

Environmental Influences on the Demersal Fish Assemblages in the Sepetiba Bay, Brazil

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ABSTRACT: The structure of the demersal fish assemblage in Sepetiba Bay, southeast Brazil (22°54'–23°04'S, 43°34'–44°10'W) was described and related to environmental variables. A 3-yr long trawl survey (from July 1993 to June 1996) was conducted using a stratified random sampling strategy at 158 stations. One hundred and seven species of fishes in 80 genera and 44 families were identified. Gerreidae and Ariidae made up 30.5% and 28.6%, and 19.8% and 28.1% of the total number and weight, respectively. Sciaenidae, Engraulididae, Sparidae, and Carangidae were other prominent families. Three assemblages existed in the bay: one inhabited shallow, less saline and less transparent water in the inner zone (depth < 5 m, transparency < 2 m, salinity < 30 psu, and slightly higher temperature); another in the outer zone with the opposite situation (depth > 10 m, transparency > 3 m, salinity > 30 psu, and slightly lower temperature); and a third assemblage in the middle zone likely to prefer average values or show no clear preferences. Most species decreased in abundance over the 3-yr period of study. No seasonal change was detected in the assemblage structure, but many species were rare, indicating high spatial and temporal patchiness. Canonical correlation analyses were used to describe and compare the fish assemblages in the three different habitats. The outer zone had the greatest number of species recorded, lowest abundance, highest diversity and evenness, and was comprised mainly by *Cynoscion leiarchus*, *Prionotus punctatus*, *Anchoa tricolor*, *Haemulon steindachneri*, *Diplectrum radiale*, *Etropus crossotus*, and *Sphoeroides greeleyi*; the inner zone had the lowest number of species recorded but the greatest number of species per sample, highest abundance, lowest diversity and evenness, being comprised mainly by *Diapterus rhombeus*, *Genidens genidens*, *Cathrops spixii*, *Chloroschombrus chrysurus*, *Sciadeichthyes luniscutis*, *Cetengraulis edentulus*, and *Archorsargus rhomboidalis*; while the third group had the lowest number of species per sample, being comprised by species widely distributed as *Gerres aprion*, *G. genidens*, *Gerres gula*, and *Micropogonias furnieri*. Depth, followed by transparency and salinity, were the primary factors influencing assemblage distribution.

Introduction

Fish assemblages are ecological units that function in an orderly manner, so their structures can have unique attributes (Odum 1969). The structure of assemblages can be used to evaluate effects of environmental changes and help to develop conservation policies. Demersal fishes inhabiting temperate bays and coastal lagoons are relatively well studied (McHugh 1967; Livingston et al. 1974; Weinstein et al. 1980; De Ben et al. 1990; Marshall and Elliott 1998), although little attention has been devoted to tropical and subtropical areas. The life histories of many fishes, some of which are commercially significant, are inextricably associated with these systems. Studies of fish assemblages in the tropics included those in Indo-Pacific region (Adjeroud et al. 1998), southeast Africa (Cyrus and Blaber 1987), Australia (Blaber et al. 1989), the

lagoons of Mexico (Yáñez-Arancibia et al. 1980; Yáñez-Arancibia and Lara-Domingues 1983; Amezcua Linares et al. 1987), the Laguna Joyuda, Puerto Rico (Stoner 1986), the Golfo of Nicoya, Costa Rica (Rojas et al. 1994), and some South American countries such as Venezuela (Villarreal 1994), Colombia (Garcia et al. 1998), and Brazil (Paiva Filho et al. 1987; Araújo et al. 1997, 1998; Chaves and Corrêa 1998).

Sepetiba Bay is located in the State of Rio de Janeiro, southeast Brazil. Its connection with the sea is through a wide area at the west and a narrow channel at the east with a sandbank forming the southern limit and the continental margin at the north. Several marine fishes enter and leave the bay for nursery, reproductive, and feeding purposes (Araújo et al. 1997, 1998). Human impacts originate from the outskirts of Rio de Janeiro City, and a few medium-sized towns that have limited agriculture and fishing in addition to an increasing in-

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dustrial development. Sewage effluent into the bay is about $290,900 \text{ m}^3 \text{ d}^{-1}$ resulting in organic loads of approximately $70,000 \text{ kg BOD d}^{-1}$ (SEMA 1998). It is estimated that the bay is receiving industrial outflow of $153,835 \text{ m}^3 \text{ d}^{-1}$, which corresponds potentially to $3,332 \text{ kg d}^{-1} \text{ DBO}_5$ and $48,694 \text{ kg d}^{-1}$ suspended solids (Pfeiffer et al. 1985). Recent enhancement of the Sepetiba Bay Port included dredging of the access channel to 20 m depth, which will enable it to receive ships up to 150,000 ton of capacity.

Fish assemblages are known to change in composition as their habitat is modified (Araújo et al. 2000). Cycles of fish abundance in estuaries and bays appear to be related to intrinsic biotic interactions and respond to variations in environmental conditions and could confound annual trends if not properly understood. Abiotic variables are expected to change outside their expected level of seasonal variation with pollution influence, changing fish assemblages structure (Gray 1989; Loeb 1994; Deegan et al. 1997). As most human activities in the drainage basin of Sepetiba Bay are concentrated in the innermost region we hypothesized that there would be inner, middle, and outer zones with differences in fish abundance and assemblages, and that these differences would be related to environmental variables and anthropogenic influences.

The objective of this study is to describe the structure of demersal fish assemblages in Sepetiba Bay. The influences of 4 environmental variables (temperature, salinity, depth, and transparency) on the most common 39 fish species were examined. The aim was to determine whether these environmental variables were correlated with fish assemblage structure, and whether assemblage structure changed in a predictable way as abiotic factors differed among the three sections of the bay.

