SPECIES RICHNESS, ABUNDANCE AND OCCURRENCE OF GRASSBED FISHES FROM JUPITER INLET, FLORIDA

DAVID B. SNYDER

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by

David B. Snyder

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To my parents, Mr. and Mrs. R.B. Snyder

for their support and encouragement over the years.

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Walter R. Courtenay, Jr., Department of Biological Sciences and has been approved by the members of his supervisory committee. It was submitted to the faculty of the College of Science and was accepted in partial fulfillment of the requirements for the degree of Master of Science.

SUPERVISORY COMMITTEE:

Walter R. Courtenay, Jr.
Thesis Advisor

Jeffrey N. Taylor

Sheldon Dobkin

Walter R. Courtenay, Jr.
Chairperson, Department of Biological Sciences

Sheldon Dobkin
Dean, College of Science

J. T. Kirby
Dean for Advanced Studies

April 17, 1984
Date

ABSTRACT

Author: David B. Snyder

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The fish communities of two seagrass habitats near Jupiter Inlet, Florida, were studied from April 1981 to March 1982 to determine species composition, abundance, richness and occurrence. Monthly collections yielded a total of 23,156 specimens representing 47 families and 146 species. Both sites were numerically dominated by Lagodon rhomboides, Eucinostomus gula, and E. argenteus, which (combined) comprised 63% of the total catch. The presence of young lutjanids, haemulids, serranids and sphyraenids indicates the role of this area as a nursery ground. Temporal patterns in species composition and abundance were examined through numerical classification. Species composition was more consistent over time than were corresponding abundances. Despite their proximity, the two sites exhibited differences in species composition and abundance. The role of biological, physical and historical factors are discussed in relation to the observed community patterns.

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INTRODUCTION

Marine fish assemblages associated with particular habitats are often classified accordingly. For example, it is not uncommon to encounter references in the literature to "coral reef fishes" or "salt marsh fishes". Despite the fact that constituent species may exhibit exchange (e.g., ontogenetic or diurnal) between adjacent habitats, such designations agree with Mills' (1969:1472) definition of a community -- "a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and separable by means of ecological survey from other such groups." Following this definition, fish communities provide investigators with opportunities to conduct comparative studies that attempt to identify underlying physical and biological factors responsible for their organization.

Seagrass beds are productive, shallow water marine habitats that occur in both tropical and temperate zones. In the western Atlantic and Gulf of Mexico, seagrass beds are composed primarily of three marine spermatophytes, turtle grass (Thalassia testudinum), manatee grass (Syringodium filiforme) and shoal grass (Halodule wrightii). These biotopes are known to support diverse assemblages of epibiota (Marsh, 1973; Harlin, 1980), infaunal invertebrates (O'Gower and Wacasey, 1968; Santos and Simon, 1974; Lewis and Stoner, 1983),

macroinvertebrates (Tabb et al. 1961; Heck, 1976; 1977; 1979) and fishes (reviewed by Heck and Orth, 1980). For macroinvertebrates and fishes, seagrass beds serve as nursery areas, providing shelter and food for young stages of many recreationally and commercially important species such as; spiny lobsters, Panuluris spp., shrimps, Penaeus spp., snappers, Lutjanus spp. and Ocyurus chrysurus, grunts, Haemulon spp., barracudas, Sphyraena barracuda, groupers, Epinephelus spp. and Mycteroperca spp., redfish, Sciaenops ocellatus; and trout, Cynoscion nebulousus. Since the fishes mentioned above are primarily reef dwellers as adults, the use of alternate habitats by their young has been interpreted as an adaptation to avoid the intense predation which characterizes reefs (Johannes, 1978).

In the Caribbean where seagrass beds and coral reefs are in close proximity, there is some overlap in habitat use by some members of the reef fish community (Ogden and Zieman, 1977). It is well known that grunts (Haemulon spp.) and snappers (Lutjanus spp.) school over reefs by day, but forage individually in adjacent seagrass and sand flats at night (Starck and Davis 1966; Ogden and Ehrlich 1977; Ogden and Zieman 1977). Recent studies indicate that daytime excretory products of nocturnally foraging grunts enhance nutrient input and consequently coral growth on the inhabited patch reefs. This represents an important mode of energy and nutrient transport between the two biotopes.

Herbivorous fishes, particularly parrotfishes of the genus Sparisoma, are especially prevalent in seagrass beds which surround

reefs (Randall 1965; Ogden 1976; 1980; Lobel and Ogden, 1981). The abundance of parrotfishes and other direct seagrass consumers in the Caribbean is an indication of the greater importance of direct herbivory as opposed to detritivory as a means of carbon transport in tropical seagrass communities (Ogden, 1980).

There is apparently a latitudinal gradient in habitat complexity of seagrass biotopes, ranging from complex tropical environments (with seagrasses, coral, sponges, and macroalgae) to subtropical environments (with seagrasses, sponges and macroalgae) to temperate environments consisting only of seagrasses (Heck and Orth, 1980). Weinstein and Heck (1979) contend that many fishes, especially nocturnal foragers, perceive reef-seagrass-sand areas as a continuum, and that this structural heterogeneity contributes to greater species richness in low latitude seagrass habitats. Complexity in structure may also explain local differences in composition and richness of associated macrofaunal communities (e.g., within a particular bay or lagoon: Jones et al. 1975; Heck, 1977; Thorhaug and Roesseler 1977; Brook, 1978; Martin and Cooper, 1981; Sogard, 1982).

