
Synodus intermedius	3 4 7			x				85	13.9
Bothus ocellatus	4 6 7							44	10.1
Opsanus beta	7							49	10.6
Mugil curema	2 7			x				121	321.5
Atherinomorus stipes	1 3 4 7			x		x		37	29.4
Strongylura timucu	1 3	x		x		x		61	266.8
Strongylura notata	2 3 4	x		x		x		257	2678.2
Chilomycterus antennatus	2			x				31	6.7
Hyporhamphus unifasciatus		x						139	81.4
Gambusia sexradiata			x					35	1.0
Gambusia yucatana			x				x	64	1.4
Heterandria bimaculata			x					22	3.5
Poecilia mexicana			x				x	40	5.7
Poecilia orri			x					22	6.0
Poecilia velifera			x					50	19.7
Cyprinodon artifrons	1				x			24	4.0
Floridichthys polyommus	1 2 3 4 5 6 7			x	x	x		28	695.1
Garmanella pulchra	7							28	3.1
Hippocampus erectus	4							115	1.5
Lucania parva	7								
Centropomus undecimalis		x	x	x		x		550	138.5
Apogon aurolineatus	7							36	1.1
Caranx latus	1			x				39	6.0
Lutjanus griseus	1 2 3 4 5			x				150	1369.6
Ocyurus chrysurus	3							52	9.5
Gerres cinereus	1 2 3 4 5 6			x	x	x		46	2267.6
Eugerres plumieri	2 4 5 7			x	x	x		43.8	1647.2
Haemulon aurolineatum	7							78	279.6
Haemulon parra	3 7							104	209.6
Haemulon plumieri	2 3 5 6							52	112.3
Archosargus rhomboidalis	1 2 3 4 5 6 7							59	1522.7
Calamus penna		x		x				79	17.6
Cynoscion nebulosus	7							40	10.0

Table 1. Continued.

Chaetodon capistratus	3							45	3.7
"Cichlasoma" urophthalmus		x	x					70	260.1
Sparisoma aurofrenatum	3							102	6.5
Sparisoma radians	3							64	8.6
Scomberomorus regalis		x						122	250.1
Sphyraena barracuda	1 2 3 4 5 6 7			x	x	x	x	180	12474.3
Monacanthus ciliatus	3							73	32.3
Sphoeroides spengleri	2 4 5 7							51	32.2
Sphoeroides testudineus	1 2 4 5 6							77	3240.3
Lactophrys quadricomis	1 2 3 4 5 7			x	x			133	7700.0
Lactophrys trigonus	7			x	x			111	67.9
Chilomycterus schoepfi	4 5 7			x				77	377.3

not work properly, so those data were not analyzed quantitatively.

Physicochemical conditions were determined in situ with a multiparametric sonde YSI 6600, measuring temperature, salinity, dissolved oxygen, pH, turbidity, depth, chlorophyll, TDS, ammonium, nitrates, and transparency. Organic matter was measured by the Walkley-Black method (Jackson, 1976). Submerged vegetation was measured by a quadrant method (percent cover in a square meter), and granulometric analysis was performed with sieves (12, 14, 16, 18, 20, 22, 45, 60, 80, 100, 140 and 200 mm) (Folk, 1969).

All fishes collected were fixed in 10% formaldehyde and preserved in 70% ethanol (Cailliet *et al*., 1986) for later identification in the laboratory, using methods described by Guitart (1977, 1978), Randall (1983), Humann (1994), Schmitter-Soto (1998), and Castro-Aguirre *et al*. (1999).

Each specimen was measured (standard length, SL) to the nearest mm, using a digital vernier caliper, and weighed to the nearest tenth of gram, with an electronic balance. All specimens were deposited as vouchers in the fish collection at ECOSUR-Chetumal (acronym ECOCH).

To check the reliability of our richness estimate, an accumulation curve of fishes to predict the total number of species in an area was adjusted, following the model S(t)= a/b (1 – exp(-bt)), where S(t) is the expected richness, t= is the effort (man-hours), and a and b are parameters. This model is especially adequate when one is sampling a relatively small area, a taxonomically well-known group, or both (Soberón & Llorente, 1993).

Community attributes measured were diversity by abundance (H´n) and biomass (H´w) (Shannon-Wiener index, bits·individual^{-1} or bits·g^{-1}) (Ludwig & Reynolds, 1988), richness (Margalef, 1968), and evenness (Pielou, 1975). Species dominance was measured with the Sanders biological value index (BVIS) (Subrahmanyam & Drake, 1975). All indices were calculated with the ANACOM software (de la Cruz, 1994). Two-way ANOVA tests (Zar 1984) were used to test differences for each variable between the sample sites and sampling periods; data were log-transformed for this analysis. For all tests, $P > 0.05$ was used.

A cluster analysis (flexible sorting, Euclidean distance) determined sites associations, based on abundance of fishes. A principal components analysis (PCA) (Pla, 1986) was performed, separately for each season and also for the annual cycle, to explore the relationship between the presence and abundance of dominant species and environmental variables. These analyses were performed with MVSP (Kovach, 1995), and Statgraphics 7.0 software (Statistical Graphics Corporation, 1993).

