ECOLOGY, COMMUNITY STRUCTURE AND EVALUATION OF TROPICAL DEMERSAL FISHES IN THE SOUTHERN GULF OF MEXICO*

by

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Résumé

De juin 1978 à mars 1982, une étude sur les poissons démersaux a été faite sur le banc de Campeche, près de la Lagune de Terminos au Mexique. Au total 53.508 poissons de 152 espèces ont été pris en six sorties. Un ensemble d'analyses basées sur (les paramètres d'environnement ont permis d'identifier deux types d'habitats. La zone A est caractérisée par l'influence estuarienne, la zone B par les aspects typiquement marins. A partir de ces données ont été étudiés les similarités et les différences entre les poissons des deux habitats, la diversité, l'abondance et la distribution de ces poissons.

Introduction

Campeche Sound in the southern Gulf of Mexico is being intensively studied because of 1) a high diversity of species and well defined habitats; 2) its poorly known fish resources; 3) ils relationship with adjacent estuarine systems (Terminos Lagoon); 4) the industrial expansion in the region, principally the oil industry; and 5) because it has not yet reached critical levels of pollution.

The main goals of this study were: to establish diversity, abundance and distribution of demersal fish and to define probable patterns of variation in space and lime with respect to significant environmental parameters; to characterize demersal fish communities by examining correlations with habitat characteristics; to define species related to adjacent estuarine systems; and to comment on the fishery potential of these resources in terms of diversity and catch volume in comparison to conventional shrimp fisheries in this area.

Previous studies of demersal fish of the region considered the patterns of diversity, distribution and abundance, as well as environ-

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meniul interpretations of the ecological system (Sanchez-Gil *et al.,* 1981; Yáñez-Arancibia and Sánchez-Gil 1983). Those paper adressed the question of mechanisms of interactions between Campeche Sound and the adjacent estuarine systems. Yáñez-Arancibia *et al.* (1981, 1982) presented the first results on the estrucure and funcion of fish communities. A preliminary abstrai of this research was published bv Yáñ-Arancibia *et al.* (1983a).

Background

A number of published studies have adressed fish ecology in tidal inlets associated with the continental shelf or estuarine systems (Simmons and Hoese, 1959; Copeland, 1965; Hoese *ei al.,* 1968; Kind, 1971; Sabins and Truesdale, 1974; Darnell and Soniai, 197í»; Bravo-Nuñez and Yáñez-Arancibia, 1979; Amezcua Linares and Yáñez-Arancibia, 198«; Yáñez-Arancibia *vi al.*, 1983b). Other researchers have been able to directly relate coastal physical-biological processes and production mechanisms to lagoon-estuarine influences. Copeland *et al.* (1974) found thal migrations of nekton in the lemperate zones were correlated with high productivity pulses. In later works, community parameters were correlated lo ecological parameters, such as: species diversity to variations of salinity and temperature (Livingston, 1970; Yáñez-Arancibia *et al.,* 1980, 1983b); abundance and number of species to variations of salinity (Heck, 1977); diversity and abundance lo depth and temperature (Oviatt and Nixon, 1973) and fish movements and migrations to depth and temperature (Ogren and Brusher, 1977).

The role of coastal systems in determining the community composition and fishery productivity of some species on the adjacent shelf frequently reported. Moore *et al.* (1970) correlated demersal fish distribution off Louisiana and Texas to the influence of Mississippi Hiver. Furthermore, Sánchez-Gil *et al.* (1981) proposed that diversity, distribution and abundance of fish communities of Campeche Sound are highly influenced by bathymetry, sediments, and effects of Terminos Lagoon and other adjacent estuarine systems.

Stone (1976) associated the flow of the Mississippi River with volunus of commercial catches of репанні shrimps, and e lupeid fish and, Sulcliffe (1972) correlated the volumes of comercial catches to f Inviiti discharges of the Gulf of St. Lawrence. Turner (1977) reported that volumes of commercial catches of penaeids were correlated with latitude, areas of inttertidal vegetation in the coastal zone, and hydrologie conditions which control cimiate and fluvial discharge, and Stone *et al.* (1978) concluded thai neritic fisheries were related to intertidal marshlands. Yáñez-Arancibia *et al.* (1980) reported that fish production in Terminos Lagoon was higher in fluvial lagoon areas that in marine influenced areas. A number of other parameters considered influencing factors have received special attention from Gunter (.1967), Moore *et al.* (1970), Walne (1972), Darnell and Soniai (1979), Sánchez-Gil *et al.* (1981), Day *et al.* (1982). Deegan *et al.* (1982).

The results of this studies support the idea that there is a strong estuarine-continental shelf interaction and that a number of factors are important in infliuencing structure, distribution, diversity. abundance and production of the communities. These parameters seem to the bathymetry, sediments, water clarity, nutrients, salinity, temperature, latitude, adjacent estuarine systems involved, and local meteorology and climatology.

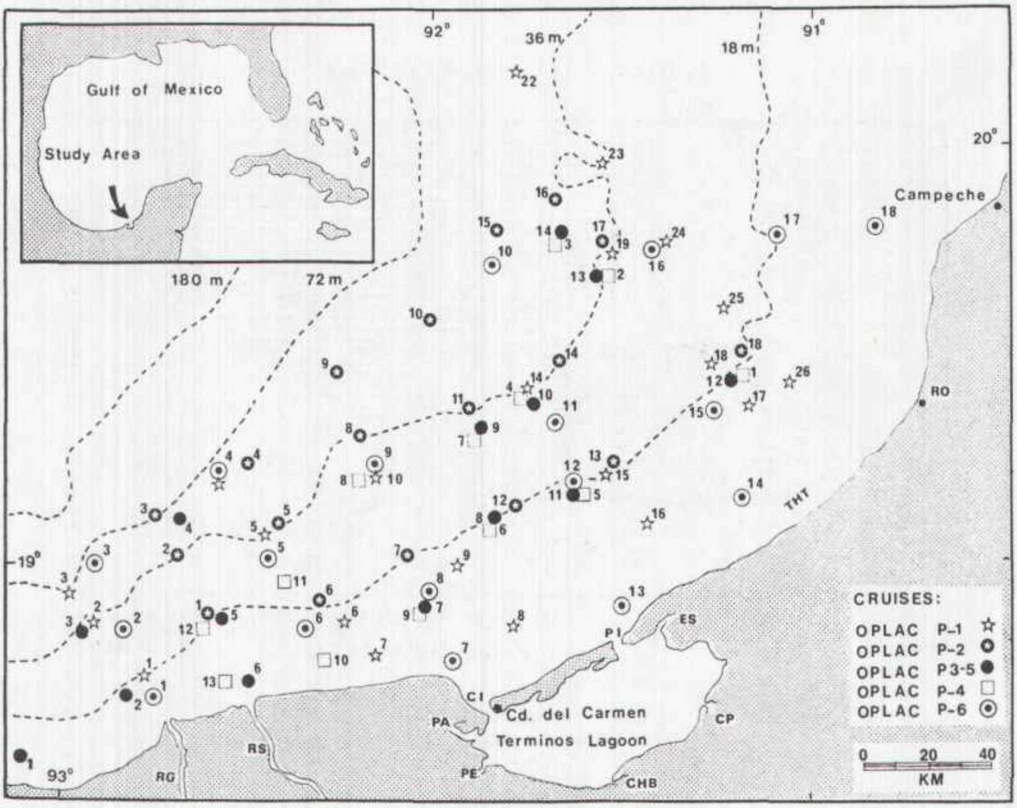

FIG. 1.

Campeche Sound off Terminos Lagoon. Principal physiographie and bathymetrie characteristics of the area are shown. Sampling stations of the six restearch cruises are also sliown : OPLAC/P-1 June 1978, OPLAC/ P-2 August 1980, OPLAC/P-3 and 5 November 1980 and October 1981, OPLAC/ P-4 July 1981. and OPLAC/P-6 March 1982 (OPLAC/P-3=Occanography off the continental shelf of Campeche/ Fishes).