Seasonal fluctuation in the abundance of grassbed fishes is more pronounced in Chesapeake Bay (Orth and Heck, 1980) and the Gulf of Mexico (Livingston, 1975) than in the Caribbean (Weinstein and Heck, 1979). While physical factors, such as temperature, are important in promoting temporal variation in richness and abundance, periodic recruitment of young also contributes to observed fluctuations (Weinstein and Brooks, 1983).

Along the east coast of Florida north of Biscayne Bay and Lake Worth, seagrass beds are found primarily in the peripheral areas of the Indian River Lagoon. Investigations of fish communities within the lagoon have been concentrated in the central portion (Springer, 1960; Jones et al. 1975; Gilmore, 1977; Haunert and Startzman, 1980; Gilmore et al. 1981) and northern (Schooley, 1977; Snelson and Williams 1981; Snelson , 1983; Mulligan and Snelson, 1983). Only Jones et al. (1975) looked exclusively at seagrass communities. Trophic interactions between fishes and invertebrates occupying seagrass beds in the Indian River have been examined by Young (1978) and Virnstein et al. (1983). Jupiter Inlet and the Loxahatchee River, which represent the southern terminus of the Indian River Lagoon, have received little attention. Christensen's (1965) seasonal survey of all major habitats in Jupiter Inlet and the Loxahatchee River constitutes the single ichthyofaunal survey conducted in the southern portion of the Indian River lagoon. His report included a grassbed site that yielded 103 fish species, many of which were of tropical origin.

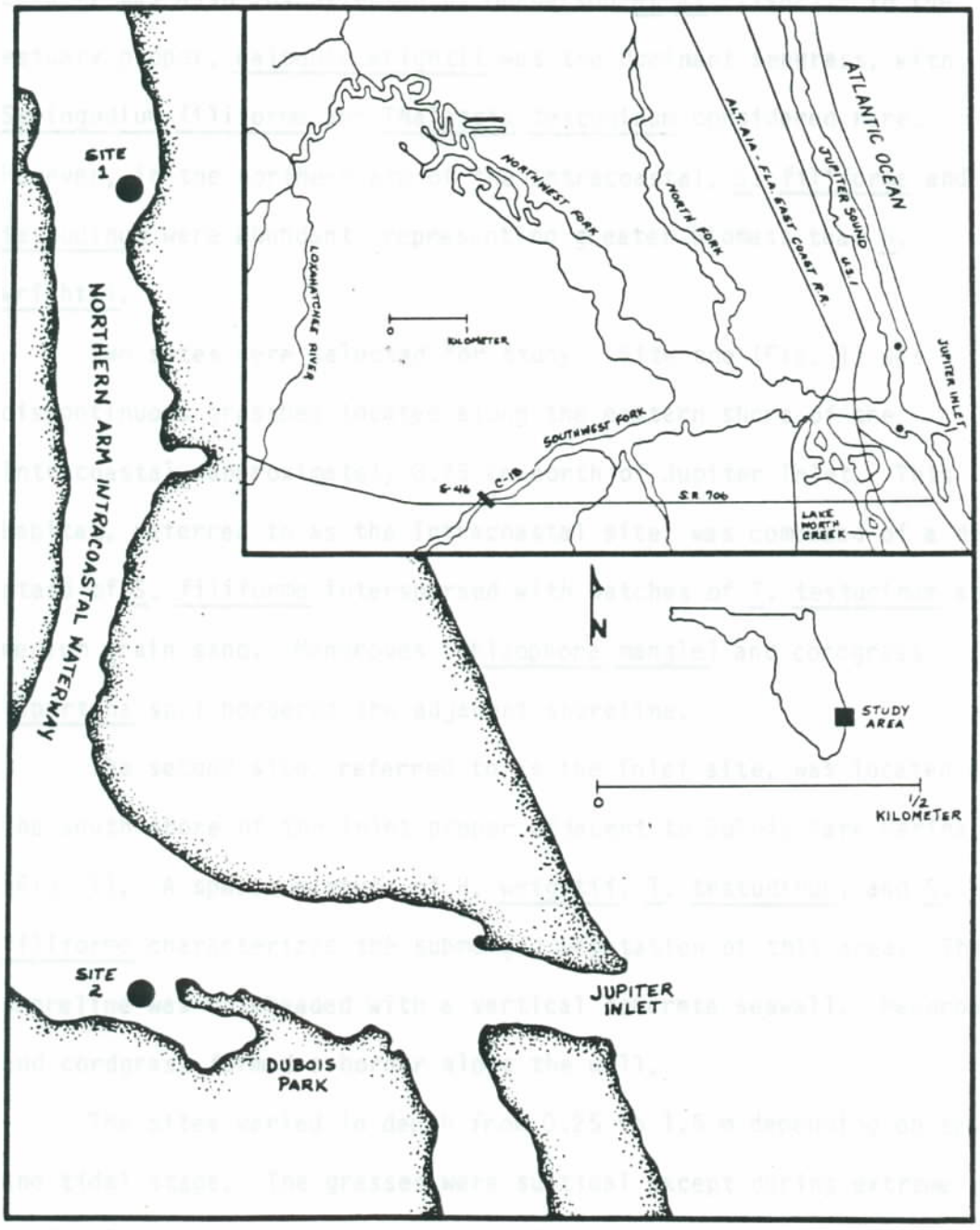
The present study was carried out to assess basic features of community organization in two seagrass habitats located near Jupiter Inlet, Florida. The major objectives were to assess overall fish species composition of the grassbed habitat; discern temporal patterns in species richness, abundance, and occurrence; examine correlations between environmental variables and species richness and abundance; and identify between-site differences in various community parameters.