RESULTS

A total of 3124 specimens, 50 species, 39 genera, and 31 families were obtained; 14 species represented 95% of the total abundance. Total weight was 36.9 kg; 20 species represented 99% of the total biomass (Table 1). Most species are peripheral: 26 are euryhaline marine and 18 stenohaline marine (according to Castro-Aguirre *et al*., 1999). Six were freshwater secondary, and none were primary (sensu Myers, 1938). Two species, *Apogon aurolineatus* and *Chaetodon capistratus*, are new records for epicontinental waters of Quintana Roo.

The species-effort curve showed that the observed number of species was close to the estimated true richness (Figure 2).

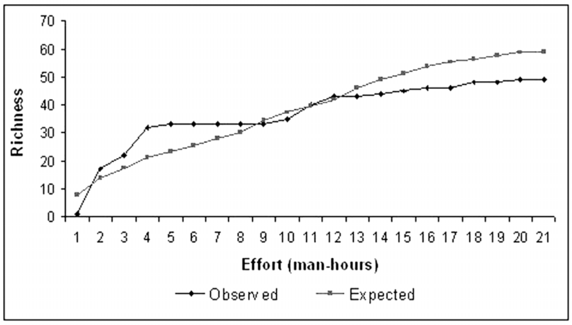

Figure 2. Species-effort curve in Chacmochuch Lagoon.

Gerres cinereus was the dominant species throughout the year (Table 2). Juvenile fishes (considered as such based on lengths at first maturity from Claro, 1994) were collected in high proportion in all samples (Table 1).

The most widespread species were *G. cinereus, Floridichthys polyommus, and Eugerres plumieri,* which are bottom-feeders. Also common were Harengula *jaguana, Archosargus rhomboidalis*, *Sphyraena barracuda*, and *Strongylura notata*, among others. This includes carnivores as well as filter feeders (Claro, 1994).

In September, 1527 specimens in 36 species were obtained. *G. cinereus, F. polyommus, E. plumieri, H. jaguana, A. rhomboidalis*, and *S. barracuda* were the dominant species, representing 88% of the total abundance in this season. In April, 997 specimens in 21 species were recorded; total weight was 10.1 kg, with the same dominant species, plus *Anchoa parva*. In June, 600 individuals and 21 species were collected, with a total weight of 17.2 kg and the same dominant species, plus *Lactophrys quadricornis* and *S. notata* (Table 3).

There was no significant difference among seasons and sites in abundance, diversity, biomass, richness or evenness, perhaps because of the continuous dominance of the abovementioned species. On the other hand, salinity, pH, TDS, dissolved oxygen, nitrate, and turbidity all had significant differences between seasons and sites. Temperature, ammonium, chlorophyll a, and depth showed significant differences among sampling sites, but not between seasons. Abiotic data are shown in Table 4; ANOVA results for these variables, in Table 5.

Cluster analyses of sites by species in every month presented nearly pectinate patterns, with no clear-cut groupings. On the other hand, a cluster analysis of the data pooled for the whole year produced three rather distinct groups (Figures 3 and 4):

Group I, characterized by stenohaline and marine species, captured mainly in sites 1, 3, 4 and 7 of Chacmochuch Bay. These fishes are temporary and occasional visitors: *Hyporhamphus unifasciatus, Hippocampus erectus*, and *Caranx latus*. They grouped together with L. quadricornis, Mugil curema, and *Chilomycterus schoepfi*, which are euryhaline species. Others, as *A. aurolineatus*, *Haemulon aurolineatum* and *H. plumieri*, are stenohaline and sporadic.

Group II, estuarine and euryhaline fishes captured mainly in sites 2 and 5 of Chacmochuch Bay. These permanent residents or common visitors include *Atherinomorus stipes, H. jaguana, S. notata, A. rhomboidalis, E. plumieri, G. cinereus, A. parva, Centropomus undecimalis, Sphoeroides testudineus, S. barracuda*, and *F. polyommus*. Together with Opsanus beta and Megalops atlanticus, these are peripheral species.

Group III, freshwater fishes, in the smaller water bodies Esperanza, Manatí, Zapatito, Larga and Ría Nagigo. These fishes are resident species, found all year long in fresh to oligohaline waters: "*Cichlasoma*" *urophthalmus, Gambusia yucatana, G. sexradiata, Poecilia mexicana, P. velifera*, and *P. orri*. The association of sampling sites, the salinity gradient and turbidity values are present in Chacmochuch lagoon system throughout the year (Figure 4).

Group IV, consisting only of site 6 in Chacmochuch Bay, separates clearly both in the species-based dendrogram and the environment-based PCA (Figures 3 and 5, see below). All the most abundant and frequent species in the system are

Table 2. Sanders biological value index (BVIS) for dominant species by month in Chacmochuch lagoon.