Materials and Methods

STUDY AREA AND SURVEY PROGRAM

Sepetiba Bay (Fig. 1) is a sedimentary embayment in the coast of Rio de Janeiro State ($22^{\circ}54' - 23^{\circ}04'S$, $43^{\circ}34' - 44^{\circ}10'W$) in southeastern Brazil. It originated by an extensive process of sand deposition, which formed a barrier beach at its southern end. It has a wide communication with the Atlantic Ocean at its western end. The bay has a surface area of approximately 305 km^2 , a mean depth of 8.6 m, a maximum depth of 30 m, and is within a drainage area of $2,700 \text{ km}^2$ (Fonseca 1978). Waters are predominantly polyhaline (salinity around 30 psu). The annual rainfall is between 1,000 and 2,100 mm (Barbieri and Kronemberger 1994) but this does not influence the bay salinity much due

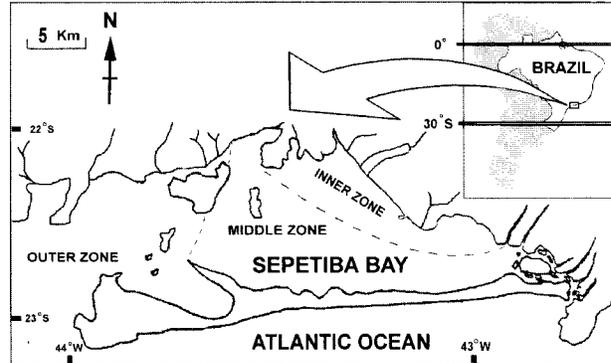


Fig. 1. Map showing the three zones (outer, middle, and inner) of the Sepetiba Bay, Brazil.

the existence of only small tributaries. Most of the substrate in the inner bay is silt and mud. It is sand at the southern end, and sand and gravel in the west near the sea. The tidal range is approximately 1 m. Predominantly northeasterly and southwesterly winds activate thermal currents between the bay and the ocean.

Sampling was conducted during daylight hours, between July 1993 and June 1996, in the three zones (Fig. 1) according to a stratified random design to maximize variation in habitat characteristics, mainly depth, salinity, transparency, temperature, and influences of human activities. In each zone, three replicates samples were taken at random, monthly in 1993 and 1994 and bimonthly in 1995 and 1996. The outer zone has a sand and gravel bottom and is close to the sea limit; the inner zone has a heavy mud bottom and is located within a protected area of the Bay; and the middle zone has a mud bottom. Bottom trawl tows were against the current, of 30-min duration on the bottom, at a towing speed of approximately 3 km h^{-1} , and a distance of 1,500 m, thus defining the unit effort. The trawl had an 8-m headline, 11-m ground rope, 2.5-cm stretched mesh, and 1.2-cm mesh cod-end liner. The bottom depth in the areas trawled ranged from 4 to 25 m. The actual position of the stations inside the zone was chosen randomly. Following each trawl, hydrographic data were taken from waters near the bottom, collected by Van Dorn bottle, including temperature with 0.5°C precision and salinity with 0.5 psu precision. Transparency was recorded using a Secchi disc (cm) and depth was determined with a weighted line marked in 10-cm intervals.

All fish were identified to species, counted, and the total mass of the pooled individuals of each species was taken. For very large catches, samples were divided in four to ten equally weighted portions, then two to five randomly selected portions

TABLE 1. Means (\pm SE) of environmental variables and ANOVA comparisons for season in the three zones in the Sepetiba Bay. W = Winter, S = Spring, Su = Summer, A = Autumn; ns = no significance; ** highly significant ($p < 0.01$).

Seasons	Outer Zone			Middle Zone			Inner Zone		
	1993/1994	1994/1995	1995/1996	1993/1994	1994/1995	1995/1996	1993/1994	1994/1995	1995/1996
Temperature									
Winter	22.3 (0.2)	22.9 (0.3)	22.9 (0.3)	21.8 (0.2)	23.1 (0.6)	21.6 (0.4)	22.0 (0.4)	22.6 (0.9)	21.5 (0.6)
Spring	23.1 (0.4)	24.1 (0.2)	24.1 (0.2)	23.9 (0.3)	24.5 (0.6)	22.5 (0.4)	24.3 (0.7)	26.5 (1.0)	22.0 (0.0)
Summer	24.2 (0.6)	26.0 (0.6)	26.0 (0.6)	25.0 (0.3)	27.0 (0.6)	25.1 (0.4)	26.8 (0.4)	27.5 (0.8)	26.9 (0.8)
Autumn	24.7 (0.4)	24.7 (0.3)	24.7 (0.3)	25.5 (0.6)	24.5 (0.4)	23.7 (0.0)	26.2 (0.5)	24.9 (0.1)	24.7 (0.2)
F-Anova	5.5**	10.6**	13.9**	10.3**	6.8**	12.8**	14.07**	4.8**	12.1**
Tukey	A, Su > W	Su > W	Su > W, S	Su > S, W	Su > W	Su > S > W	Su > S > W	Su > W	Su > W
Salinity									
Winter	30.2 (1.2)	33.5 (0.3)	34.0 (0.5)	30.3 (0.4)	33.0 (0.5)	33.5 (0.4)	29.5 (0.7)	32.5 (0.4)	31.0 (0.5)
Spring	30.8 (0.3)	32.3 (0.3)	34.0 (0.0)	29.9 (0.4)	31.0 (0.7)	33.5 (0.4)	29.2 (0.5)	31.0 (0.7)	30.0 (0.0)
Summer	31.3 (0.9)	30.2 (0.4)	31.2 (0.4)	31.3 (0.7)	30.0 (0.7)	30.5 (0.4)	30.4 (0.2)	30.0 (0.4)	28.3 (1.1)
Autumn	31.3 (0.2)	32.3 (0.3)	34.0 (0.0)	30.8 (0.5)	30.0 (0.0)	34.0 (0.0)	29.5 (0.8)	31.0 (0.7)	29.5 (0.4)
F-Anova	ns	13.5**	11.9**	ns	ns	10.87**	ns	ns	ns
Tukey		W > Su	W, S, A > Su			W, S, A > Su			
Transparency									
Winter	3.0 (0.3)	2.9 (0.4)	3.7 (0.6)	2.3 (0.3)	2.6 (0.2)	3.0 (0.4)	1.5 (0.3)	1.4 (0.2)	1.6 (0.3)
Spring	3.4 (0.2)	4.2 (0.4)	2.3 (0.2)	3.0 (0.2)	4.3 (0.2)	2.0 (0.0)	1.0 (0.1)	2.5 (0.4)	0.9 (0.1)
Summer	3.7 (0.2)	2.3 (0.2)	3.7 (0.7)	3.9 (0.2)	2.6 (0.5)	1.7 (0.4)	2.1 (0.2)	1.5 (0.1)	1.2 (0.2)
Autumn	3.9 (0.5)	2.6 (0.2)	4.8 (0.1)	3.3 (0.4)	2.4 (0.2)	3.5 (0.4)	2.1 (0.3)	2.5 (0.0)	2.3 (0.0)
F-Anova	ns	ns	ns	ns	ns	ns	ns	ns	ns
Depth									
Winter	12.4 (2.1)	9.7 (0.5)	9.6 (1.0)	9.2 (1.1)	10.5 (0.6)	8.0 (1.4)	4.2 (0.4)	3.8 (0.2)	4.5 (0.2)
Spring	8.9 (0.7)	11.0 (1.9)	10.2 (1.9)	8.7 (0.2)	8.5 (1.4)	8.0 (2.1)	3.9 (0.7)	3.2 (0.6)	2.8 (0.5)
Summer	11.5 (0.5)	9.3 (1.4)	10.7 (1.4)	8.7 (0.8)	8.8 (1.1)	9.0 (1.1)	4.2 (0.4)	4.5 (0.8)	3.3 (0.8)
Autumn	12.1 (1.2)	9.7 (2.3)	12.0 (0.9)	8.8 (0.4)	6.0 (0.0)	9.5 (1.1)	5.0 (1.0)	5.0 (1.1)	3.3 (0.2)
F-Anova	ns	ns	ns	ns	ns	ns	ns	ns	ns