MATERIALS AND METHODS

Study Site

Jupiter Inlet (ca. 26°9'N), located on the southeastern coast of Florida in northern Palm Beach County, occupies a unique hydrographic position for two primary reasons. First, to the west lies the Loxahatchee River estuary (Fig. 1), constituting the southernmost natural river system on the east coast of Florida. Second, ca. 5 km offshore to the east, along the edge of a compressed continental shelf, flows the Florida Current (Gulf Stream), representing the northernmost point along the east coast where the Gulf Stream occurs so close to shore. Due to the narrowness of the shelf and proximity of this current, Jupiter Inlet and adjacent lagoonal waters are under considerable oceanic influence, which is especially evident during incoming tide. Hydrodynamic studies (Chiu, 1975) showed that 45% of the tidal prism pushes into the northern arm of the Intracoastal Waterway (Fig. 1), 44% enters the estuary west of State Road A1A, and 11% enters the southern arm of the Intracoastal Waterway. Freshwater discharge to the Loxahatchee estuary from its three major tributaries, the North Fork, Northwest Fork, and the Southwest Fork (C-18 canal; Fig. 1), is small, equalling only approximately 5% of the incoming tidal discharge (McPherson et al., 1982).

Figure 1. Sampling sites, Jupiter Inlet, Florida. Loxahatchee river estuary depicted in inset. (Adopted from McPherson et al., 1982.)


ATLANTIC OCEAN
JUPITER SOUND
A1A - FLA. EAST COAST R.R.
U.S.1
JUPITER INLET
NORTHWEST FORK
NORTH FORK
LOXAHATCHEE RIVER
SOUTHWEST FORK
0
KILOMETER
S-46
C-18
S.R. 706
LAKE WORTH CREEK
N
STUDY AREA
0
1/2 KILOMETER
SITE 1
NORTHERN ARM INTRACOASTAL WATERWAY
SITE 2
JUPITER INLET
DUBOIS PARK

Distribution of submerged macrophytes within the Loxahatchee estuary was also investigated by McPherson et al. (1982). In the estuary proper, Halodule wrightii was the dominant seagrass, with Syringodium filiforme and Thalassia testudinum considered rare. However, in the northern arm of the Intracoastal, S. filiforme and T. testudinum were abundant, representing greater biomass than H. wrightii.

Two sites were selected for study. Site one (Fig. 1) was a discontinuous grassbed located along the eastern shore of the Intracoastal, approximately 0.75 km north of Jupiter Inlet. This habitat, referred to as the Intracoastal site, was composed of a dense stand of S. filiforme interspersed with patches of T. testudinum and medium grain sand. Mangroves (Rhizophora mangle) and cordgrass (Spartina sp.) bordered the adjacent shoreline.

The second site, referred to as the inlet site, was located along the south shore of the inlet proper adjacent to DuBois Park Marina (Fig. 1). A sparse mixture of H. wrightii, T. testudinum, and S. filiforme characterized the submerged vegetation of this area. The shoreline was bulkheaded with a vertical concrete seawall. Mangroves and cordgrass formed a border along the wall.

The sites varied in depth from 0.25 to 1.5 m depending on season and tidal stage. The grasses were subtidal except during extreme spring lows which exposed portions of the beds.

Field Methods

Monthly fish collections were made from April 1981 to March 1982

with a 20 m x 1.5 m seine with 3.2 mm mesh webbing. Sampling coverage was ca. 500 m^2 at each site. Three to five hauls were taken at each site, and results were expressed as number of fish per seine haul (catch per unit effort or CPUE). All samples were done during daylight hours at falling tide. To complete the taxonomic survey, additional collections were made using a pushnet (Strawn, 1954), castnet (3.0 m radius), and handnet. Samples were preserved in the field in 15% formalin-seawater. After transfer to 50% isopropyl alcohol, samples were sorted by species, and individuals were measured to the nearest millimeter (standard lengths). Abundant species were subsampled prior to measurement. New recruits were separated from other growth stages by examining length frequency distributions (Grossman, 1982). At each sampling date, temperature was measured to the nearest 0.1 degree centigrade with a handheld stem thermometer; salinity (ppt) was determined by chlorinity (Mohr) titration, and dissolved oxygen (ml/l) by Winkler titration. Percent cover of seagrass was estimated by walking 10 m transects perpendicular to the shore, estimating the cover of all grasses 1 m on either side of the transect (Jones et al., 1975).