Abbreviations : RG = Grijalva River,RS = San Pedro River, RO = Champoton River, CP = Candelaria Panlau river-lagoon system, CHB — Chumpam Balchacah river-lagoon system, PE = Palizada del Este river-lagoon system. PA = Pom Atasta river-lagoon system, ES = Estero Sabancuy. CI = El Carmen Inlet, PI = Puerto Real Inlet, THT — *Thalassia testudinum* area on the inner shelf.

Study area

Campeche Sound is part of the continental shelf west of Yucatan Peninsula, in the southern Gulf of Mexico (Fig. 1). It has an area of approximately 129,500 km^2 and a maximum depth of 200 m. The climate of the region is hot-subhumid, with a mean anmual temperature of about 26° C and annual precipitation of between 1.100 and 2,000 mm. Winds are predominantly, from the E-SE, with an annual average maximum speed of 8 knots, except in the «nortes» months of winter when winds blow from a N-NW direction at speeds of 50-72 knots. Three climatic seasons can be defined: the rainy season from June to September, the stormy winter season with nortes winds from October to March, and the dry season from February to May (Yáñez-Arancibia and Day, 1982: Yáñez-Arancibia

ECOLOGICAL SUBSYSTEMS

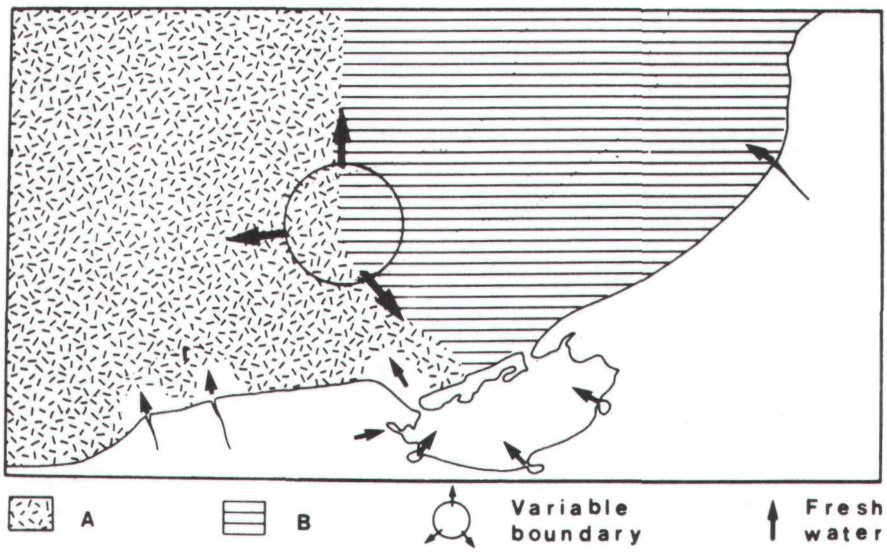

FIG. 2

Conceptual diagram of the distribution of the two habitats or ecological subsystem (Zones A and b), based on characteristics of sediments, pH, oxygen. sulinity, temperuture, and water transparency.

et al., 1983c). Off Terminos Lagoon lies the area of sedimentological transition between the deltaic (to the west) and carbonate provinces (to the east) (Fig. 1) of the Gulf of Mexico. The principal sediment sources are the Grijalva-Usumacinta, fluvial system and the carbonaie Yucatan shelf (Price. 1954; Lynch, 1954 and Gutierrez-Estrada, 1977).

Seasonal change» in coastal circulation are minor and water temperature remains between 25 and 29°C However, a semi-permanent horizontal physical-chemical gradient of salinity, pH, dissolved oxygen and organic materials is present, principally due to the supply of epicontinental and etsuarine waters. These processes, along with the distribution of sediments, determine the two habitats or ecological subsystems, herein called *Zones A and B* (Fig. 2) (Sánchez-Gil *et al*., 1981; Yáñez-Araneibia and Sánchez-Gil, 1983). *Zone A* is estuarine and riverine influenced with the folowing characteristics: turbid waters (transparency 7 to 42 p. 100), absence of benthic plants, silty clay sediments with to 10 to 60 p. 100 $CaCO_3$ and high organic content (> 10 p. 100), pH of 7.6 to 8.3, dissolved oxygen <4 ml/1, surface salinity of 32.2 to 37.0 p. 1000, bulloni salinity of 35.6 to 37.0 p. 1000. surface temperature of 22.8 to 27.7°C. and bottoni temperature of 23.3 to 28.0 °C. *Zone B* is a typical marine arca willi the following characteristics: clear waters (transparency 50 to 99 p. 100), sea grasses and macroalgae, sandy sediments with 70 to 90 p. 100 $CaCO_3$ and low organic content (<10 p. 100), pH of 7.7 to 8.9, dissolved oxygen >4 ml/1, surface and boltom salinity of 35.7 to 37.2 p. 1000, surface temperature of 26.1 to 28.8'C and bottom temperature of 24.2 to 28.1°C.

Material and methods

Fishes were sampled in Campeche Sound during six OPLAC/P cruises (Oceanography of Campeche Shelf) in June 1978, August and November 1980, July and October 1981, and March 1982. Duplicated measurements were made al each station (Fig. 1). A total number of Kit) trawl collection were made with a commercial shrimp net (9 m mouth opening while fishing; mesh size 1 1/4 inches), and fish catch and dala were processed according to criteria discussed by Stevenson (1982), Doubleday and Rivard (1981), Clark (1981), Parsons and Sandenulan (1981). During each collection, salinity, temperature, dissolved oxygen, vegetation, sediment and macroepifauna were determined. In the laboratory, fish were identified, counted, weighed and measured. The stale of gonadic maturity were determined according to Nikolsky's (1963) method. In order to eslimate the biomass of fish population, an index ol' average weight per individual was calculated (Yáñez-Arancibia *et al.,* 1983b).

Based upon fish size, stomach conteni and morphology of gul, monili and gill rakers, the trophic posilion ol' each species was determined (Yáñez-Arancibia, 1978 and *et* «í., 1980). Fish were placed in one ol' three trophic categories; 1) first-order consumers, such as plankton feeders (phylo- and zoo-), feeders on detritus and other vegetable remains, and omnivorous (plani detritus and small sized fauna); 2) second-order consumers, primarilly carnivorous fishes that also consume small amounts of plants and detritus; 3) third-order consumers that are exclusively carnivorous and feed only incidentally on plants and detritus.

Dominant species were determined through ecological indices, as well as frequency of species occurrence, biomass and numerical abundance. Shannon and Weaver's diversity index (H'n) (1963), which increases with the number of species (richness) and equitability of species abundance (evenness), was used.

Separate ratios used lo evaluated richness and evenness were also calculated since diversity components may behave differently with respect to certain factors. For the species richness component, Margalef's D function (1969) was chosen. Pielou's J'index (1966) was used to determine species evenness. All calculations were based on natural logarithms.

Fish abundance was calculate in terms of number ol' individuals, density (individuals/m^2), and biomass (g/m^2). Whilin's H'w function

(1968) which is a modification of Shannon and Weaver's (1963) expression. was also calculated as a comparative complementary index in order to have an idea of biomass distribution.

Cluster analysis was used lo construct dendograms to indicate habitats types fish assemblages, according to lhe criteria discussed by Horn and Allen (1976), Warburton (1978), Livingston (1978). Daniels (1979). Yáñez-Arancibia *et at.* (1980. 1982, 1983b), Sánchez-Gil *et al.* (1981), and Vargas Maldonado *et al.* (1981). Clustering is a descriptive technique that objelively groups data in similar units based upon shared characteristics. Simple matching coefficient method were employed (Davies, 1971; Snealh and Sokal, 1973). Results are presented in three different kinds of dendograms: a) assemblages of stations clustered tising their environmental characteristics; b) assemblages of species clustered using presence or absence of species al sampling stations; c) assemblages of stations clustered using composition of fish species. This allowed quantification of fish-habitat conciai ions.

An affinity ratio based upon common fish populations obtained by comparing sampling areas (Amezcua Linares and Yáñez-Arancibia, 1980) also was utilized.

Official governmental statistics (Secretaria de Pesca, Direccion General de Planeación, Informática y Estadística; 1977-1981) for the shrimp fishery of Campeche Sound were used to estimate biomass of demersal fish (ground fish or by-catch) based on the cruise data. This methodology and results were interpreted in relation to accuracy and statistical goodness by Stevenson (1982), Parsons and Sandeman (1981).