April		June		September	
Species	**BVIS (%)**	**Species**	**BVIS (%)**	**Species**	**BVIS (%)**
G. cinereus	50.0	*G. cinereus*	22.2	*G. cinereus*	25.0
F. polyommus	12.5	*F. polyommus*	22.2	*E. plumieri*	18.8
E. plumieri	12.5	*A. rhomboidalis*	11.1	*A. rhomboidalis*	12.5
A. rhomboidalis	12.5	*S. barracuda*	11.1	*L. quadricornis*	12.5
L. quadricornis	12.5	*H. jaguana*	11.1	*S. barracuda*	6.3

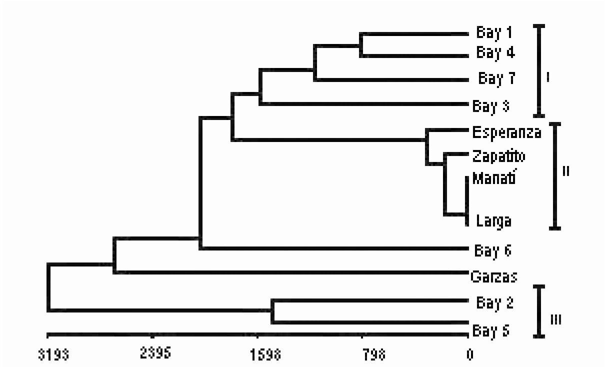

Figure 3. Clusters of sites in Chacmochuch Lagoon by species during the whole year. See text.

included here, a fact attributable to the high productivity of that site, as shown by the values of nitrate concentration and turbidity.

As for environmental variables, a PCA for the pooled yearly data showed three groups of sites. One consists of sites 1-5 and 7 of Chacmochuch Bay, where high salinity, TDS, ammonia, and pH are determinant. A second group consisted of lagunas Zapatito, Esperanza and Garzas, with a high level of chlorophyll a, temperature homogeneity and low salinity. The last group consisted only of site 6 of Chacmochuch Bay, and it is set apart by its high turbidity, nitrate and chlorophyll a (Figure 5).

DISCUSSION

Chacmochuch has 50 recorded fish species in an area of 11,527 ha; nearby lagoons Nichupté and Bojórquez have 37 species in 4452 ha (Reséndez-Medina, 1979). On the other hand, the richness of these systems in the northern coast of Quintana Roo is lower than that of Río Huach lagoon (southern coast), with 65 species in only 145 ha (Avilés-Torres, 2002). Even the predicted real richness of Chacmochuch, 59 species, fails to correct this large divergence. We do not see obvious differences in habitat complexity between the sites. As for the effect of regional faunas (cf. Caley and Schluter, 1997), we expected Chacmochuch to be more diverse because of the possible influence of fauna from the Gulf of Mexico. We speculate that the higher diversity of Río Huach might be explained because of its closer proximity to a well-developed coral reef (Avilés-Torres *et al.*, 2001). Also, the extension of the wetlands bordering Río Huach is larger, a fact that can increase the productivity and as a consequence the diversity (Boero, 1994).

Numerical processes (i.e. abundance and ultimately diversity) and energetic processes (closely approximated by biomass) are two sides of the same phenomenon. For example, individual growth and condition, which are energetic processes, influence mortality, a numerical process. Habitat selection and recruitment are a compromise of both kinds of processes (Jones & McCormick, 2002; Gillanders *et al.*, 2003).

The utilization of lagoon environments by marine and freshwater organisms is not random (Day & Yáñez-Arancibia, 1985); many species have evolved adaptations that optimize the use of estuarine and lagoon system habitat. One example are juvenile and preadult fishes that live in lagoons and migrate to the sea when they become adults, exporting energy and importing it again as larvae and juveniles (Deegan, 1993 — again, a linkage of numerical and energetic processes). Lagoons have a fundamental role in the storage and flow