were processed individually to species and the total number of individuals were estimated from the mean of the counted portions (mean number of fishes per unit of weight). Small fishes, and randomly selected specimens, were preserved in 10% formalin (diluted with bay water). Fish identification followed Figueiredo (1977), Figueiredo and Menezes (1978, 1980, 2000), and Menezes and Figueiredo (1980, 1985).

DATA ANALYSIS

Fish and environmental data were $\log_{10}(x+1)$ transformed to fulfill homoscedasticity and normality requirements of parametric analyses, to reduce the weighting of abundant species, and to balance the effect of different units of measurement of environmental parameters. Analysis of variance (ANOVA) was used to determine whether there were differences among zone, year, and season in fish and environmental data. Tukey's multiple range test was used to determine differences in mean values following ANOVA. A number of commonly used ecological indices calculated were: Margalef's species richness (D), Shannon-Wiener (H') diversity, Pielou evenness (J), and the Simpson's Index (SI). The natural logarithm was used for computations of all indices. Canonical corre-

lation analyses (CCA) were used to visualize and describe the relations between fish species and environmental variables. This ordination method is a powerful multivariate technique to describe how multiple species respond simultaneously to environmental factors and is designed to extract synthetic environmental gradients from ecological data sets (ter Braak 1991). Following the recommendation of Clifford and Stevenson (1975), only the most commonly occurring species ($> 0.1\%$ of abundance) were included in the analysis. The CCA constrains the axes in classical correspondence analysis to be linear functions of environmental factors. The gradients are the basis for succinctly describing species' differential habitat preference via ordination diagrams (ter Braak and Verdondchot 1995). Species and sample sites were marked with points representing their mean distribution. The explanatory variables were tested by linear correlation coefficient in order to ascertain whether there was no correlation among them (collinearity) and are represented by vectors pointing towards the maximum change in the value of the associated variable. Informally, the length is equal to the multiple correlation of the variable with the displayed ordination axes. The Spearman rank correlation coefficient was used to determine the sig-

TABLE 2. Rank by number, total number (N), mass (g), and frequency of occurrence (FO, %) of the 39 most abundant fishes captured in Sepetiba Bay, Brazil, 1993–1996. Code of species is in brackets.

	Number			Mass			Rank by N	FO
	1993/1994	1994/1995	1995/1996	1993/1994	1994/1995	1995/1996		
Ariidae (marine catfish)								
<i>Genidens genidens</i> (Gen gen)	4,204	3,319	385	99,195	81,130	14,153	2	62.8
<i>Cathorops spixii</i> (Cat spi)	1,418	973	5,392	77,978	31,353	69,543	3	40.4
<i>Sciadeichthyes luniscutis</i> (Sci lun)	468	888	893	47,727	82,625	28,636	9	50.0
<i>Netuma barba</i> (Net bar)	334	462	5	14,227	10,275	100	17	20.5
Gerreidae (mojarras)								
<i>Diapterus rhombeus</i> (Dia rho)	1,073	4,533	7,453	37,036	139,630	106,505	1	57.7
<i>Geres aprion</i> (Ger apr)	2,261	1,270	482	38,353	21,506	7,545	4	69.2
<i>Geres gula</i> (Ger gul)	928	1,634	119	18,281	18,792	1,482	6	50.6
<i>Geres melanopterus</i> (Ger mel)	57	0	93	1,080	0	1,863	35	5.1
Sciaenidae (croakers)								
<i>Micropogonias furnieri</i> (Mic fur)	1,291	678	443	39,571	16,766	10,349	7	70.5
<i>Cynoscion leiarchus</i> (Cyn lei)	587	531	718	11,663	8,456	5,145	10	35.9
<i>Isopisthus parvipinnis</i> (Iso par)	67	256	84	1,100	1,450	708	25	6.4
<i>Menticirrhus americanus</i> (Men ame)	165	164	72	8,988	4,423	1,850	26	58.3
<i>Ctenosciaena gracilicirrus</i> (Cte gra)	186	136	67	1,885	706	521	28	26.2
Carangidae (jacks)								
<i>Chloroschombrus chrysurus</i> (Chl chr)	1,276	369	2,054	22,371	7,435	14,876	5	66.6
<i>Selene setapinnis</i> (Sel set)	404	20	30	3,531	206	630	24	24.3
Engraulidae (anchovies)								
<i>Anchoa tricolor</i> (Anc tri)	558	1,116	677	4,545	9,815	3,639	8	48.7
<i>Anchoa januaria</i> (Anc jan)	22	42	139	162	336	780	32	14.1
<i>Cetengraulis edentulus</i> (Cet ede)	329	199	1,071	18,123	2,903	46,067	11	28.2
Sparidae (porgies)								
<i>Archosargus rhomboidalis</i> (Arc rho)	768	626	130	92,010	134,595	28,550	12	36.5
Serranidae (sea basses)								
<i>Diplectrum radiale</i> (Dip rad)	526	421	366	19,660	10,994	6,992	13	74.3
Triglidae (searobins)								
<i>Prionotus punctatus</i> (Pri pun)	557	352	294	10,930	6,484	4,012	14	87.1
Haemulidae (grunts)								
<i>Orthopristis ruber</i> (Ort rub)	515	485	159	39,724	30,778	10,459	15	69.2
<i>Haemulon steindachneri</i> (Hae ste)	560	66	9	41,598	3,150	710	19	12.1
Paralichthyidae (flounders)								
<i>Etropus crossotus</i> (Etr cro)	549	233	288	9,015	2,310	4,114	16	72.4
<i>Etropus longimanus</i> (Etr lon)	251	122	129	3,804	1,917	1,213	21	54.4
<i>Etropus intermedius</i> (Etr int)	112	47	25	1,710	857	216	34	37.1
<i>Citarrichthys spilopterus</i> (Cit spi)	28	139	145	639	2,537	2,237	29	39.7
Tetraodontidae (puffers)								
<i>Sphoeroides greeleyi</i> (Sph gre)	707	35	4	16,143	1,369	47	18	25.0
<i>Sphoeroides testudineus</i> (Sph tes)	162	46	97	14,252	5,450	12,381	30	36.5
Cynoglossidae (tonguefishes)								
<i>Symphurus tessellatus</i> (Sym tes)	305	139	130	8,183	2,777	1,537	20	63.4
Achiridae (soles)								
<i>Trinectes paulistanus</i> (Tri pau)	295	120	60	8,369	3,914	1,849	22	35.2
<i>Achirus lineatus</i> (Ach lin)	320	73	71	11,950	1,469	1,575	23	43.5
Synodontidae (lizardfishes)								
<i>Synodus foetens</i> (Syn foe)	40	150	205	3,700	7,370	6,012	27	32.6
Gobiidae (gobies)								
<i>Gobionellus oceanicus</i> (Gob oce)	34	21	237	1,936	608	7,325	31	12.8
Ephippidae (spadefishes)								
<i>Chaetodipterus faber</i> (Cha fab)	62	99	38	7,406	1,911	1,025	33	25.6