RESULTS

Distribution, Abundance and Diversity

During the six cruises, 53,508 specimens of 152 species, 102 genera and 55 families (Table 1) were collected. Apparently, fish population distribution was highly correlated to seasonal environmental characteristics. The presence of two species groups associated with the two ecological subsystems in the Sound (*Zones A* and *B)* (Yáñez-Arancibia *et al.,* 1981, 1982) was generally observed.

Total biomass ranged from 0.03 g/m^2 to .3.74 g/m^2 at the sampling stations, willi a mean standing crop ol' 1.1 g/m^2 (11 Kg/ha) for *Zone A,* and 0.8 g/m^2 (8 Kg/ha) for *Zone B.* Biomass distribution displayed a regular spatial pattern during the seasons analyzed (Fig. 3). Generally, the highest biomass was close to the coast and the lowest from the 10 m isobath to the deepest zone.

During summer (1980) and fall (1981), biomass distribution shifted towards the NE portion ol' *Zone B* regardless of water depth. Likewise, the biomass distribution pattern during summer (1978)

TABLE 1

Distribution of species in the ecological subsystems of Campeche Sound Zone A and Zone B). (TC) Trophie categories. 1°, 2°, 3° refer to first, second and third-order consumers, respectively.
* Dominat species by frequency, weight and Individuals number.

	Fish species	Zone A	Zone B	No.	Tc
1	*Carcharhinus remotus*		×	1	3°
2	*Carcharhinus sp.*	×		1	3°
3	*Sphyrna tiburo*	×	×	25	3°
4	*Rhinobatus lentiginosus*		×	16	3°
5	*Raja texana*	×	×	30	3°
6	*Aetobatus narinari*	×		3	3°
7	*Dasyatis sabina*	×	×	16	3°
8	*Rhinoptera bonasus*	×		4	3°
9	*Urolophus jamaicensis*		×	6	3°
10	*Narcine brasiliensis*	×	×	22	3°
11	*Hildebrandia flava*	×	×	7	2°-3°
12	*Hoplunnis diomedianus*	×	×	72	2°-3°
13	*Ophichthus puncticeps*	×		1	2°
*14	*Harengula jaguana*	×	×	2265	1°
*15	*Opisthonema oglinum*	×	×	820	1°
*16	*Sardinella aurita*	×	×	252	1°
17	*Anchoa lamprotaenia*	×	×	201	1°
18	*Anchoa pectoralis*	×		50	1°
19	*Anchoa mitchilli mitchilli*	×		11	1°
20	*Anchoa hepsetus hepsetus*	×	×	114	1°
*21	*Cetengraulis edentulus*	×	×	2022	1°
*22	*Synodus foetens*	×	×	1499	3°
23	*Synodus intermedius*		×	2	3°
24	*Saurida brasiliensis*	×	×	73	2°
*25	*Arius felis*	×	×	889	2°-3°
*26	*Bagre marinus*	×	×	183	2°-3°
*27	*Porichthys porosissimus*	×	×	285	2°
28	*Antennarius ocellatus*	×	×	30	2°
29	*Antennarius scaber*	×	×	56	2°
30	*Ogcocephalus vespertilio*		×	6	2°
31	*Ogcocephalus radiatus*	×	×	6	2°
32	*Halieutichthys aculeatus*	×		9	2°
33	*Bregmaceros atlanticus*	×		1	2°
34	*Lepophidium brevibarbe*	×	×	57	2°
35	*Lepophidium marmoratum*	×	×	10	2°
36	*Brotula barbata*	×		3	2°
37	*Fistularia petimba*	×	×	7	2°
38	*Hipoccampus hudsonius*		×	2	2°
39	*Scorpaena calcarata*	×	×	325	2°
40	*Scorpaena dispar*	×		1	2°
41	*Scorpaena brasiliensis*	×	×	13	2°
42	*Scorpaena plumieri*	×	×	5	2°
43	*Prionotus tribulus*	×		4	2°-3°
44	*Prionotus punctatus/beani*	×	×	1312	2°-3°
45	*Prionotus carolinus*	×		17	3°
46	*Prionotus scitulus*		×	43	2°
47	*Prionotus stearnsi*	×	×	143	2°-3°
48	*Prionotus roseus*	×		18	2°-3°
49	*Prionotus ophryas*	×	×	31	2°-3°
50	*Prionotus sp.*	×		79	3°
51	*Prionotus cf. evolans*		×	4	2°-3°

	Fish species	Zone A	Zone B	No.	Tc
52	*Bellator militaris*		×	30	3°
53	*Peristedion gracile*	×		1	2°
54	*Dactylopterus volitans*	×	×	113	3°
55	*Centropomus undecimalis*	×		13	3°
56	*Epinephelus guttatus*	×		1	3°
57	*Epinephelus niveatus*	×		2	3°
58	*Epinephelus nigritus*		×	1	3°
59	*Epinephelus morio*		×	1	3°
60	*Epinephelus sp.*		×	2	3°
*61	*Diplectrum radiale*	×	×	645	3°
62	*Diplectrum formosum*	×	×	285	3°
*63	*Serranus atrobranchus*	×	×	903	2°
64	*Centropristis ocyurus*		×	1	2°
65	*Rhomboplites aurorubens*	×	×	76	3°
66	*Pristipomoides macrophthalmus*	×	×	127	3°
*67	*Priacanthus arenatus*	×	×	1324	3°
68	*Pristigenys alta*	×	×	8	2°
69	*Caulolatilus intermedius*	×		4	2°
70	*Echeneis naucrates*		×	34	2°
71	*Caranx latus*	×	×	10	2°
72	*Caranx hippos*	×		8	2°
73	*Caranx crysos*	×	×	41	2°
*74	*Chloroscombrus chrysurus*	×	×	5971	2°
*75	*Trachurus lathami*	×	×	5541	2°
76	*Selene vomer*	×	×	67	2°
77	*Decapterus punctatus*	×		1	1°
*78	*Selene setapinnis*	×	×	759	2°
79	*Selar crumenophthalmus*	×	×	10	2°
*80	*Lutjanus synagris*	×	×	175	3°
81	*Lutjanus campechanus*	×	×	121	3°
82	*Lutjanus cyanopterus*		×	1	3°
*83	*Eucinostomus gula*	×	×	3288	1°
*84	*Eucinostomus argenteus*	×	×	1104	1°
85	*Eucinostomus melanopterus*	×	×	34	1°
86	*Diapterus rhombeus*	×	×	226	1°
87	*Diapterus auratus*	×		48	1°
88	*Orthopristis chrysopterus*		×	33	2°
*89	*Haemulon aurolineatum*	×	×	580	2°
90	*Haemulon plumieri*		×	33	2°
91	*Anisotremus virginicus*		×	10	2°
92	*Conodon nobilis*	×		5	2°
*93	*Stenostomus caprinus*	×	×	1818	2°
94	*Archosargus rhomboidalis*	×	×	40	2°
95	*Archosargus probatocephalus*		×	4	2°
96	*Lagodon rhomboides*		×	41	2°
97	*Calamus penna*		×	54	2°
*98	*Cynoscion arenarius*	×	×	423	2°
*99	*Cynoscion nothus*	×	×	4214	2°
100	*Bairdiella chrysoura*	×		1	2°
101	*Menticirrhus americanus*	×	×	57	2°
102	*Menticirrhus saxatilis*	×	×	42	2°
*103	*Stellifer colonensis/lanceolatus*	×		1142	2°
104	*Equetus lanceolatus*		×	7	2°
105	*Equetus acuminatus*	×	×	10	2°
106	*Micropogonias undulatus*	×	×	77	2°
107	*Umbrina broussoneti*	×		1	2°