Rainfall and freshwater discharge into the Loxahatchee River were monitored by the U.S. Geological Survey from February 1980 to March 1982. Due to extreme high tides sampling was precluded at the inlet site during November 1981 and February 1982.

Data Analysis

The use of various information theoretic diversity indices as a means of data reduction in community evaluations has been criticized (i.e., Hurlburt, 1971; Peet, 1975; Green, 1979). Poole (1974) contended

that the number of species is the only truly objective measure of diversity. In the present study, the number of species per collection was selected as a measure of species richness. Dominance-diversity curves (Whittaker, 1965) were used to compare dominance and evenness of species distributions at the two sites.

Numerical classification was employed to discern temporal patterns in species co-occurrence; this analytic technique objectively simplifies large, multispecific data sets into smaller, related groups. The general procedure in numerical classification begins with a raw data matrix reflecting species composition of monthly samples. Data entries may be either a measure of abundance or presence-absence values. Next, using a similarity index to compare all possible pairs of samples by their species composition, a matrix of sample similarities is generated. This matrix was then scanned for pairs of samples with high similarity values. These pairs were successively linked, based on a specific grouping algorithm, to pairs with similar values, producing a dendrogram which displayed the final grouping of the samples. The process described above, where samples were compared, is referred to as "normal analysis," while similarity between species based on their occurrence in the samples is termed "inverse analysis" (Clifford and Stephensen, 1975; Boesch, 1977). The raw data matrix used here consisted of untransformed species abundances ($n/500m^2$) by month of collection. For analysis of temporal patterns at both sites simultaneously, the appropriate data matrix was obtained by summing the species from the two

sites over time (Richardson and Stephensen, 1978). Following this approach, the data sets from the two site (inlet and Intracoastal) were summed over months; species represented by fewer than 15 total individuals were eliminated, resulting in a 50-species by 12-month matrix. Similarity for both inverse and normal analyses was calculated using Pinkham and Pearson's (1976) coefficient of biotic similarity (B):

$$B = \frac{1}{K} \sum_{i=1}^{K} \frac{\text{Min } X_{ia}, X_{ib}}{\text{Max } X_{ia}, X_{ib}}$$

where X_{ia} and X_{ib} are the number of individuals of species i in months a and b (normal analysis), or the numbers of individuals of species a and b at month i (inverse analysis). K is equal to the number of comparisons (species or months) considered. This index is useful because it considers abundance and occurrence of species simultaneously (Pinkham and Pearson, 1976).

Months and species were clustered separately by similarity patterns using the weighted group average sorting method (Sneath and Sokal, 1973). All analyses were run using the program of Pinkham et al (1975) on the Control Data Corp. (CDC) Cyber 170/730 computer at the South Florida Water Management District Headquarters, West Palm Beach, Florida.

Following the classifications, relationships between normal and inverse analyses were examined through two-way coincidence tables (Stephensen et al. 1972; Clifford and Stephensen, 1975; Boesch, 1977).

A two-way coincidence table was constructed by rearranging the original data matrix into month and species groups as indicated by the respective normal and inverse analyses. This helps identify particular abundance concentrations between time and species groups. Further examination of the two-way table can reveal patterns of temporal constancy. Temporal constancy is how consistently members of a species group occur within a particular time group and is expressed as the proportion of observed species occurrences in a certain time group, over the total number of possible occurrences. Constancy has a value of 1 when all species occur in all months of a time group and 0 when none of the species occur in the months of a time group (Boesch, 1977).

Additional evaluation of community constancy was carried out by plotting the similar values (B) between the first sampling month and each successive month over time, employing abundance as well as presence-absence data (Heck, 1977). This procedure was carried out for both sites separately and on the combined data set described above.

RESULTS

An extreme drought occurred during the first four months of the study period (Fig. 2). April 1981 was the driest April on record for southern Florida. Following the dry months, there was a marked increase in precipitation during August and September 1981, primarily due to tropical storm Dennis. Freshwater inflow into the Loxahatchee via its three tributaries is closely correlated with ambient rainfall (Fig. 2). Surface salinity is also associated with rainfall and subsequent discharge; hypersaline (>40 o/oo) conditions were found at both sites during the spring dry period (Fig. 3). Salinity values at the inlet site were lower due to local hydrodynamic effects, causing the estuarine discharge to bypass the northern arm of the Intracoastal during ebb tide. Thus, the primary discharge into the Intracoastal was by direct runoff (USGS, unpublished data).

Temperatures were never below 20°C during any sampling period (Fig. 4). Unusually low readings in July and November 1981 at the Intracoastal site were the result of offshore upwellings. These upwellings, which have been documented for the east coast of Florida (Taylor and Stewart, 1958; Christensen, 1965; Gilmore et al., 1981), will often affect inshore water temperatures when prevailing hydrographic conditions permit shoreward transport of the cold-water mass (personal

Figure 2. Monthly rainfall and discharge data for the Loxahatchee River. Discharge includes all three tributaries.