TABLE 2. Continued.

	Number			Mass			Rank by N	FO
	1993/1994	1994/1995	1995/1996	1993/1994	1994/1995	1995/1996	1993/ 1996	1993/ 1996
Clupeidae (herrings)								
<i>Harengula clupeiola</i> (Har clu)	70	47	18	2,232	1,070	644	36	15.3
<i>Peloma harroweri</i> (Pel har)	99	7	0	915	75	0	39	1.9
Trichiuridae (swordfishes)								
<i>Trichiurus lepturus</i> (Tri lep)	63	24	45	8,039	569	627	37	21.1
Muraenidae (moray eels)								
<i>Gymnothorax ocellatus</i> (Gym oce)	45	53	17	4,050	5,350	1,050	38	34.0
39 top abundant fishes	21,696	19,895	22,644	752,081	663,361	406,967		
All fishes	22,259	20,171	22,932	838,620	702,342	437,498		

nificance of each relationship between environmental variables and fish abundance (Zar 1984).

Results

ENVIRONMENTAL CHARACTERISTICS

The temperatures showed similar cyclical trends and similar maximum and minimum values over all 3 yr of study (Table 1). The highest average values were found in summer (26–27°C) with the lowest being recorded in winter (21–22°C). There were significant differences ($p < 0.01$) between higher means values in summer and autumn and lower values in winter. Slightly higher temperatures were observed in the inner zone than in outer zone, but this difference was not significant (Table 1). Mean salinity generally did not vary much among the zones during the three years of study, although there is a trend for higher values in the inner zone and lower values in the outer zone. Significant seasonal differences in mean values ($p < 0.01$) were shown only for the outer zone (1994–1995 and 1995–1996) and middle zone (1995–1996) with salinities higher in winter than summer. There was a well defined pattern for water transparency with higher mean values in the outer zone and lower values in the inner zone ($p < 0.01$), but no difference was shown among years or seasons. Depth increased significantly from the inner zone toward the outer zone. No significant difference in mean depth was shown among the years nor among the seasons.

FISH ASSEMBLAGES

One hundred and seven species were caught during the 158 otter trawls carried out between July 1993 and June 1996 in Sepetiba Bay. This corresponded to 65,362 fishes representing 80 genera and 44 families. The Gerreidae *Diapterus rhombeus* and the Ariidae *Genidens genidens* and *Cathorops spixii* were the most abundant species with each comprising over 10% of the number and 9% of

the weight of the total catches (Table 2). Although not so abundant, *Diplectrum radiale*, *Etropus crossotus*, *Prionotus punctatus*, and *Micropogonias furnieri* were the most frequent species, each appearing in over 70% of the samples. Sciaenidae, Engraulidae, Sparidae, and Carangidae were the other prominent families and made up an additional 23.68% of total abundance and 14.24% of total biomass. Families contributing the most species were Sciaenidae (11), Carangidae (10), Paralichthyidae (8), Haemulidae and Gerreidae (7), and Ariidae and Clupeidae (5; Table 2). Thirty-two percent of the species were represented by less than 5 individual and some 46% were represented by a single specimen.

On the basis of percent of total abundance, the 107 species captured fell into five general categories: category 1 (abundant) consisted only of 1 species (*D. rhombeus*) and made up 20% of total abundance and 14.3% of biomass (Table 2); category 2 included 2 moderately abundant species (*G. genidens* and *C. spixii*) and made up approximately 11% and 9% of total abundance and biomass, respectively; category 3 included 16 low abundant species and made up each one between 1% and 6% of total abundance and biomass; category 4 including 35 occasional species which ranked between 0.1% and 0.9%; and category 5 including 57 rare species that accounted for $< 0.1\%$ of the abundance and biomass (Table 2).

There was a trend toward higher species diversity, richness, and species recorded in the outer zone and lower values in the inner zone (Table 3). On the other hand, the greatest number of fish and species per sample were recorded in the inner zone. Ninety species were recorded in the outer zone during the studied period, while only 75 and 74 in the inner and middle zones, respectively.

Total number of fish did not change among the 3 years of study but total weight was lower in 1995 and 1996. The numerically dominant species

TABLE 3. Estimated mean abundance (number per sample), species recorded, and diversity indexes in the Sepetiba Bay. Mean (SE).

	Outer Zone	Middle Zone	Inner Zone
Fish/sample	215.47 (20.37)	343.71 (58.0)	756.27 (157.7)
Species/sample	17.24 (0.6)	17.63 (0.5)	18.46 (0.7)
Species recorded	90	74	75
H'-Shannon	2.06 (0.06)	1.94 (0.06)	1.75 (0.08)
D-Margalef	3.17 (0.1)	3.15 (0.08)	3.05 (0.13)
J-Evenness	0.74 (0.01)	0.68 (0.02)	0.60 (0.02)
SI-Simpson	0.79 (0.01)	0.76 (0.02)	0.68 (0.03)
Top 6 species in rank order			
1	<i>C. leiarchus</i>	<i>G. genidens</i>	<i>D. rhombeus</i>
2	<i>G. aprion</i>	<i>G. aprion</i>	<i>C. spixii</i>
3	<i>D. radiale</i>	<i>G. gula</i>	<i>G. genidens</i>
4	<i>A. tricolor</i>	<i>C. spixii</i>	<i>C. chrysurus</i>
5	<i>P. punctatus</i>	<i>A. tricolor</i>	<i>S. luniscutis</i>
6	<i>H. steindachneri</i>	<i>M. furnieri</i>	<i>A. rhomboidalis</i>