	Fish species	Zone A	Zone B	No.	Tc
108	*Larimus fasciatus*	×		1	2°
*109	*Upeneus parvus*	×	×	895	2°
110	*Chaetodipterus faber*	×	×	58	1°
111	*Chaetodon ocellatus*		×	14	1°
112	*Pomacanthus arcuatus*		×	3	1°
113	*Sphyraena guachancho*	×	×	56	3°
*114	*Polydactylus octonemus*	×	×	854	2°
115	*Lachnolaimus maximus*		×	2	2°
116	*Nicholsina usta*	×	×	39	2°
117	*Bollmannia boqueronensis*	×	×	96	2°
*118	*Trichiurus lepturus*	×	×	2956	2°
119	*Scomberomorus maculatus*	×		4	3°
120	*Scomber japonicus*	×	×	24	2°
121	*Peprilus triacanthus*	×	×	87	1°
122	*Peprilus paru*	×	×	72	1°
*123	*Syacium gunteri*	×	×	5732	2°
124	*Syacium micrurum*	×	×	11	2°
125	*Syacium papillosum*	×	×	27	2°
126	*Ancylopsetta quadrocellata*	×	×	113	3°
127	*Ancylopsetta dilecta*	×		1	2°-3°
128	*Cyclopsetta fimbr.ata*	×	×	21	2°-3°
129	*Cyclopsetta chittendeni*	×	×	69	2°-3°
130	*Trichopsetta ventralis*	×		26	3°
131	*Engyophrys sentus*	×	×	7	2°
*132	*Citharichthys spilopterus*	×	×	273	3°
133	*Ctharichthys macrops*		×	55	3°
*134	*Etropus crossotus*	×	×	374	3°
135	*Bothus robinsi*	×	×	77	2°-3°
*136	*Symphurus plagiusa*	×	×	219	2°
137	*Gymnachirus nudus*	×	×	49	2°
138	*Gymnachirus sp.*	×		1	2°
139	*Achirus lineatus*	×	×	5	2°
140	*Trinectes maculatus*	×	×	7	2°
141	*Stephanolepis hispidus*		×	18	2°
142	*Aluterus schoepfi*	×	×	33	2°
143	*Aluterus monoceros*		×	1	2°
144	*Aluterus heudeloti*		×	3	2°
145	*Balistes capriscus*	×	×	124	2°
146	*Acanthostracion quadricornis*		×	162	2°
147	*Sphoeroides greeleyi*	×	×	63	2°-3°
148	*Sphoeroides nephelus*		×	12	2°
149	*Sphoeroides dorsalis*	×	×	85	2°
*150	*Lagocephalus laevigatus*	×	×	199	2°-3°
151	*Chilomycterus schoepfi*	×	×	12	2°-3°

described a gradient for *Zone A* appeared otherwise (Fig. 3). Spatial diversity distribution (H'n) showed range of 0,08 to 2.83 at the different sampling stations, and averaged *'.\.2* for *Zone A* and 3.3 for *Zone B*. The diversity pattern was complicated (Fig. 4). Generally, diversity was lowest near the coast in both zones, and highest near the boundary of *Zone A* and *B* and in deeper water. However, during Rummer and fall (1980) a completely different paltern was found: during summer, highest diversity values were limited to *Zone A* and lowest ones to *Zone B;* in fall, the opposite was true, i.e., lowest values of distribution predominated in *Zone A* (Fig. 4).

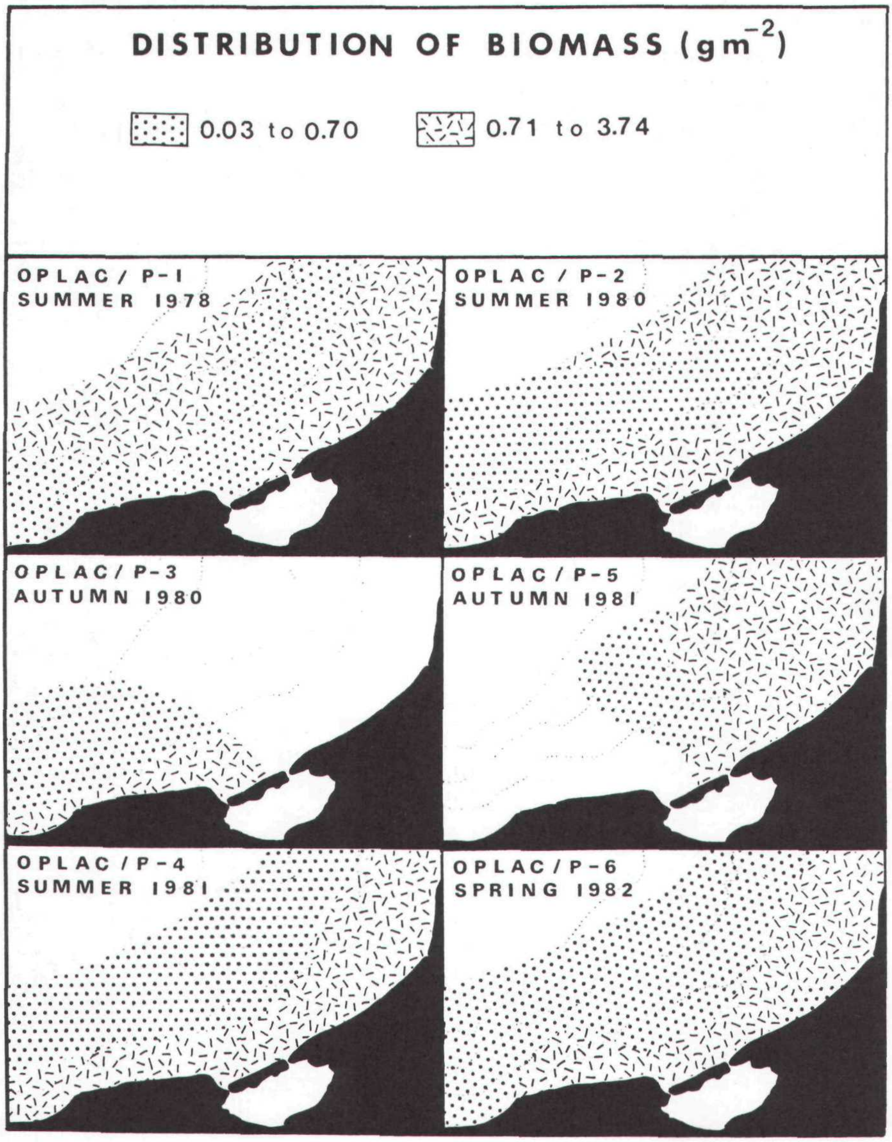

FIG. 3

Spatial distribution of biomass (g/m^2) *of* demersal fish in Campechc Sound during different climatic seasons. Ranges are bused on average bioinass of total fish capture.

Community Parameters

There were also seasonal patterns in the community parameters for the two subsystems (Fig. 5). Similar patterns Cor density and bioinass were observed; in *Zone A* the highest values were during the dry season, intermediate values during the rainy season, and lowest ones during stormy winter season («norles»). In *Zone Ii* the highest values were observed during the «norles» season: the lowest fish density was found in the dry season and the lowest biomass was found in the rainy season.

Changes in the H'n diversity index were not clearly associated with any season of the year or area, since values remained within a narrow range. Values of this parameter were highly influenced by the presence of those species that were dominant during the whole year, both in *Zone A* and in *Zon B.* The evenness index did not show a defined seasonal or spatial pattern.