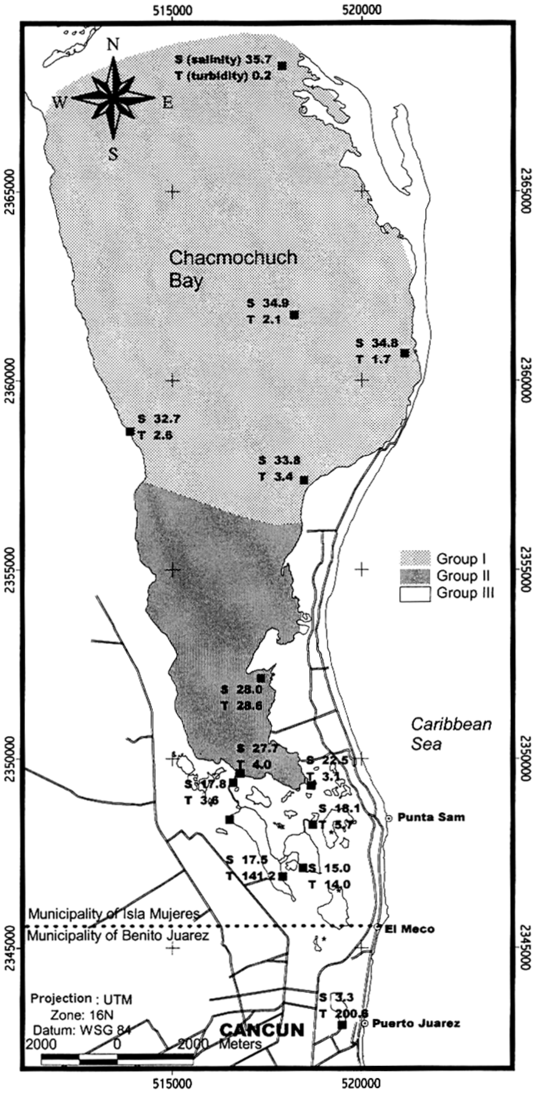

Figure 4. Association of sampling sites by salinity and turbidity values:
group I, stenohaline and marine species
group II, estuarine and euryhaline fishes
group III, freshwater fishes

Table 3. Abundance (N) and biomass (W) of fishes by month in the Chacmochuch lagoon system.

	April			June			Septembre	
Species	N	W	Species	N	W	Species	N	W
Gerres cinereus	581	2542.5	*Floridichthys polyommus*	390	5643.0	*Gerres cinereus*	195	4987.2
Floridichthys polyommus	242	1403.8	*Gerres cinereus*	222	1784.3	*Harengula jaguana*	62	4288.8
Eugerres plumieri	211	1138.5	*Anchoa parva*	76	621.0	*Lactophrys quadricornis*	55	2210.5
Harengula jaguana	147	928.5	*Archosargus rhomboidalis*	75	403.0	*Archosargus rhomboidalis*	52	1525.2
Archosargus rhomboidalis	79	706.4	*Sphyraena barracuda*	62	311.3	*Sphyraena barracuda*	51	1122.9
Sphoeroides testudineus	48	539.6	*Harengula jaguana*	61	267.7	*Strongylura notata*	51	1002.9
Sphyraena barracuda	46	391.0	*Eugerres plumieri*	37	229.4	*Eugerres plumieri*	38	728.7
Haemulon aurolineatum	26	371.6	*A. stipes*	23	202.1	*Sphoreoides testudineus*	34	508.1
Poecilia mexicana	23	294.9	*Lactophrys quadricomis*	21	149.5	*Anchoa parva*	12	248.5
Anchoa parva	16	275.9	*Sphoeroides testudineus*	7	111.0	*Haemulon plumieri*	11	217.7
Gambusia yucatana	14	266.8	*Strongylura notata*	5	103.8	*Mugil curema*	11	138.5
Lactophrys quadricomis	13	200.0	*Mugil curema*	4	71.1	*Lutjanus griseus*	7	94.0
A. stipes	12	164.6	*Caranx latus*	3	67.9	*A. stipes*	4	74.4
Haemulon plumieri	9	114.6	*Ch. schoepfi*	3	13.7	*Floridichthys polyommus*	4	21.9
Ch. schoepfi	6	90.4	*Sparisoma radians*	2	9.7	*Opsanus beta*	3	13.5
Poecilia vellifera	6	57.0	*Haemulon aurolineatum*	1	8.6	*Harengula clupeola*	3	26.2
Strongylura timucu	6	32.3	*H. unifasciatus*	1	7.0	*Haemulon parra*	2	10.6
Haemulon parra	5	28.7	*Lactophrys trigonus*	1	5.7	*H. unifasciatus*	2	6.0
Strongylura notata	5	27.8	*Lutjanus griseus*	1	3.7	*Centropomus undecimalis*	1	4.7
Bothus ocellatus	4	19.7	*Poecilia orri*	1	1.7	*Megalops atlanticus*	1	3.7
Lutjanus griseus	3	18.7	*Urolophus jamaicensis*	1	0.1	*Sphoeroides spengleri*	1	2.9
M. ciliatus	3	17.6						
Sphoeroides spengleri	3	13.9						
Ch. antennatus	2	12.0						
Ocyurus chrysurus	2	10.1						
Poecilia orri	2	9.5						
S. aurofrenatum	2	6.7						
Synodus intermedius	2	6.5						
Synodus saurus	2	4.3						
Apogon aurolineatus	1	3.7						
Calamus penna	1	1.5						
Caranx latus	1	1.41						
Cyprinodon artifrons	1	1.1						
Chaetodon capistratus	1	1.0						
Gambusia sexradiata	1	0.4						
H. erectus	1	0.4						
Lucania parva	2	0.2						

Table 4. Abiotic variables in the Chacmochuch lagoon system. Ranges are yearly maxima and minima. Organic matter, in percent dry weight.