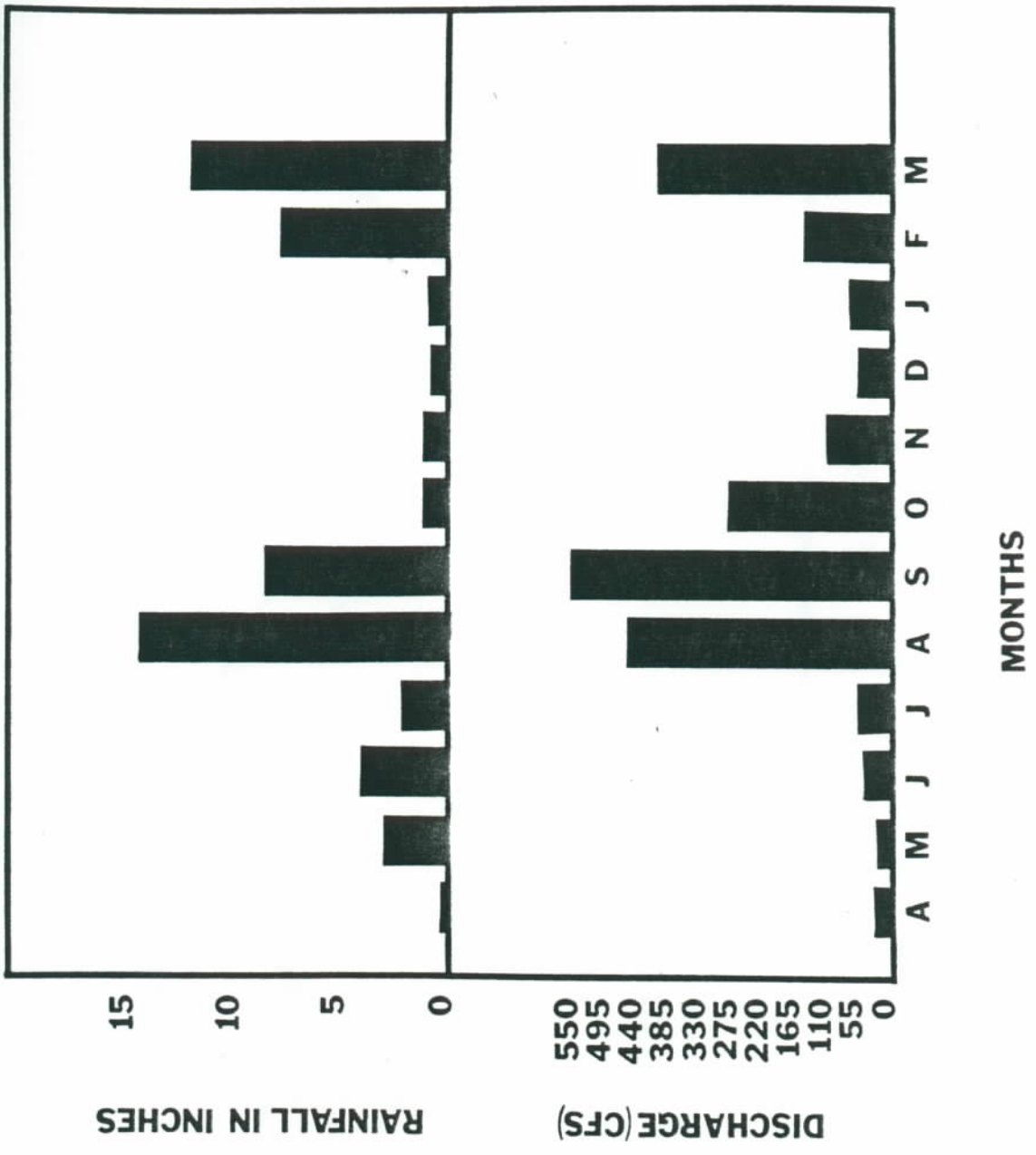

RAINFALL IN INCHES
15
10
5
0
DISCHARGE (CFS)
550
495
440
385
330
275
220
165
110
55
0
A M J J A S O N D J F M
MONTHS

Figure 3. Monthly salinity values at both sites. (-----) = Inlet; (———) = Intracoastal.