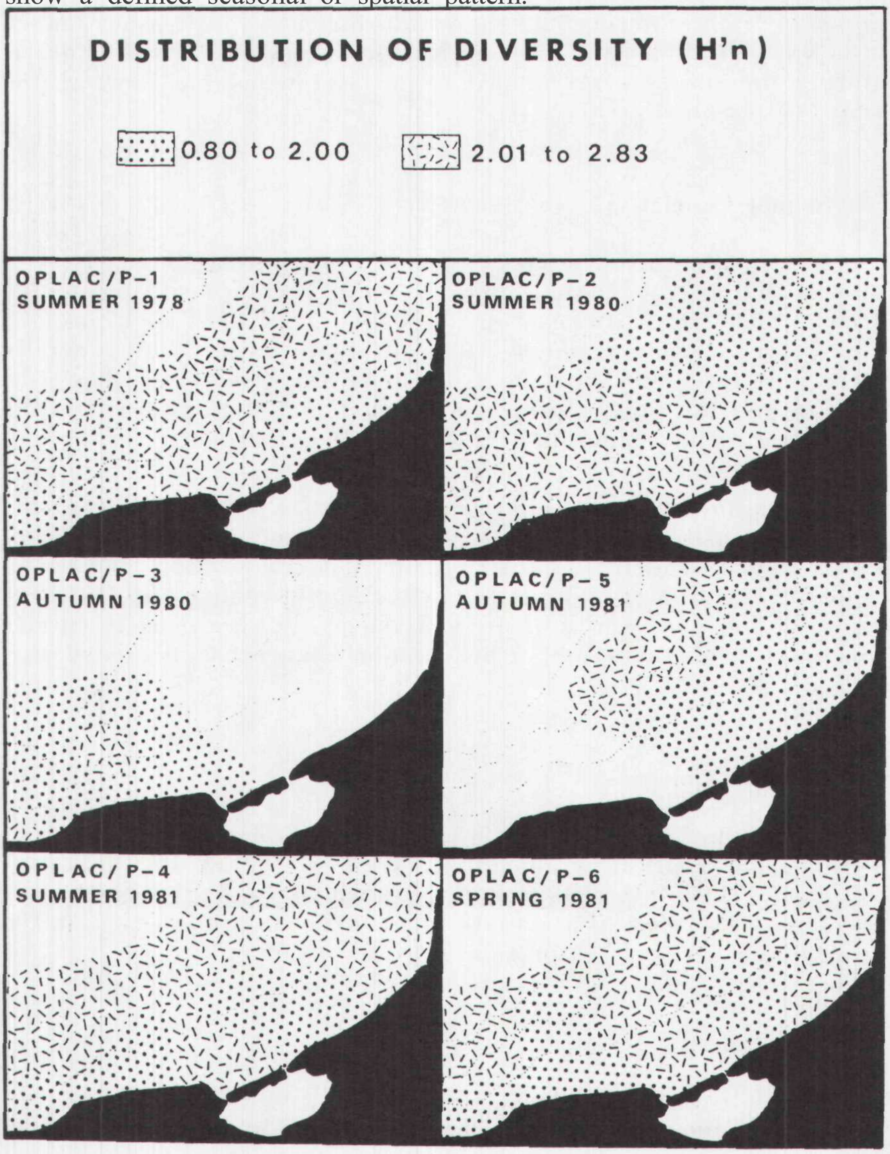

FIG. 4

Diversity (H'n) of demersal fish in Campeche Sound during different climatic seasons. **Ranges** are hased on average diversity of total fish capture.

Generally, the mean number of species changed only slightly during the year. In *Zone li,* the highest values for this parameter occurred during the « nortes » season, with the lowest ones during the rainy season. There was no apparent seasonal pattern of number of species in *Zone A* (Fig. 5).

Values for the richness index showed high seasonal and spatial variation. The highest l'or Zone A was during the «nortes» season and the lowest was during the dry season. On the other hand, the highest values in *Zone B* were during the rainy season and the lowest were during the «nortes» season. The most evident seasonal differences in richness and eveness were during the «nortes» season. For *Zone A* the intermediale values (during the rainy season) tended to he as high as those of the «nortes» season, while those of *Zone It* (during the dry season) tended to he as low as the ones of the «nortes» season (Fig. 5).

Fish-Habitat Correlation

Fish-habitat affinity analysis in the Campeche Sound system showed that fish population were generally highly correlated to the principal habitats of the continental shelf i.e., *Zone A* and *Zone B).* There were variations among the different cruises, hut generally there were three clusters; one associated with *Zone A,* another with *Zone B,* and the third representing transitional stations between the two zones. The composition of the clusters, the degree on affinity and the common species are indicated in Table 2.

Based on the analysis of common species between subsystems and the transitional points an affinity percentage was calculated, which indicated that Ihe distribution and composition of species (Table 2, Fig. 6) were related to environmental changes: a) different values of the species affinity by subsystems, b) variations in species common to both zones, and c) distribution changes at the transitional stations.

Ichthyotrophic Categories

Ichlhyothrophic categories were similar in *Zone A* and *Zone B*. Second-order consumers amounted to 53 p. the total fish collected. Third-order consumers represented 35 p. 100 in *Zone A* and 37 p. 100 in *Zone* ***li*** and first-order consumers comprised 12 p. 100 in ***Zone A*** and **11 p. 100 in *Zone B*** Table **1).**

Dominant Species

Thirty-two species (21 p. 100) oul of a total of 132, made up 93 p. 100 of the numbers and 7!) p. 100 of weight of the total calch These species were broadly distributed, therefore we considered them tipical and/or dominant in the community. Bight of these species were sampled during all climatic seasons (Table 1): *Haren-*

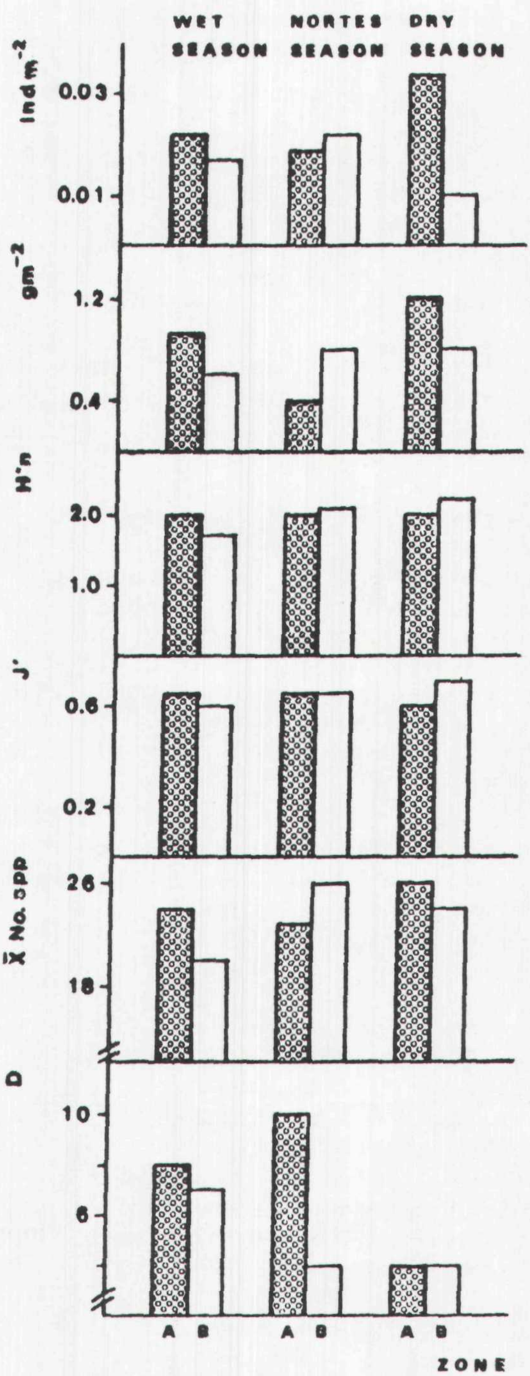

FIG. 5

Distribution of fish density (individuals/m^2), biomass (g/m^2), diversity indices (H'n, J', D), and average species number ($\bar{x}$ No. spp.), in the two zones of the Campeche Sound during three climatic seasons : rainy season (June to September), « nortes » season (October to January), and dry season (February to May).

TABLE 2
Fish-habitat correlation, species composition and affinities

	Species Affinity (%)*			Representative Common Selected Species**								
Cruises OPLAC	Zone A	Zone B	Zone T	Between Zones A and B N° sp.	Aff%	Species	Between Zones T and A N° sp.	Aff%	Species	Between Zones T and B N° sp.	Aff%	Species
P-1	70.0	65.0	41.0	43	63.8	(47), (79)	36	69.6	(21), (29)	33	65.6	(24), (64)
P-2	87.5	58.7	55.0	37	67.8	(11), (25)	44	81.4	(27), (32)	27	59.4	
***P 3-5	83.0	66.0	47.0	51	69.4	(9), (50)	47	78.3	(67), (88)	36	65.6	
P-4	73.3	78.6	61.3	39	68.5	(28), (103)	42	83.8	(87), (119)	41	79.3	(16)
P-6	67.5	77.7	42.5	49	62.7	(3), (7)	37	65.6		46	77.4	(117), (132)

Zone T = Transitional zone
Aff% = Affinity percentage
* Calculation based on the total catch by Cruise.
** Each number represent correlated species in Table 1.
*** Values of OPLAC/P-3 and OPLAC/P-5 were combined because they were carry out in the same season of the year.

gula fagliano, Synodus foetens, Chloroscombrus chrysurus, Eucinostomus gula, Diplectrum radiale, Arius felis, Cynoscion nothus and *Syacium gunteri.* All these species, except *Syacium gynteri, depend* on estuarine conditions and have been found in Terminos Lagoon. There loo, they seem to be dominant in the community (Váñez-Arancibia *ci* ***al.,*** 1982).