changed in number and mass over the three years of study. *G. genidens*, *Netuma barba*, *Sciadeichthyes luniscutis*, *Gerres gula*, *M. furnieri*, *C. gracilicirrhus*, *Menticirrhus americanus*, *Archosargus rhomboidalis*, *E. crossotus*, *Etropus longimanus*, *Etropus intermedius*, *Orthopristis ruber*, *Haemulon steindachneri*, *P. punctatus*, *D. radiale*, *Harengula clupeiola*, *Peloma harroweri*, *Trichiurus lepturus*, *Gymnotorax ocellatus*, *Chaetodipterus faber*, *Sphaeroides greeleyi*, *Symphurus tessellatus*, *Trinectes paulistanus*, and *Achirus lineatus* decreased in number and biomass over the study period, while *C. spixii*, *D. rhombeus*, *Gerres aprion*, *Anchoa januaria*, *Cetengraulis edentulus*, *Citarichthys spilopterus*, *Synodus foetens*, and *Gobionellus oceanicus* increased, and in most case interannual differences were significant (Tables 2 and 4). No clear trend was shown for *C. spixii*, *Cynoscion leiarchus*, *Chloroschombrus chrysurus*, *Anchoa tricolor*, and *S. testudineus*. Only two species (*S. tessellatus* and *Selene setapinnis*) showed significant differences ($p < 0.01$) in abundance among seasons, but the great majority of species showed significant differences in relative abundance among the zones of the bay (Table 4).

ENVIRONMENTAL INFLUENCES ON SPECIES DISTRIBUTION

The canonical correlation triplot describes the principal tendencies in the relationship between fish species and their environment (Fig. 2). Each arrow represents an environmental variable. The projections of a species on this axis shows its preference for high or low values of this environmental gradient (ter Braak 1991). The first and second ordination axes represent this variation best and showed eigenvalues of 0.132 and 0.027, respectively, which amounted to 68.3% and 14.1% of the variation in fish abundance (Table 5). The variation left unexplained by this method may be attributed to inherent noise in fish assemblage data, factors and processes not evaluated in the study, or

methodological and interpretation errors. According to canonical correspondence analysis, the most significant factor correlated with the fish species was depth, followed by transparency and salinity, and, to a lesser extent, temperature. Correlation between species and the four environmental axes were high for the first axis (0.769) and lower for the second (0.463), third (0.552), and fourth (0.382) axes.

The major source of patterned variation in the data is a marked shift in fish assemblage structure from the inner zone to the outer zone along axis 1, coinciding with spatial gradient of increasing depth, salinity, and transparency. Axis 1 separated the outer zone samples, on the right side, which are characterized by highest depth, salinity, and transparency, and slightly lower temperature, in opposition to the inner samples, on the left side, which are characterized by lowest depth, salinity, and transparency, and slightly higher temperature. Samples from the middle zone in central area in the diagram, were characterized by average values for those environmental parameters (Fig. 2). Fish species associated with the inner zone samples included mainly *G. oceanicus*, *N. barba*, *A. rhomboidalis*, *D. rhombeus*, *A. lineatus*, *T. paulistanus*, *C. edentulus*, *C. faber*, *G. genidens*, *C. spixii*, *C. chrysurus*, *A. januaria*, and *M. furnieri* (left side), while species associated with the outer zone included *H. steindachneri*, *C. gracilicirrhus*, *S. foetens*, *D. radiale*, *S. tessellatus*, *A. tricolor*, *O. ruber*, *G. ocellatus*, *S. setapinnis*, and *S. greeleyi* (right side). Species likely to prefer average values or showing no clear preferences were associated with the middle zone, namely *G. gula* and *C. spilopterus*.

Discussion

The three zones of the bay support three different fish assemblages with a shift in species abundance and proportional compositions between the

TABLE 4. Results of ANOVA comparing mean transformed abundances of fishes among 3 years, 3 zones, and 4 seasons. Zones: 1 = Outer, 2 = Middle, 3 = Inner; Year 1 = 1993/1994, 2 = 1994/1995, 3 = 1995/1996. Species code as in Table 2.

Species Code	Year		Zone		Season	
	F-ratio	Tukey Post-hoc	F-ratio	Tukey Post-hoc	F-ratio	Tukey Post-hoc
Gen gen	ns		53**	2,3 > 1	ns	
Cat spix	ns		15.2**	3 > 2,1	ns	
Sci lun	ns		5.9**	3 > 1	ns	
Dia rho	3.6**	3 > 1	24.2**	3 > 2,1	ns	
Mic fur	ns		11.4**	3 > 2 > 1	ns	
Chl chr	ns		18.1**	3 > 2 > 1	ns	
Net bar	5.8**	2 > 3	11.9**	3 > 1,2	ns	
Cet ede	ns		4.7**	3 > 1	ns	
Arc rho	ns		19.2**	3 > 2 > 1	ns	
Cha fab	ns		ns		ns	
Sph tes	ns		ns		ns	
Gob oce	ns		4.2**	3 > 1	ns	
Ger gul	8.5**	2 > 3	ns		ns	
Cit spi	8.1**	2,3 > 1	ns		ns	
Ger apr	4.3**	1 > 3	6.6**	2 > 1 > 3	ns	
Ach lin	4.8**	1 > 3	25.2**	3 > 2 > 1	ns	
Tri pau	3.5**	1 > 3	30.4**	3 > 2 > 1	ns	
Gym oce	ns		17.9**	1 > 2 > 3	ns	
Dip rad	3.1*		29.2**	1 > 2 > 3	ns	
Etr cro	ns		ns		ns	
Hae ste	5.2**	1 > 2 > 3	14.2**	1 > 2 > 3	ns	
Syn foe	7.3*	3 > 1	17.8**	1 > 2 > 3	ns	
Cte gra	ns		15.1**	1 > 2 > 3	ns	
Pri pun	ns		5.2**	1 > 3	ns	
Ger mel	ns		ns		ns	
Har clu	ns		ns		ns	
Sym tes	ns		3.5**	1 > 3	5.7**	Summer > winter
Ort rub	ns		3.7**	1 > 3	ns	
Etr int	4.9**	1,2 > 3	4.6**	1 > 2 > 3	ns	
Pel har	ns		ns		ns	
Cyn lei	ns		3.3**	1 > 3	ns	
Etr lon	ns		ns		ns	
Sel set	4.2*	1 > 2	ns		11.5**	Summer > winter
Iso par	ns		5**	1 < 2,3	ns	
Men ame	ns		ns		ns	
Anc tri	4.1**	1 > 3	ns		ns	
Sph gre	9.1**	1 > 2,3	ns		ns	
Tri lep	ns		3.2**	2 < 3	ns	
Anc jan	3.4*	3 > 1	ns		ns	
Temperature	3.9**	2 > 3	ns		53.6**	Summer > winter
Salinity	9.2**	2,3 > 1	10.6**	1 > 3	3.0**	Summer > winter
Depth	ns		129.4**	1 > 2 > 3	ns	
Transparency	ns		47.2**	1 > 2 > 3	ns	
D-Margalef	3.4**	1 > 3	ns		ns	
H'-Shannon	ns		5.3**	1 > 3	ns	
J-Evenness	ns		8.14**	1 > 3	ns	
Simpson	ns		5.6**	1 > 3	ns	