Site	**Bottom vegetation cover (%)**	**Organic matter (%)**	**Dominant plant species in bottom vegetation**	**Sediment type**	
Bay (site 1)	45	6.20	*Thalassia testudinum, Syringodium filiforme*	Medium sand, mud	
Bay (site 2)	35	7.20	*T. testudinum, S. filiforme*, macroalgae	Medium sand	
Bay (site 3)	15	2.50	*T .testudinum*	Thick sand, very muddy	
Bay (site 4)	100	7.17	*T .testudinum, S. filiforme*	Thick sand, very muddy	
Bay (site 5)	0	3.47	Macroalgae	Thick sand, mud, some rocks	
Bay (site 6)	100	5.81	*T. testudinum, S. filiforme* and macroalgae	Thick sand, very muddy	
Bay (site 7)	25	14.94	*T. testudinum, S. filiforme* and macroalgae	Thick sand, mud	
Ría Nagigo	0	11.57	None observed	Thick sand, rocks, organic matter	
L. Larga	0	9.97	*T. testudinum* and macroalgae	Thick sand, muddy	
L. Las Garzas	0	5.61	Macroalgae	Medium sand, muddy	
L. Zapatito	15	7.69	Macroalgae	Sandy, muddy	
L. La Esperanza	25	4.14	Small macroalgae, *T. testudinum*	Thick sand, very muddy	
L. Manatí	100	5.00	Macroalgae	Sandy	
Site	**Temperature(°C)**	**Salinity(ppt)**	**Dissolved oxygen (ppt)**	**Nitrates(mg·l^{-1})**	**pH**
Bay (site 1)	28.0-31.4	34.0-37.1	0.9-7.6	93.3-595.6	8.1-8.5
Bay (site 2)	28.0-30.4	33.0-35.1	1.4-8.9	80.6-509.5	8.3-8.5
Bay (site 3)	28.0-31.5	34.6-35.0	0.4-8.8	79.3-354.3	8.4-8.9
Bay (site 4)	29.0-30.8	33.0-34.1	0.5-8.2	99.9-334.1	8.5-8.7
Bay (site 5)	25.5-30.8	30.0-32.9	0.4-6.4	99.6-218.3	8.3-8.4
Bay (site 6)	28.0-30.5	27.6-29.0	0.5-8.8	34.7-420.1	8.3-8.4
Bay (site 7)	27.0-31.0	17.0-28.7	4.6-7.4	73.5-854.2	8.2-8.4
Ría Nagigo	26.2-31.1	15.0-21.6	2.5-17.9	49.0-468.9	7.9-8.0
L. Larga	27.3-34.0	12.7-21.6	3.5-20.2	41.8-369.6	7.3-8.2
L. Las Garzas	29.0-30.3	14.7-27.0	0.4-4.2	350.2-350.5	7.7-8.0
L. Zapatito	28.3-32.0	16.2-28.0	2.0-4.2	58.5-431.4	7.3-7.7
L. La Esperanza	28.6-30.1	12.7-29.5	1.3-9.4	44.4-810.2	7.9
L. Manatí	28.9-32.3	3.6-4.0	0.0-4.5	25.1-215.8	7.4-8.4
Site	**Total dissolved solids (g·l^{-1})**	**Ammonium (mg·l^{-1})**	**Chlorophyll a (µg·l^{-1})**	**Depth (m)**	**Turbidity (NTU)**
Bay (site 1)	33.9-36.5	0.01-0.09	1.3	0.6	0.4-0.8
Bay (site 2)	34.7	0.09-0.14	1.2-1.4	0.3-0.4	1.7-2.5
Bay (site 3)	34.2-34.7	0.09-0.13	0.1-1.7	0.3-0.5	0.7-2.7
Bay (site 4)	33.2-33.9	0.08-0.16	0.5-3.6	0.3-0.5	1.6-5.3
Bay (site 5)	32.4-32.7	0.08-0.17	1.1-1.3	0.3-0.6	0.9-4.2
Bay (site 6)	27.6-28.6	0.07-0.10	0.9-37.8	0.4-0.7	1.2-56.0
Bay (site 7)	27.1-29.1	0.08-0.10	4.8-8.3	0.4-0.6	2.2-5.8
Ría Nagigo	18.9-22.5	0.04-0.07	5.0-15.2	1.0-2.0	0.2-7.0
L. Larga	13.8-22.3	0.01-0.17	10.2-120.1	0.7-1.9	0.0-509.8
L. Las Garzas	15.4-15.9	0.03-0.04	13.6-15.1	0.3-0.6	1.4-2.6
L. Zapatito	17.3-21.9	0.04-0.07	13.7-57.5	0.5-1.0	2.4-8.2
L. La Esperanza	13.8-29.8	0.04-0.48	1.7-9.8	0.4-0.8	0.5-5.0
L. Manatí	3.8-4.3	0.01-0.02	2.5-96.7	0.4-1.2	0.0-544.8