DISCUSSION

Tropical waters shelter a higher number of species than the waters of temperate zones. At least 152 species make up the ichthyological fauna of the continental shelf of Campeche Sound; 32 species are dominant in the community (Tables 1, 2).

Diversity values are lowest in areas where highest environmental heterogeneity exists, where the inner shelft has strong influence of coastal processes. These same areas, however, have the highest biomass, meaning that few species account for most of the biomass. This may be response to both the high productivity and environmental stress prevailing in these areas; an increase in population diversity and a decrease in biomass within stable environments can be observed offshore and in deeper waters. On (he other hand, in *Zone li* there was a direct relationship between diversity and biomass, perhaps as a response to a stable environment and to the high productivity which is characteristic of areas with ***Thalassia testudia um*** beds, in **the** inner shelf of *Zone B.*

Biomass increase or diminution can be related to several factors. The high values that appear toward the coastal regions of *Zone A* near Puerto Heal Inlet (Terminos Lagoon) seem to be due to a few large specimens that enter the lagoon to perform specific biological functions such as feeding, spawing and nursery. The high values observed toward **the** exit of the lagoon (Carmen Inlet) may result from small fishes occurring in great numbers, leaving the lagoon-estuarine system to enter the sea. Similar observations were published by Bravo-Nuñez and Yáñez-Araneibia (1979), Yáñez-Arancibia and Day (1982), Day and Váñez-Arancibia (1982) and Alvarez Guillén el *al.* 11985).

A comparative analysis of the different community parameters **for** each subsystem during all climatic seasons showed that highest values of density and biomass appeared during the dry season and lowest ones during the «nortes» season. This pattern systems discharges. Váñez-Arancibia and Day (11)82), and Day *et al.* (1983) mentioned that nutrient levels in the estilarme system of the Terminos Lagoon are high during seasons of river maximum discharge (at the end of **the** rainy season and starting of the «nortes» season). Váñez-Arancibia *el al.* (1982) reported highest biomass values, number of species and abundance of juveniles in Terminos Lagoon during the same period.

Species richness was highest towards the end of the rainy season and the begining of «nortes». Apparently this seasonal trend is caused by characteristic environmental heterogeneity of this period; it is most clearly noticiable in *Zone A,* which gels the highest fluvial-lagoon influence. There were slight variations of the diversity and evenness indices, principally due to the presence of large numbers of the dominant species. Diversity indices for number (H'n) and biomass (H'w) were somewhat higher than values of other similar areas in Central and North America (Table 3). The magnitude and correlation between diversities, outlined in Table3 seem to be dependent on latitude, meteorological conditions, ecological-coastal processes, habitat diversity and productivity.

Our analysis indicates that the dominant species belonged to two groups: l) those species that were found year round, and 2) those species that occurred in only one or two seasons of Ihe year. Spatial analysis of the distribution of dominant species showed that a great similarity of frequency of occurrence of those species exists in each of the two subsystems. A spatial succession by the dominant species cannot yet be established however, seasonal variations associated with numerical abundance and biomass were confirmed. This phenomenon was reflected in the presence of biomass distribution and diversity gradients, which were observed in each of the seasons we sampled. On the other hand, almost all species we collected have been reported to be estuarine dependent (Moore et al., 1970; Chittenden and McEachran, 1976). For instance, 75 p. 100 of the 32 dominant species of the continental shelf have been collected in Termino» Lagoon, two of them being dominant in this esluarine system (Yáñez-Arancibia ***fi al.,*** 1982). This fact suggesls the existence of migration and colonization patterns, as well as various interrelations between fish of the continental shelf and this esluarine system. Bravo-Nuñez and Yáñcz-Arancibia (1879) and Yáñcz-Araneibia ***et* al.** (1980, 1982, 1983b presented evidence of seasonal migrations of species that are esluarine dependent. Ecological importance of Terminos Lagoon lo Campeche Sound production is indicated by Day and Yáñez-Arancibia (1982).

The results indicateli that two distinctive groups of fish were associated with *Zones A* and B (Fig. 6). These groups were directly associated to environmental characteristics of the two zones. However, because of seasonal variations, Hiere were seasonal changes in the two groups resulting in a transition area between *Zone A* and *Zone B. th*e limits of which fluctuate with season (Yáñez-Arancibia ***ei*** *al.,* 1982 and 1983b). Fish populations of *Zone A* were characterized by specimens that are generally elongated, flattened, and silvery; this may be due to the turbid nature of the area. The opposite is true for *Zone li,* which shelters fish of different forms and colors, associated with quie and highly transparent waters.

Among the dominant species (Table 1), some have been studied in the Caribbean area (Erdman, 1977). Erdman provided information concerning reproduction of 336 species. Reproductive stales, as defined by Erdman, of some species in Campeche Sound are listed in Table 4. The tropical characteristics of the southern Gulf of Mexico enables us to assume that the reproductive patterns listed in Table 4

TABLE 3

Diversity values of fish communities in selected coastal areas of North America

H'n	H'w	Locality	References
2.2-3.0	—	Block Island Sound, Massachusetts	Merrimand and Warfel (1948)
2.6	—	Long Island Sound, Connecticut	Richards (1963)
2.1	—	Aransas Bay, Texas	Miller (1965)
0.9-2.1	1.5-2.0	Aransas Bay, Texas	Hoese et al. (1968)
1.2-2.3	2.7	Galveston Bay, Texas	Bechtel and Copeland (1970)
1.5	—	Corpus Christi Bay, Texas	Bechtel and Copeland (1970)
1.3	—	Redfish Bay, Texas	Bechtel and Copeland (1970)
1.3-1.7	—	Sapelo and St. Catherine Sound, Georgia	Dahlberg and Odum (1970)
0.4-1.7	—	Patuxen Estuary, Chesapeake Bay, Virginia	McErlean *et al.* (1973)
2.2-2.8	—	Golfo de Nicoya, Costa Rica	Leon (1972)
2.0	1.9	Cape Fear, North Carolina	Copeland and Birkhead (1972)
2.5-2.7	—	Narangansett Bay, Rhode Island	Oviatt and Nixon (1973)
0.7-1.4	0.2-5.5	Albemarle Sound, North Carolina	Hester and Copeland (1975)
1.8-3.7	—	Wakulla and St. Marks, Florida	Subrahmanyan and Drake (1975)
0.2-1.2	0.5-1.3	Bogue Sound, North Carolina	Adams (1976)
1.1	—	Apalachicola Bay, Florida	Livingston (1976)
0.2-2.7	—	*Long Island Sound, Connecticut*	*Hillman et al.* (1977)
1.3-2.1	—	Aransas Bay, Texas	Moore (1978)
1.0-3.5	1.1-2.5	Zone A, Campeche Sound, Mexico	Sanchez-Gil *et al.* (1981)
0.8-2.3	1.1-2.0	Zone B, Campeche Sound, Mexico	Sanchez-Gil *et al.* (1981)
0.8-2.4	1.1-2.5	Total Area, Campeche Sound, Mexico	Sanchez-Gil *et al.* (1981)
3.2	3.4	Zone A, Campeche Sound, Mexico	(this study)
3.2	3.4	Zone B, Campeche Sound, Mexico	(this study)

are similar to those exhibited by species in the northern part of the Caribbean Sea. The environmental conditions of Campeehe Sound (Yanez-Araneibia and Sanehez-Gil, 1983 and Terminos Lagoon (Yañez-Arancibia et *al. 1983*c) influence productivity and species