outer and inner zone. The middle zone may be viewed as a transition area between the environmentally more harsh conditions of the inner zone and the more typical and stable oceanographic conditions of the outer zone. It is possible to differentiate patterns of fish structure and composition among the inner zone, composed of abundant resident fish species, the middle zone, a transition area characterized by rare species, and an outer zone with high diversity but low abundance char-

acterized by typically marine species. Despite these overall patterns, there is still a wide dispersion of uncommon species throughout the study area.

Depth, followed by transparency and salinity were the major factors influencing the spatial patterns of fish assemblage in the Sepetiba Bay, which can be interpreted as a land-ocean (inner zone-outer zone) gradient. Horne and Campana (1989) found a similar distributional pattern with coastal assemblages associated with higher salinity, higher

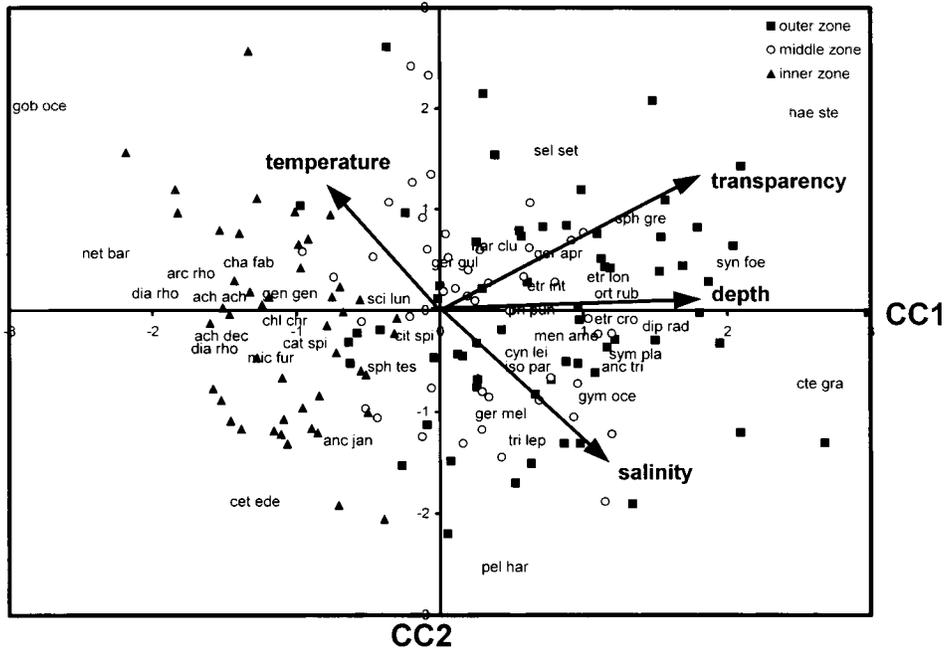


Fig. 2. CCA ordination diagram of abundance data with sites, species, and environmental factors represented by vectors. Species code as stated in Table 2.

transparency, and coarser substrate than estuarine assemblages, and these results match closely Sepetiba Bay.

Because of the relatively shallow (< 5 m) depth in the inner zone and the gradual, featureless seaward slope, it seems surprising that the multivariate analyses identified depth as an important correlate of fish distributions. Depth may have been significant because it acted in concert with other factors such as sediment. Fargo and Tyler (1991)

found four species assemblages separated by depth and sediment, and their species assemblages and sediment types did not coincide exactly; two sediment types were found at the same depth. Pearcy (1978) found an interaction between depth and sediment type. Shallow assemblages showed a high similarity between stations regardless of sediment type, but deep assemblages were assorted according to differences in substrates. Although depth and sediment are often correlated, caution is nec-

TABLE 5. Results of the main ordination diagnostics calculated by the canonical correspondence analysis. Trace = 0.50, F-ratio: 4.01, p-value = 0.01

Axes	1	2	3	4
Canonical coefficients for standardized variables:				
Temperature	-0.178	0.154	-0.928	-0.497
Salinity	0.105	-0.972	-0.632	-0.016
Depth	0.729	0.278	0.311	-0.917
Transparency	0.2729	0.445	-0.399	0.997
Inter-set correlation of environment variables:				
Temperature	-0.270	0.204	-0.379	-0.149
Salinity	0.414	-0.365	-0.148	0.035
Depth	0.727	0.049	0.003	-0.117
Transparency	0.541	0.141	-0.191	0.201
Summary of the main ordination diagnostics:				
Eigenvalues	0.132	0.027	0.024	0.010
Correlation species-environment variance accumulative	0.769	0.463	0.522	0.382
Species data	6.2	7.5	8.6	9.1
Relation species-environmental	68.3	82.4	94.6	100.0
Inertia	2.11997			

essary because sometimes they vary independently. The fish assemblages in this study were depicted as having assemblage boundaries related to depth, and this factor may be correlated with sediment, which tends to be relatively coarse in the outer zone and muddy in the middle and inner zones.

Transparency is the second important factor revealed by the analyses, and increases from the inner zone to the outer zone. The inner zone water is turbid and sedimentation was relatively high. It has been postulated that turbidity gradients between the sea and adjacent estuaries and bays act as one of the orientation cues for juveniles migrating into estuaries (Blaber 1997). Maes et al. (1998) presented evidence that juveniles occurring in estuaries occupy different turbidity ranges from those of adults and it was concluded that the influence of high turbidity on fish may be linked to reduced predation pressure. How the increasing transparency gradient from the inner to the outer zone is translated into increasing species diversity is unknown, but its high correlation to fish assemblages detected by analyses indicates its important role as a factor influencing fish distribution in the Sepetiba Bay.