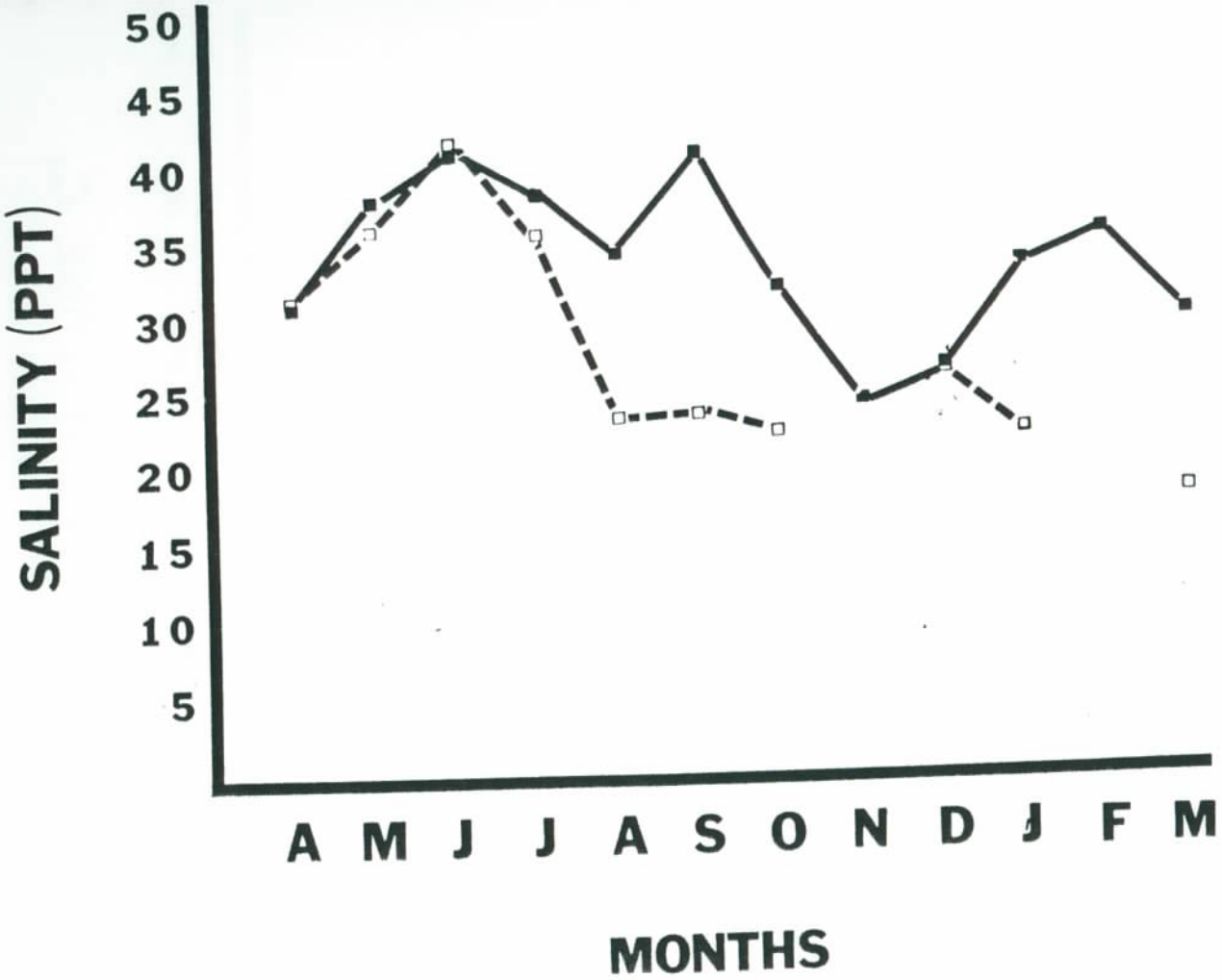
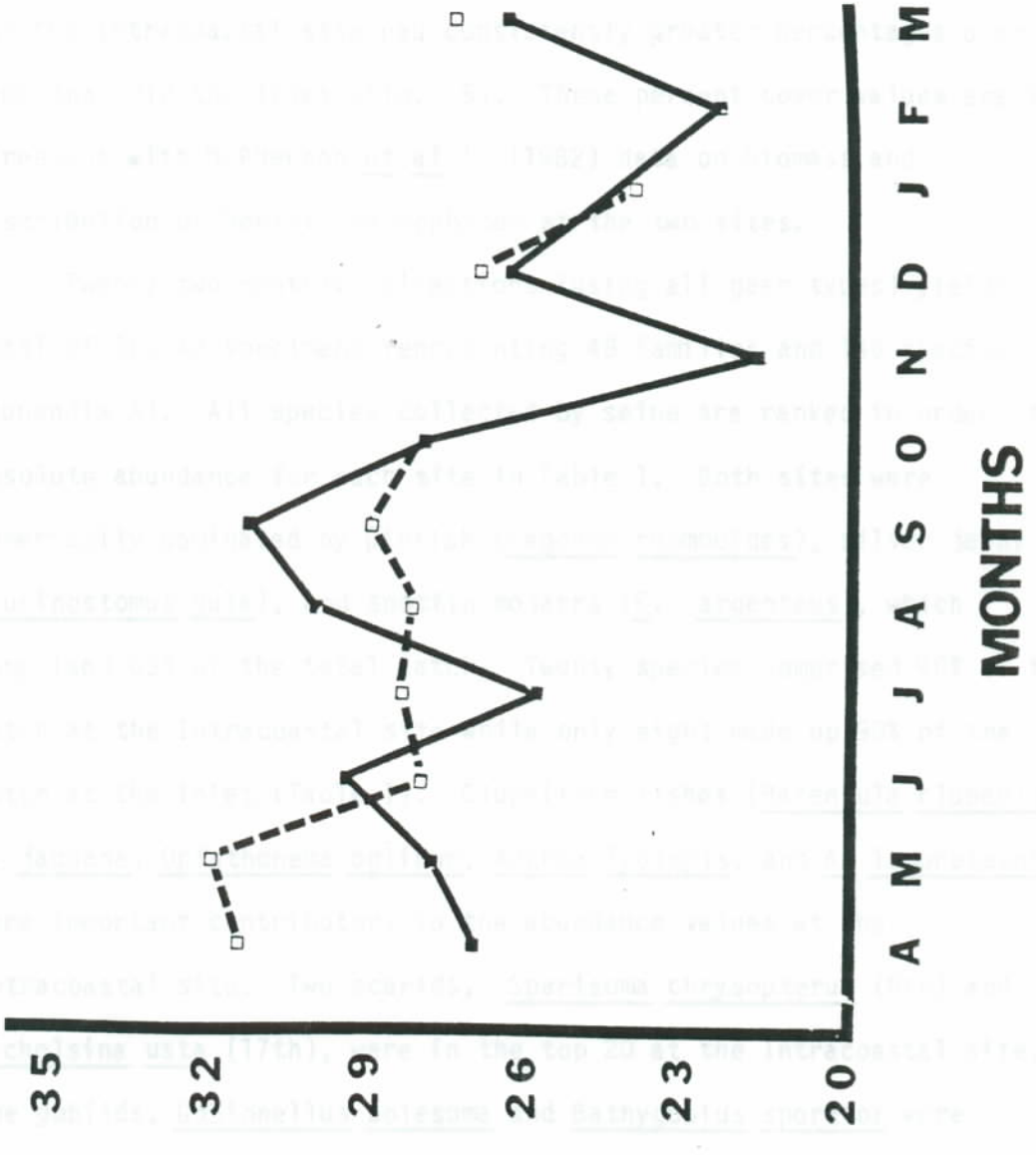