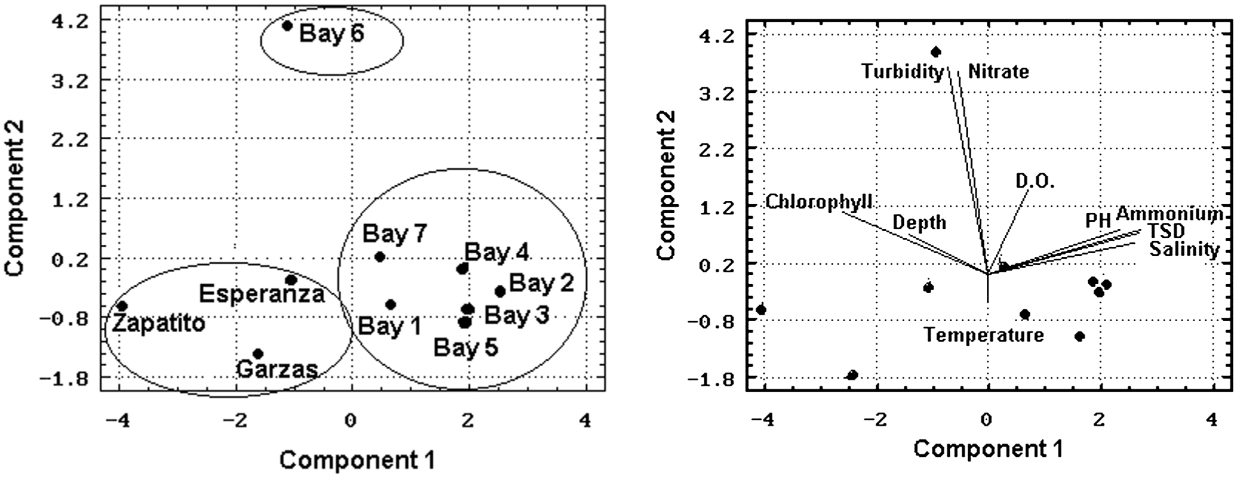

Figure 5. PCA: scatterplot of sampling stations (left), plot of original variables (right), in the Chacmochuch Lagoon system during the annual cycle.

of energy to the sea; this fact explains the oligotrophy of reef systems. In Chacmochuch, water circulation patterns are generally complex and are strongly affected by wind, which, together with the tidal oscillation and geomorphology, helps keep larvae within the system (Stoner & Lewis, 1985; Joyeux, 1998; Jager & Mulder, 1999; Barleta-Bergan *et al.*, 2002; Chittaro *et al.*, 2005).

The influence of environmental parameters on estuarine fish communities has been verified many times. For example, Pauly (1975) found that biotic and abiotic variables controlled the composition of the community in a coastal semiclosed lagoon in West and South Africa. Apart from a single site separated because of its high turbidity and nutrient concentration, we found that our sampling sites were grouped by the PCA based mainly on salinity and temperature. This is also what Castro-Aguirre (1982) found in a coastal lagoon in the Mexican state of Oaxaca. In Southeastern Asia and Australia a gradient of several variables helps young fishes find breeding areas (Blaber, 1985; Griffiths, 2001). Avilés-Torres (2002) found that salinity, bottom type and other abiotic variables controlled the composition of the community in the small coastal lagoon of Río Huach. On the other hand, in Chesapeake Bay, vegetation is more important than variables such as temperature (Orth & Heck, 1980). Similar conditions were found at two lakes in southeastern Brazil (Vono & Barbosa, 2001).

On the other hand, throughout the year there are species widely distributed in Chacmochuch, in spite of habitat heterogeneity. A possible explanation for this pattern is the tolerance of dominant species to environmental conditions; most of the fishes in Chacmochuch are either marine euryhaline or freshwater euryhaline (that is, secondary sensu Myers, 1938). On the other hand, the groupings of fish (marine stenohalyne, marine euryhalyne, and freshwater) maintain their spatial distribution in the lagoon throughout the year, in spite of the changes in the environmental variables, possibly

Table 5. Abiotic variables in Chacmochuch Lagoon: significant differences by month and sampling station (ns, not significant).

Variable	By site		By month	
	F	p	F	p
Salinity	12.09	>0.0001	14.59	0.0002
Total dissolved solids	0.982	>0.0001	12.82	0.0101
Ammonium	35.33	>0.0001	12.66	>0.0001
Turbidity	2.175	0.0191	68.24	>0.0001
pH	13.13	>0.0001	0.998	>0.0001
Dissolved oxygen	3.506	0.0030	115.1	>0.0001
Nitrates	2.260	0.0143	238.3	>0.0001
Temperature	6.38	0.0350	0.600	0.448, ns
Chlorophyll *a*	9.30	>0.0001	3.211	0.764, ns
Depth	3.606	0.0002	0.414	0.503, ns

because the gradient of the salinity and other parameters remain in spite of those variations.

Commercial species fished in the adjacent marine area (mojarras, jacks, snappers, snook, barracuda, among others) show up as juveniles in the lagoon system, whose conservation is thus important not only for the sake of tourism or for intrinsic reasons, but also for the welfare of fishermen not yet assimilated by the tourism-oriented economy of the region.

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REFERENCES

Avilés-Torres, S., 2002. *Influencia de la heterogeneidad espacial y la fluctuación climática en la comunidad de peces del sistema lagunar Río Huach, sur de Quintana Roo*, México. M.Sc. Thesis. Centro de Investigación Científica y Educación Superior de Ensenada. Ensenada, 100 p.