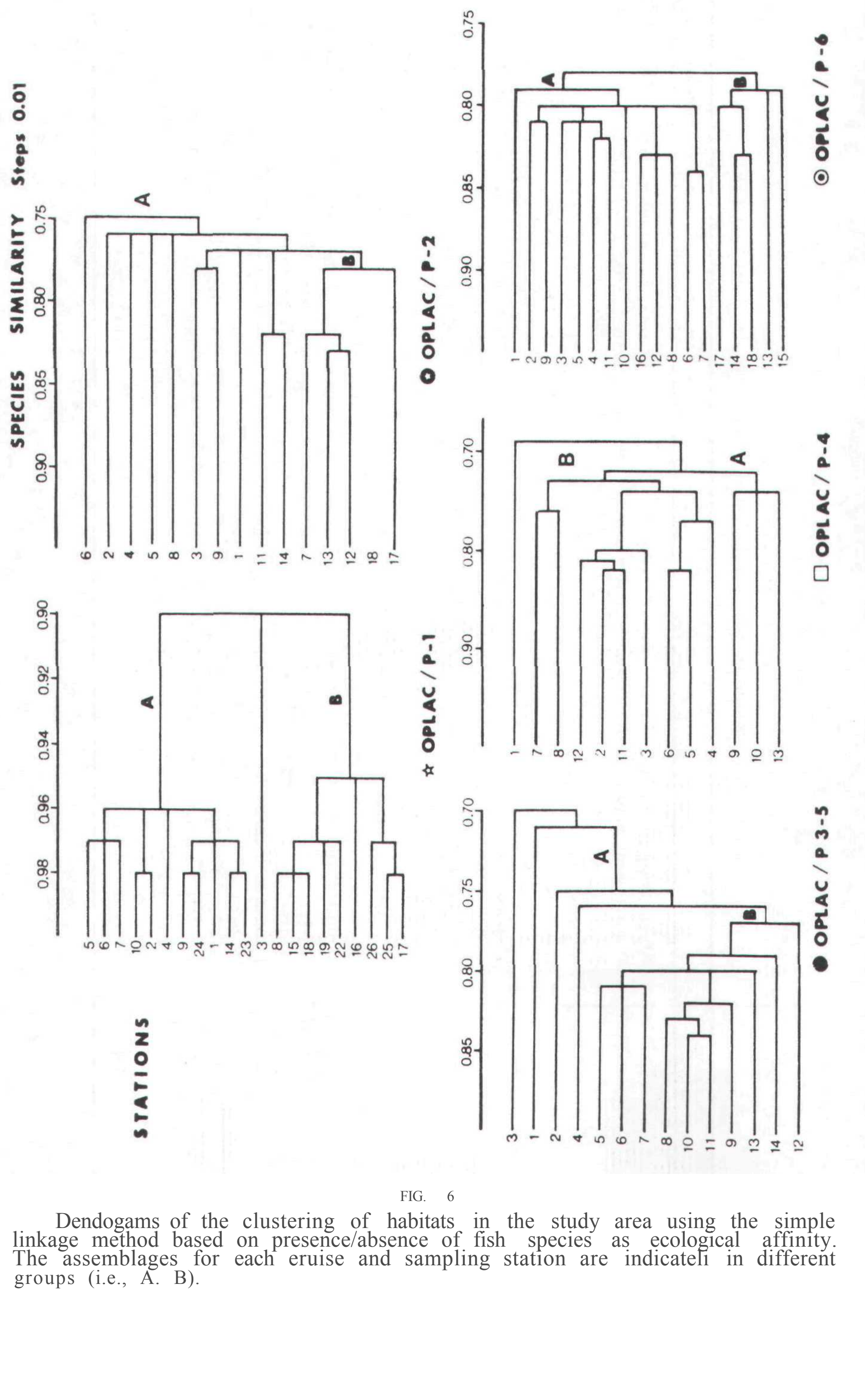

FIG. 6

Dendogams of the clustering of habitats in the study area using the simple linkage method based on presence/absence of fish species as ecological affinity. The assemblages for each eruise and sampling station are indicateli in different groups (i.e., A. B).

TABLE 4

Spawning seasnos of selected dominant species (see Table 1) from Campeche Sound

Fishs pecies	Months					
	J-F	M-A	M-J	J-A	S-O	N-D
Harengula jaguana		f	F			
Opisthonema oglinum			M R			
Cetengraulis edentulus						
Diplectrum radiale	f	F				
Priacanthus arenatus			r		F	f
Selene setapinnis	f	M			j	
Chloroscombrus chrysurus	f	j		M,F		
Eucinostomus gula						
Eucinostomus argenteus				f		
Haemulon aurolineatum	F R	R M	F	R F		
Upeneus parvus						
Trichiurus lepturus	M,f	f				
Lagocephalus laevigatus		m	j			

Code symbols used : *V* — ovaries with ripe ova, usually transparent and colorless: f = ovaries with sub-ripe ova, usually yellow or opaque white and distinguishable without magnification; M = ripe testes with loose or running milt; R = both males and females with ripe gonads; m = sub-ripe enlarged testes with slight or no loose milt: j = juvenile fish.

biology. Further studies are required to substantiate interrelations of control mechanisms (Table 6) and reproductive strategies (Table 4). Apart from fish specimens already listed in Tables 1 and 4, some other species contribute greatly to the ecological understanding of the system; thus, in further studies, special attention should be paid to them. Particularly some dominant species in the tropical West Atlantic have reproductive activities during the entire year (Table 4).

Fisheries research in the tropics is complicated because of: 1) the large number of species present in a community, and 2) the diffi-

TABLE 5)

by-catch : shrimp weight relationships in the Campeche Sound.

Cruises	Weight proportion			
	Fishes (F)	Shrimps (S)	Crabs (C)	Others* (O)
OPLAC/P-1	11	1	1	*2*
OP'L.AC/P-2	8	1	1	1
OPLAC/P-3	10	3	*2*	1
OPLAC/P-4	21	3	3	1
OPLAC/P-5	30	1	2	0
OPLAC/P-6	57	4	1	1
Total average:	*23*		2	1

Macroinvertebrates (squids, gastropods, bivalves, echinoderms, stomatopods. sponges, other decapods).

TABLE 6

Diagram of the space-time distribution analysis of the 152 fish species, showing interactions between fish assemblages in Campeche Sound-Terminos Lagoon : I. Fish populations association distributed exclusively in Zone A. II. Populations association distributed in Zone A as well as in Zone B. III. Populations association distributed exclusively in Zone B. IV. Exclusive populations of Zone A that are estuarine dependent (Terminos Lagoon). V. Populations association with common fish to the Zone A and Zone B and are estuarine dependent. VI. Exclusive populations of Zone B which are estuarine dependent.

ZONE A	CAMPECHE SOUND		ZONE B
I	II		III
Carcharhinus sp	*Sphyrna tiburo*	*Pristigenis altus*	*Carcharhinus remotus*
Aetobatus narinari	*Raja texana*	*Caranx crysos*	*Rhinobatus lentiginosus*
Rhinoptera bonasus	*Hildebrandia flava*	*Trachurus lathami*	*Synodus intermedius*
Ophictus puncticeps	*Hoplunnis diomedianus*	*Selene setapinnis*	*Ogcocephalus vespertilio*
Anchoa pectoralis	*Sardinella aurita*	*Selar crumenophthalmus*	*Prionotus cf. evolans*
Halieutichthys aculeatus	*Saurida brasiliensis*	*Lutjanus campechanus*	*Bellator militaris*
Bregmaceros atlanticus	*Antennarius scaber*	*Stenostomus caprinus*	*Epinephelus nigritus*
Bortula barbata	*Antennarius ocellatus*	*Upeneus parvus*	*Epinephelus itajara*
Scorpaena dispar	*Ogcocephalus radiatus*	*Sphyraena guachancho*	*Epinephelus sp.*
Prionotus roseus	*Lepophidium brevibarbe*	*Bollmania boqueronensis*	*Centropristes ocyurus*
Peristedion gracile	*Lepophidium marmoratum*	*Scomber japonicus*	*Lutjanus cyanopterus*
Epinephelus niveatus	*Fistularia petimba*	*Peprilus paru*	*Lagodon rhomboides*
Caulolatilus intermedius	*Scorpanea calcarata*	*Pepripulus triacanthus*	*Equetus lanceolatus*
Decapterus punctatus	*Scorpaena brasiliensis*	*Syacium gunteri*	*Citharichthys macrops*
Conodon nobilis	*Prionotus ophryas*	*Syacium micrurum*	*Aluterus monoceros*
Umbrina broussonetii	*Prionotus stearnsi*	*Syacium papillosum*	*Aluterus heudelotii*
Larimus fasciatus	*Serranus atrobranchus*	*Cyclopsetta fimbriata*	
Ancylopsetta dilecta	*Rhomboplites aurorubens*	*Cyclopsetta chittendeni*	
Trichopsetta ventralis	*Pristipomoides macrophtalmus*	*Engyophrys sentus*	
Gymnachirus sp.	*Priacanthus arenatus*	*Sphoeroides dorsalis*	