SALINITY (PPT)
50
45
40
35
30
25
20
15
10
5
A M J J A S O N D J F M
MONTHS

Figure 4. Monthly temperature readings from both sites. (-----) = Inlet; (———) = Intracoastal.


TEMPERATURE C°
35
32
29
26
23
20
A M J J A S O N D J F M
MONTHS

observation).

Percent seagrass cover followed a similar trend at both sites, but the Intracoastal site had consistently greater percentages over time than did the inlet (Fig. 5). These percent cover values are in agreement with McPherson et al.'s (1982) data on biomass and distribution of benthic macrophytes at the two sites.

Twenty-two monthly collections (using all gear types) yielded a total of 26,442 specimens representing 48 families and 146 species (Appendix A). All species collected by seine are ranked in order of absolute abundance for each site in Table 1. Both sites were numerically dominated by pinfish (Lagodon rhomboides), silver jenny (Eucinostomus gula), and spotfin mojarra (E. argenteus), which comprised 63% of the total catch. Twenty species comprised 90% of the catch at the Intracoastal site while only eight made up 90% of the catch at the inlet (Table 1). Clupeiform fishes (Harengula clupeola, H. jaguana, Opisthonema oglinum, Anchoa lyolepis, and A. lamprotaenia) were important contributors to the abundance values at the Intracoastal site. Two scarids, Sparisoma chrysopterum (8th) and Nicholsina usta (17th), were in the top 20 at the Intracoastal site. The gobiids, Gobionellus bolesoma and Bathygobius sporator were abundant at the inlet site, ranking 7th and 9th, respectively. Haemulids (Orthopristis chrysoptera, Haemulon parrai), lutjanids (Lutjanus griseus, L. synagris, L. apodus), and sphyraenids (Sphyraena barracuda) were common to abundant at both sites (Table 1).

The dominance-diversity curves (Fig. 6) illustrate a somewhat

TABLE 1

SPECIES COLLECTED BY SIENE AT BOTH SITES RANKED IN ORDER OF ABUNDANCE (n/500m^2).

Intracoastal		Inlet	
SPECIES	NUMBER	SPECIES	NUMBER
Lagodon rhomboides	3630	Lagodon rhomboides	5352
Eucinostomus gula	1668	Eucinostomus gula	3893
Harengula clupeola	1100	Eucinostomus argenteus	1452
E. argenteus	814	Orthopristis chrysoptera	542
Lutjanus synagris	303	Monacanthus hispidus	385
H. jaguana	193	Gobionellus boleosoma	277
Sparisoma chrysopterum	106	Haemulon parrai	265
A. lamprotaenia	93	Bathygobius soporator	221
Opisthonema oglinum	89	Leiostomus xanthurus	118
E. jonesi	84	Lutjanus synagris	99
Sphyraena barracuda	80	Syngnathus louisianae	98
Lutjanus apodus	74	Sphyraena barracuda	95
Orthopristis chrysoptera	64	Sphoeroides testudineus	73
Haemulon flavolineatum	62	Lutjanus apodus	61
Strongylura notata	58	Sphoeroides spengleri	59
Harengula humeralis	50	Lactophrys trigonus	39
Nicholsina usta	48	Lutjanus analis	37
Haemulon parrai	48	Sparisoma chrysopterum	35
Syngnathus louisianae	47	Syngnathus scovelli	33
Anchoa cayorum	46	Gobionellus stigmaturus	32
Monacanthus hispidus	46	Synodus foetens	30
Syngnathus floridae	45	Eucinostomus melanopterus	30
Coryphopterus glaucofraenum	44	Chilomycterus schoepfi	26
Malacoctenus macropus	42	Strongylura notata	25
Monacanthus ciliatus	39	Syngnathus floridae	23