Salinity has a greater influence on the species composition in the Sepetiba Bay than temperature. Marshall and Elliot (1998) found this same pattern for the fish community in the Humber estuary, England, and that salinity influences the distribution of fish through their salinity tolerance. As salinity decreases, species number, species diversity, evenness, and frequency of marine species all decrease (Thiel et al. 1995), and this coincided with our findings for the three zones of Sepetiba Bay. The spatial gradient in fish assemblage structure could be associated with the stability in environmental conditions common in tropical regions. In Sepetiba Bay there is no large river contribution to cause dramatic changes in the salinity gradient. Relatively stable hydrological conditions typically create a well-defined salinity gradient, and this may physiologically limit the spatial distributions of some marine fish. A similar pattern of demersal fish spatially ordered along a large-scale gradient was found for a Louisiana estuary (Rakocinski et al. 1992); whether fishes were transients or resident had no bearing on where they were centered along the salinity gradient. Weinstein et al. (1980) concluded that the large-scale salinity gradient was the primary factor influencing the community structure of estuarine fish and biotic interaction was secondary. In this study, the highest salinity in the outer zone would be allowing a higher number of marine species to penetrate in this part of the bay, but some of these species may have their dis-

tribution limited by the lowest salinity of the inner zone.

Temperature seems to show lesser importance in structuring fish assemblage in Sepetiba Bay. Temperature can affect fish distributions through the thermal tolerance of different species. Araújo et al. (1998) did not find a clear seasonal pattern in the fish distribution in the Sepetiba Bay, attributing this to the relative stability of the environmental parameters.

Effects of anthropogenic bay degradation could also be contributing to the structure the fish assemblage. Degraded areas can be less diverse and dominated by a few tolerant taxa, whereas higher-quality areas support a more balanced assemblage structure (Scott and Hall 1997). In the inner zone, organic nutrients from urban areas enrich the water and fewer fish species may tolerate this condition compared to the more pristine conditions in the outer zone. This may be another reason for the shift in assemblage composition from inner to outer bay. There may also be other unmeasured environmental variables affecting the assemblage such as habitat selection, recruitment, biotic interactions, and other climatic events.

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LITERATURE CITED

- ADJEROUD, M., Y. LETOURNEUR, M. PORCHER, AND B. SALVAT. 1998. Factors influencing spatial distribution of fish communities on a fringing reef at Mauritius, S.W. Indian Ocean. *Environmental Biology of Fishes* 53:169–182.
- AMZCUA LINARES, F., M. A. RUBIO, AND A. YAÑEZ-ARANCIBIA. 1987. Dinámica y estructura de la comunidad de peces en un sistema ecológico de manglars de la costa del Pacífico de México, Nayarit. *Annal del Institute de Ciências del Mar y Limnología da Universidad Autónoma de México* 14:221–248.
- ARAÚJO, F. G., A. G. CRUZ-FILHO, M. C. C. AZEVEDO, AND A. C. A. SANTOS. 1998. Structure of demersal fish community in the Sepetiba Bay, RJ. *Revista Brasileira de Biologia* 58:417–430 (in Portuguese).
- ARAÚJO, F. G., A. G. CRUZ-FILHO, M. C. C. AZEVEDO, A. C. A. SANTOS, AND L. A. M. FERNANDES. 1997. Community structure of the juvenile fish at the continental margin of the Sepetiba Bay, RJ, Brazil. *Acta Biologica Leopoldensia* 19:61–83 (in Portuguese).
- ARAÚJO, F. G., W. P. WILLIAMS, AND R. G. BAILEY. 2000. Fish assemblages as indicators of water quality in the middle Thames estuary, England (1980–1989). *Estuaries* 23:305–317.
- BARBIERI, E. B. AND D. M. P. KRONENBERGER. 1994. Climatologia do litoral Sul-Sudeste do Estado do Rio de Janeiro: Um subsídio à análise ambiental. *Cadernos de Geociências. IBGE*. Rio de Janeiro, 12:57–73.
- BLABER, S. J. M. 1997. *Fish and Fisheries of Tropical Estuaries*. Chapman and Hall, London, U.K.
- BLABER, S. J. M., D. T. BREWER, AND J. P. SALINI. 1989. Species composition and biomass of fish in different habitats of a tropical northern Australian estuary: Their occurrence in the