TERMINOS LAGOON

IV

Anchoa mitchilli
Prionotus tribulus
Prionotus carolinus
Prionotus sp.
Centropomus undecimalis
Epinephelus guttatus
Caranx hippos
Diapterus olisthostomus
Bairdiella chrysoura
Stellifer colonensis
Scomberomorus maculatus

V

Dasyatis sabina
Narcine brasiliensis
Harengula jaguana
Opisthonema oglinum
Anchoa hepsetus hepsetus
Anchoa lamprotaenia
Cetengraulis edentulus
Synodus foetens
Arius felis
Bagre marinus
Porichthys porosissimus
Scorpaena plumieri
Prionotus punctatus
Prionotus beanii
Dactylopterus volitans
Diplectrum radiale
Diplectrum formosum
Caranx latus
Chloroscombrus chrysurus
Selene vomer
Lutjanus synagris
Eucinostomus gula
Eucinostomus argenteus
Eucinostomus melanopterus
Diapterus rhombeus
Haemulon aurolineatum
Archosargus rhomboidalis
Cynoscion arenarius
Cynoscion nothus
Menticirrhus americanus
Menticirrhus saxatilis
Equetus acuminatus
Micropogonias undulatus
Chaetodipterus faber
Polydactylus octonemus
Trichiurus lepturus
Anchylopsetta quadrocellata
Citharichthys spilopterus
Etropus crossotus
Bothus robinsi
Symphurus plagiusa
Gymnachirus nudus
Achirus lineatus
Trinectes maculatus
Aluterus schoephi
Balistes capriscus
Sphoeroides greeleyi
Lagocephalus laevigatus
Chilomycterus schoepfi

VI

Urolophus jamaicensis
Hippocampus hudsonius
Prionotus scitulus
Echeneis naucrates
Orthopristis chrisopterus
Haemulon plumieri
Anisotremus virginicus
Archosargus probatocephalus
Calamus penna
Chaetodon ocellatus
Pomacanthus arcuatus
Lachnolaimus maximus
Nicholsina ustus
Stephanolepis hisp'dus
Acanthostracion quadricornis
Sphoeroides nephelus

cullies of determining fish age and growth ralos. In the southern Gulf of Mexico, fish grow faster and their life cycles are shorter, with most fish maturing in less than one year (Yáñez-Arancibia *et al.* 1980). The growing season extends over the whole year and juvenile specimens form an available slock (recruitment into the system) throughout the year. Fish populations can maintain themselves due to high food availability in the system. This is in contrast to those that occur in cold shelf areas (Pope and Knights, 1982).

During fish sampling, we collected information about the associated fauna of species of commercial importance (i.e., shrimp, crayfish and other crustaceans). A comparison is most interesting. Table *i*> has been made up of data obtained during our cruises, as well as of complementary data from Soto (1979) and Solo and Gracia (pers. connu). With this information we stablished that, in each season, fish outnumbered any other group. Although there exist an apparent seasonal pattern, the ratio between fish: shrimp weight relation varied between 8:1 and 57:4, and averaged of 23:2 based on the results obtained from cruises that look place between 1978 and 1982. Fishery statistics of the past 5 years from Secretaria de Pesca (Dirección de Estadistica e Informática 1977-1981) showed a mean annual catch of 25,746.8 ml of penaied shrimp in the Gulf of Mexico. Statistics of this study indicate a relationship of 12:1 fish by-catch to shrimp: therefore, we can estimate according to Parsons and Sandeman's method (1981), that 1,544,808 ml of by-catch mainly demersal fish, have been of no benefit to Mexico, and may represent a latent fishery resource.

In recent years, literature in the field of renewable resources management has show increasing emphasis on the concept of ecosystem or multisisgie approaches. The concept of moving resources management strategies in this direction has been discussed in a range of circles including resource harvesters, other interest groups and governmental policymakers (Mercer, 1982). In Mexico this topic has not been considered. Recognition of the need for a by-calch approach to fisheries management is in agreement with the continuing trend of the industry toward greater complexity of scope, scale, technical development and survey methodologies (Doubleday and Hivard, 1981; Dickie and Kerr, 1982; Sheldon *et al.,* 1982).

Full utilization of multispecies fisheries requires a management approach which allows for the lull complexity of the fishery system and takes into account the social and economic factors that affect the deployment of the fishery fleet. This means, in turn, that the structure of the fishery should be based on natural functional groupings and not on arbitrary historial divisions. At the most highly aggregated level these are the fish-ecosystem complex and the fisherman-processor socioeconomic complex (Silver and Dickie 1982). Difficulties of managing ocean fisheries on a species-by-species basis arise due to catches of mixed species, data requirements for yield models for the large numbers of species within a region, and problems in accounting for species interaction in yield esimates. Futhermore, models have shown that the goal of yield maximization from an assemblage of species with a range of productivity capabilities leads to a reduction in the number of species that supply the yield.

Sustained high productivity of those remaining species may not be possible in the simplified system. There is also the risk that return to the original species composition will not result from subsequent reduction of fishing effort. An operational characterization for management purposes is given for an assemblage production unit of fishes. This unit is a group of trophically coupled, resident species. Temporal and geographic characteristics of component species are selected to make possible the management of the unit as an entity. In this sense, Tyler and Gabriel (1982) have analyzed approaches to adaptative management.

The demersal fish community concept embodies important implications for changes in fisheries management science and technology, and implies the need for the reconsideration of data collection and compilation. These preliminary investigations in Mexico open new outlooks for research of great ecological and economical importance to southern Gulf of Mexico, and represent a baseline for future research in this area, and for future comparison with the Louisiana and Texas shelf in the western Gulf of Mexico (Darnell *et al.,* 1983).

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Summary

From June 1978 until March 1982, a study of demersal fish was carried out on the Campeche Bank adjacent to Terminos Lagoon, Mexico. A total of 53,508 fish, of 152 species, were taken in six cruises. Cluster analysis based on environmental parameters identified two major habitats. *Zone A :* was characterized by estuarine influenced, turbid waters (transparency 7-42 p. 100), bottom salinitv 35-37 p. 1.000, bottom temperature 23-28"C, absence of benthic plants, silty clay sediments with 10-60 p. 100 $CaCO_3$ and high organic content (>10 p. 100), pH of 7.6-8.3, and dissolved oxygen < 4 ml/1. *Zone B :* was characterized by its typical marine aspects, clear water (transparency 53-99 p. 100), bottom salinity 36-37 p. 1.000, bottom temperature 24-28°C, sea grass and macroalgae, sandy sediment with 70-90 p. 100 $CaCO_3$, and low organic content «10 p. 100), pH of 7.7-8.9, and dissolved oxygen > 4 ml/1. Clustering was also used to analyze faunal similarity and demarcated two groups of fish corresponding to the two habitats. Fish frecuency of ocurrence, diversity, abundance and distribution were also analyzed. The two assemblages of fish showed differences in species richness and individuals, influenced by heterogeneity and biomass. The distribution and abundance of fish depended on depth, sediment and estuarine influence.

Standing crop in the total area averaged 0.95 g/m2 (9.5 Kg/ha). Thirty two species (21 p. 100) had a broad distribution and comprised 93 p. 100 of the total catch in Dumber and 79 p. 100 in weight; they are typical in the fish community and most of them (75 p. 100) are estuarine dependent. A 12:1 demersal fish/shrimp ratio was calculated for the survey area. Demersal fish (or by-catch) may represent a potential fishery rosource in Campeche Sound.

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