Avilés-Torres, S., J.J. Schmitter-Soto & R. Barrientos M., 2001. Patrones espaciales de la distribución de peces en lagunas costeras del sur de Quintana Roo, México. *Hidrobiológica* 11 (2): 141-148.

Barleta-Bergan, A., M. Barletta & U. Saint-Paul, 2002. Structure and seasonal dynamics of larval fish in the Caete River Estuary in North Brazil. *Estuarine, Coastal and Shelf Science* 54: 193-206.

Benedetti-Cecchi, L., F. Rindi, I. Bertocci, F. Bulleri & F. Cinelli, 2001. Spatial variation in development of epibenthic assemblages in a coastal lagoon. *Estuarine, Coastal and Shelf Science* 52: 659-668.

Blaber, S.J.M., 1985. Factors affecting the distribution of estuarine fishes of the Indo-Pacific. *In*: Yáñez-Arancibia, A. (Ed.), *Fish community ecology in estuaries and coastal lagoons: towards an ecosystem integration*. UNAM-PUAL-ICMyL, Mexico City.

Boero, F., 1994. Fluctuations and variations in coastal marine environments. *Marine Ecology* 15: 3-25.

Cailliet, G.M., M.S. Love & A.W. Ebeling, 1986. *Fishes: A field and laboratory manual on their structure, identification and natural history*. Wadsworth, Belmont. 193 p.

Caley, M.J. & D. Schluter, 1997. The relationship between local and regional diversity. *Ecology* 78 (1): 70-80.

Castro-Aguirre, J.L., 1982. Los peces de las lagunas Oriental y Occidental, Oaxaca, México, y sus relaciones con la temperatura y la salinidad. II. Análisis multifactorial. *Anales de la Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional IPN* 26: 85-100.

Castro-Aguirre, J.L., H. Espinosa P. & J.J. Schmitter-Soto, 1999. *Ictiofauna estuarino-lagunar y vicaria de México*. Limusa-Noriega/IPN, Mexico City. 705 p.

Chittaro, M.P., P. Ussenglio & P.F. Sale, 2005. Variation in fish density,assemblage composition and relative rates of predation among mangrove, seagrass and coral reef habitats. *Environmental Biology of Fishes* 72: 175-178.

Claro, R. (Ed.). 1994. *Ecología de los peces marinos de Cuba*. Centro de Investigaciones de Quintana Roo. Chetumal, 525 p.

Day Jr., J.W. & A. Yáñez-Arancibia, 1985. Coastal lagoons and estuaries as an environment for nekton. *In*: Yánez-Arancibia, A. (Ed.), Fish community ecology *in estuaries and coastal lagoons: towards an ecosystem integration*. UNAM-PUAL-ICMyL. Mexico City, pp. 17-34.

Deegan, L.A., 1993. Nutrient and energy transport between estuaries and coastal marine ecosystems by fish migration. *Canadian Journal of Fisheries and Aquatic Sciences* 50: 74-79.

de la Cruz, A.G., 1994. ANACOM, S*istema para el análisis de las comunidades. Manual del usuario*. CINVESTAV-IPN, Mérida. 99 p.

Folk, R.L., 1969. *Petrología de las rocas sedimentarias.* Instituto de Geología, UNAM, Mexico City. 399 p.

Gillanders, B.M., K.W. Able, J.A. Brown, D.B. Eggleston & P.F. Sale, 2003. Evidence of connectivity between juvenile and adult habitats for mobile marine fauna: an important component of nurseries. *Marine Ecology Progress Series* 247: 281-289.

Griffiths, S.P., 2001. Factors influencing fish composition in an Australian intermittently open estuary. Is stability salinity-dependent?. E*stuarine, Coastal and Shelf Science* 52: 739-751.

Guitart, D.J., 1977. *Sinopsis de los peces marinos de Cuba*, Vol. III. Academia de Ciencias de Cuba. Instituto de Oceanología, La Habana.

Guitart, D.J., 1978. *Sinopsis de los peces marinos de Cuba*, Vol. IV. Academia de Ciencias de Cuba. Instituto de Oceanología, La Habana.

HOLT, S.J., 1975. Los recursos alimenticios del océano. *In*: J. R. Moore (Ed.), *Oceanografía*. Blume. Barcelona, pp. 400-414.

HUMANN, P.A., 1994. *Reef fish identification. Florida, Caribbean, Bahamas. 2nd* ed. New World. Jacksonville, 400 p.

JACKSON, M.L., 1976. *Análisis químico de suelos*. 3rd ed. Omega, Barcelona. 649 p.

JAGER, Z. & H.P.J. MULDER, 1999. Transport velocity of flounder larvae (*Platichthys flesus* L.) in the Dollard (Ems Estuary). *Estuarine, Coastal and Shelf Science* 49: 327-346.