- adjoining sea and estuarine dependence. *Estuarine Coastal and Shelf Science* 29:509–531.
- CHAVES, P. T. C. AND M. F. M. CORRÊA. 1998. Fish faunal composition of the mangrove area of the Guaratuba Bay, Paraná, Brazil. *Revista Brasileira de Zoologia* 15:195–202.
- CLIFFORD, H. T. AND W. STEVENSON. 1975. An Introduction to Numerical Classification. Academic Press, New York.
- CYRUS, D. P. AND S. J. M. BLABER. 1987. Investigation into relationships between water turbidity and estuarine fish distribution. *Journal of Experimental Marine Biology and Ecology* 109:53–70.
- DE BEN, W. A., W. D. CLOTHIER, G. R. DITSWORTH, AND D. J. BAUMGARTNER. 1990. Spatio-temporal fluctuations in the distribution and abundance of demersal fish and epibenthic crustaceans in Yaquina Bay, Oregon. *Estuaries* 13:469–478.
- DEEGAN, L. A., J. T. FINN, S. G. AWVAZIAN, C. A. RYDER-KYDER-KIEFFER, AND J. BOUNACCORSI. 1997. Development and validation of an estuarine biotic integrity index. *Estuaries* 20:601–617.
- FARGO, J. AND A. V. TYLER. 1991. Sustainability of flatfish-dominated fish assemblages in Hecate Strait, British Columbia, Canada. *Netherlands Journal of Sea Research* 27:237–253.
- FIGUEIREDO, J. L. 1977. Manual of Marine Fish from Southeastern Brazil. I. Introduction: Sharks, Rays and Chimaeras. Zoology Museum. São Paulo, Brazil. (in Portuguese).
- FIGUEIREDO, J. L. AND N. A. MENEZES. 1978. Manual of Marine Fish from Southeastern Brazil. II Teleostei (1). Zoology Museum. São Paulo, Brazil. (in Portuguese).
- FIGUEIREDO, J. L. AND N. A. MENEZES. 1980. Manual of Marine Fish from Southeastern Brazil. III. Teleostei (2). Zoology Museum. São Paulo, Brazil. (in Portuguese).
- FIGUEIREDO, J. L. AND N. A. MENEZES. 2000. Manual of Marine Fish from Southeastern Brazil. III. Teleostei (5). Zoology Museum. São Paulo, Brazil. (in Portuguese).
- FONSECA, M. R. M. R. 1978. Water quality in the Sepetiba Bay. *Feema—Environmental Studies* 11:316–334. (in Portuguese).
- GARCIA, C. B., L. O. DUARTE, AND D. SCHILLER. 1998. Demersal fish assemblages of the Gulf of Salamanca, Colombia (southern Caribbean Sea). *Marine Ecology Progress Series* 174:13–25.
- GRAY, J. S. 1989. Effects of environmental stress on species rich assemblages. *Biological Journal of the Linnaeus Society* 37:19–32.
- HORNE, J. K. AND S. E. CAMPANA. 1989. Environmental factors influencing the distribution of juvenile groundfish in near-shore habitats of Southwest Nova Scotia. *Canadian Journal of Fisheries and Aquatic Sciences* 46:1277–1284.
- LIVINGSTON, R. J., R. L. IVERSON, R. H. ESTABROOK, V. E. KEYS, AND J. TAYLOR. 1974. Major features of the Apalachicola Bay system: Physiography, biota, and resource management. *Florida Sciences* 37:245–271.
- LOEB, S. L. 1994. An ecological context for biological monitoring, p. 3–7. In S. L. Loeb and A. Spacie (eds.), *Biological Monitoring of Aquatic Systems*. Lewis Publishers, Boca Raton, Florida.
- MAES, J., A. TAILLIEU, P. A. DAMMME, K. CORRENIE, AND F. OLLEVIER. 1998. Seasonal patterns in the fish and crustacean community of a turbid temperate estuary (Zeeschelde Estuary, Belgium). *Estuarine, Coastal and Shelf Science* 47:143–151.
- MARSHALL, S. AND M. ELLIOTT. 1998. Environmental influences on the fish assemblage of the Humber estuary. *Estuarine, Coastal and Shelf Science* 46:175–184.
- MCHUGH, J. L. 1967. Estuarine necton, p. 581–620. In G. H. Lauff (ed.), *Estuaries*. American Association in Advanced Sciences, Washington, D.C.
- MENEZES, N. A. AND J. L. FIGUEIREDO. 1980. Manual of Marine Fish from Southeastern Brazil. IV. Teleostei (3). Zoology Museum. São Paulo, Brazil. (in Portuguese).
- MENEZES, N. A. AND J. L. FIGUEIREDO. 1985. Manual of Marine Fish from Southeastern Brazil. IV. Teleostei (4). Zoology Museum. São Paulo, Brazil. (in Portuguese).
- ODUM, E. P. 1969. *Fundamentals of Ecology*. Saunders, Philadelphia, Pennsylvania.
- PAIVA FILHO, A. M., R. GIANNINI, F. B. RIBEIRO NETO, AND J. M. M. SCHMIEGELOW. 1987. Ichthyofauna of the complex bay-estuarine of the Santos and São Vicente, SP. Brazil. *Relatório Interno do Instituto de Oceanografia da Universidade de São Paulo* 17:1–10.
- PEARCY, W. G. 1978. Distribution and abundance of small flatfishes and other demersal fishes in a region of diverse sediments and bathymetry off Oregon. *Fishery Bulletin* 83:507–520.
- PFEIFFER, W. C., L. D. LACERDA, M. FISZMAN, AND N. R. W. LIMA. 1985. Heavy metal in fishes from Sepetiba Bay, Rio de Janeiro State. *Ciência and Cultura* 37:297–302. (in Portuguese).
- RAKOCINSKI, C. F., D. M. BALTZ, AND J. W. FLEEGER. 1992. Correspondence between environmental gradients and the community structure of marsh-edge fishes in a Louisiana estuary. *Marine Ecology Progress Series* 80:135–148.
- ROJAS, R. R., M. J. F. PIZARRO, AND M. CASTRO. 1994. Diversidad y abundancia ictica en tres áreas de manglar en Golfo de Nicoya, Costa Rica. *Revista Biología Tropical* 42:663–672.
- SCOTT, M. C. AND L. W. HALL. 1997. Fish assemblages as indicators of environmental degradation in Maryland coastal plain streams. *Transaction of the American Fisheries Society* 126:349–360.
- SEMA (RIO DE JANEIRO ENVIRONMENTAL AGENCY). 1998. Plan for management of Sepetiba Bay watershed. Final report: Environmental diagnostic. Etep/Ecologus/Sm group. Rio de Janeiro, Brazil. (in Portuguese).
- STONER, A. W. 1986. Community structure of the demersal fish species of laguna Joyuda, Puerto Rico. *Estuaries* 9:142–152.
- TER BRAAK, C. J. F. 1991. Update notes: CANOCO Version 3.1. Wageningen, The Netherlands.
- TER BRAAK, C. J. F. AND P. F. M. VERDONCHOT. 1995. Canonical correspondence analysis and related multivariate methods in aquatic ecology. *Aquatic Sciences* 57:255–289.
- THIEL, R., A. SEPÚLVEDA, R. KAFEMANN, AND W. NELLEN. 1995. Environmental factors as forces structuring the fish community of the Elbe Estuary. *Journal of Fish Biology* 46:47–69.
- VILLARROEL, P. R. 1994. Structure of the fish communities of Raya lagoon, Margarita Island, Venezuela. *Ciencias Marinas* 20:1–16.
- WEINSTEIN, M. P., S. L. WEISS, AND M. F. WALTERS. 1980. Multiple determinants of community structure in shallow marsh habitats, Cape Fear River estuary, North Carolina. *Marine Biology* 58:227–243.
- YÁÑEZ-ARANCIBIA, A., F. AMEZCUA-LINARES, AND J. W. DAY. 1980. Fish community structure and function in Terminos Lagoon, a tropical estuary in the Southern Gulf of México, p. 465–482. In V. Kennedy (ed.), *Estuarine Perspectives*. Academic Press, New York.
- YÁÑEZ-ARANCIBIA, A. AND A. L. LARA-DOMÍNGUEZ. 1983. Dinámica ambiental de la boca de estero pargo e estructura de sus comunidades de peces en cambios estacionales y ciclos de 24 horas (Laguna de Términos, sur del Golfo de México). *Annal del Institut de Ciències del Mar y Limnologia da Universidad Autónoma de México* 10:85–116.
- ZAR, J. H. 1984. *Biostatistical Analysis*. Prentice-Hall, Englewood Cliffs, California.

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