JONES, G.P. & M.I. MCCORMICK, 2002. Numerical and energetic processes in the ecology of coral reef fishes. *In*: Sale, P. (Ed.), *Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem*. Academic Press. London, pp. 221-238.

JOYEUX, J.C., 1998. Spatial and temporal entry patterns of fish larvae into North Carolina estuaries: comparisons among one pelagic and two demersal species. *Estuarine, Coastal and Shelf Science* 47: 731-752.

KOVACH, W.L., 1995. MVSP-*A multivariate statistical package for IBM-PC´s, version 2.2*. Kovach Computing Services. Pentraeth, Wales.

LARA-DOMÍNGUEZ, A.L., F. ARREGUÍN-SÁNCHEZ & H. ÁLVAREZ-GUILLÉN, 1993. Biodiversidad y uso de recursos naturales: Las comunidades de peces en el sur del golfo de México. *Revista de la Sociedad Mexicana de Historia Natural* 44: 345-385.

LORETO, R.M., M. LARA & J.J. SCHMITTER-SOTO, 2003. Coral reef fish assemblages at Banco Chinchorro, Mexican Caribbean. *Bulletin of Marine Science* 73(1): 153-170.

LUDWIG, J.A. & J.F. REYNOLDS, 1988. *Statistical Ecology*. John Wiley & Sons. New York, 377 p.

LYONS, J., S. NAVARRO-PÉREZ, P.A. COCHRAN, E. SANTANA C. & M. GUZMÁN-ARROYO, 1995. Index of biotic integrity based on fish assemblages for the conservation of streams and rivers in west-central Mexico. *Conservation Biology* 9(3): 569-584.

MARGALEF, R., 1968. *Perspectives in ecological theory*. The University of Chicago Press. Chicago, 111 p.

MYERS, G.S., 1938. Fresh-water fishes and West Indian zoogeography. *Annual Report of the Smithsonian Institution* 1937:339-364.

NELSON, J.S., 1994. *Fishes of the world*. 3rd ed. J. Wiley & Sons, New York. 600 p.

ORTH, R.J. & K.L. HECK, JR., 1980. Structural components of eelgrass (*Zostera marina*) meadows in the lower Chesapeake Bay Fishes. *Estuaries* 3 (4): 278-288.

PAULY, D., 1975. On the ecology of a small West-African lagoon. *Sonderdruck Board* 24: 46-62.

PIELOU, E.C., 1975. *Ecological diversity*. J. Wiley & Sons, New York. 165 p.

PLA, L., 1986. *Análisis multivariado*: *método de componentes principales*. Monografía No. 27. OAS, Washington. 94 p.

RANDALL, J.E., 1983. *Caribbean Reef Fishes. 2nd ed*. T.F.H., New Jersey. 350 p.

RESÉNDEZ-MEDINA, A., 1979. Estudios ictiológicos en lagunas costeras del Golfo de México y mar Caribe, entre 1966 y 1978. *Anales del Instituto de Biología de la Universidad Nacional Autónoma de México, Serie Zoología* 50 (1): 633-646.

SCHMITTER-SOTO, J.J., 1998. *Catálogo de los peces continentales de Quintana Roo*. ECOSUR, San Cristóbal de Las Casas. 239 p.

SOBERÓN, J.M. & J.B. LLORENTE, 1993. The use of species accumulation functions for the prediction of species richness. *Conservation Biology* 7: 480-488.

STATISTICAL GRAPHICS CORPORATION, 1993. *Statgraphics 7.0*. Bitstream. Cambridge, 689 p.

STONER, A. W. & F. LEWIS, 1985. Experiments on competition and predation among shrimps of seagrass meadows. *Ecology* 62: 1484-1493.

SUBRAHMANYAM, C.B. & S.H. DRAKE, 1975. Studies on the animal communities in two north Florida salt marshes. *Bulletin of Marine Science* 30 (4): 790-818.

TOLEDO, A., 1991. Algunas reflexiones en torno a la planificación y el manejo de las lagunas costeras. *In*: Figueroa Torres, M.G., C. Álvarez Silva, A. Esquivel Herrera & M.E. Ponce Márquez (Eds), *Fisicoquímica y biología de las lagunas costeras mexicanas*. Universidad Autónoma Metropolitana-Iztapalapa. Mexico City, pp: 112-119.

VONO, V. & F.A.R. BARBOSA, 2002. Habitat and littoral zone fish community structure of two natural lakes in southeast Brazil. *Environmental Biology of Fishes* 61: 371-379.

YÁÑEZ-ARANCIBIA, A., A.L. LARA-DOMÍNGUEZ & H. ÁLVAREZ GUILLÉN, 1985. Fish community ecology and dynamic in estuarine inlets. *In*: A.Yáñez-Arancibia (Ed.). *Fish Community Ecology in Estuaries and Coastal Lagoons: Towards an Ecosystem Integration*. UNAM-PUAL-ICMyL. Mexico City.

ZAR, J.H., 1984. *Biostatistical Analysis*. 2nd Ed. Prentice Hall. Englewood-Cliffs,718 p.

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