TABLE 1 - Continued

Intracoastal		Inlet	
SPECIES	NUMBER	SPECIES	NUMBER
Sardinella aurita	38	Sparisoma rubripinne	22
Lutjanus analis	34	Mugil cephalus	19
Anchoa nasuta	30	Citharichthys spilopterus	19
Gobionellus stigmaturus	30	Bairdiella chrysoura	18
Synodus foetens	29	Sphoeroides nephelus	13
Lutjanus griseus	28	Chaetodipterus faber	11
Lachnolaimus maximus	28	Sphyraena borealis	10
Sparisoma radians	26	Scorpaena grandicornis	9
Doratonotus megalepis	26	Monacanthus setifer	8
Scorpaena brasiliensis	25	Cynoscion nebulosus	7
Sphoeroides testudineus	24	Histrio histrio	7
Scorpaena grandicornis	23	Mugil curema	6
Bathygobius soporator	20	Nicholsina usta	6
Diplodus holbrooki	18	Gobionellus smaragdus	5
Eucinostomus melanopterus	17	Gobiosoma robustum	5
Sphoeroides spengleri	17	Bathygobius curacao	5
Gobionellus boleosoma	15	Achirus lineatus	5
Cryptotomus roseus	14	Eucinostomus lefroyi	5
Mugil curema	12	Symphurus plagiusa	4
Caranx bartholomaei	11	Eucinostomus jonesi	4
Sparisoma rubripinne	11	Diapterus auratus	4
Hypoatherina harringtonensis	10	Anchoa mitchilli	4
Caranx crysos	9	Acanthurus chirurgus	4
Ocyurus chrysurus	8	Diplodus holbrooki	4
Eucinostomus lefroyi	8	Scorpaena brasiliensis	3

TABLE 1 - Continued

Intracoastal		Inlet	
SPECIES	NUMBER	SPECIES	NUMBER
Monacanthus setifer	7	Hippocampus erectus	3
Syngnathus scovelli	6	H. zosterae	3
Anchoa mitchilli	6	Acanthurus bahianus	3
Astrapogon alutus	6	Monacanthus ciliatus	3
Archosargus rhomboidalis	5	Chilomycterus antillarum	3
Bathygobus curacao	5	Caranx bartholomaei	2
Bothus ocellatus	5	C. hippos	2
Citharichthys spilopterus	5	Mycteroperca microlepis	2
Hippocampus zosterae	4	Everthodus lyricus	2
H. erectus	4	Selene vomer	2
Gerres cinereus	4	Anchoa lyolepis	2
Paraclinus fasciatus	4	Lachnolaimus maximus	1
Haemulon striatum	4	Calamus arctifrons	1
Gobionellus smaragdus	4	Lutjanus jocu	1
Lactophrys quadricornis	4	Scorpaena plumieri	1
Prionotus tribulus	3	Trachinotus falcatus	1
Chilomycterus schoepfi	3	Lobotes surinamensis	1
Selar crumenopthalmus	3	Centropomus paralellus	1
Mugil cephalus	3	Sciaenops ocellatus	1
Halichores bivittatus	3	Ocyurus chrysurus	1
Fistularia tabacaria	2	Narcine brasilensis	1
Psuedopenus maculatus	2	Dasyatis sabina	1
Strongylura timicu	2	Oligoplites saurus	1
Symphurus plagiusa	2	Scarus coeruleus	1
Cynoscion nebulosus	2	Rhinoptera bonasus	1

TABLE 1 - Continued

Intracoastal		Inlet	
SPECIES	NUMBER	SPECIES	NUMBER
Calamus arctifrons	2	Syngnathus springeri	1
Syngnathus dunckeri	2	Scartella cristata	1
Haemulon chrysargereum	2	Myrophis punctatus	1
Abudefduf saxatilis	2	Psuedopenus maculatus	1
Pomacentrus luecostictus	1	Aluterus scriptus	1
Gymnothroax moringa	1	Aluterus schoepfi	1
Hemipteronotus splendens	1	Fistularia tabacaria	1
Centropomus paralellus	1	Centropomus undecimalis	1
Fundulus grandis	1		
Caranx hippos	1		
Aulostomus maculatus	1		
Serranus subligarius	1		
Epinephelus morio	1		
Hypoplectrus unicolor	1		
Balistes capriscus	1		
Paralichthys albigutta	1		
Scorpaena plumieri	1		
Arius felis	1		
Labrisomus nuchipinnis	1		
Erotelis smaragdus	1		
Diplectrum formosum	1		
Caranx latus	1		
Microgнathus criniger	1		
Cosmocampus brachycephalus	1		
Haemulon aurolineatum	1		

TABLE 1 - Continued

Intracoastal		Inlet	
SPECIES	N/500m	SPECIES	N/500m
Haemulon melanurum	1		
Anchoa cubana	1		
Cyprinodon vareigatus	1		
Diplectrum formosum	1		
Mycteroperca bonaci	1		
Trinectes inscriptus	1		
Astrapogon puncticulatus	1		
Total Species	107		83
Total Individuals	9,518		13,556

Figure 5. Monthly percent cover by all seagrasses at both sites. (-----) = Inlet; (———) = Intracoastal.

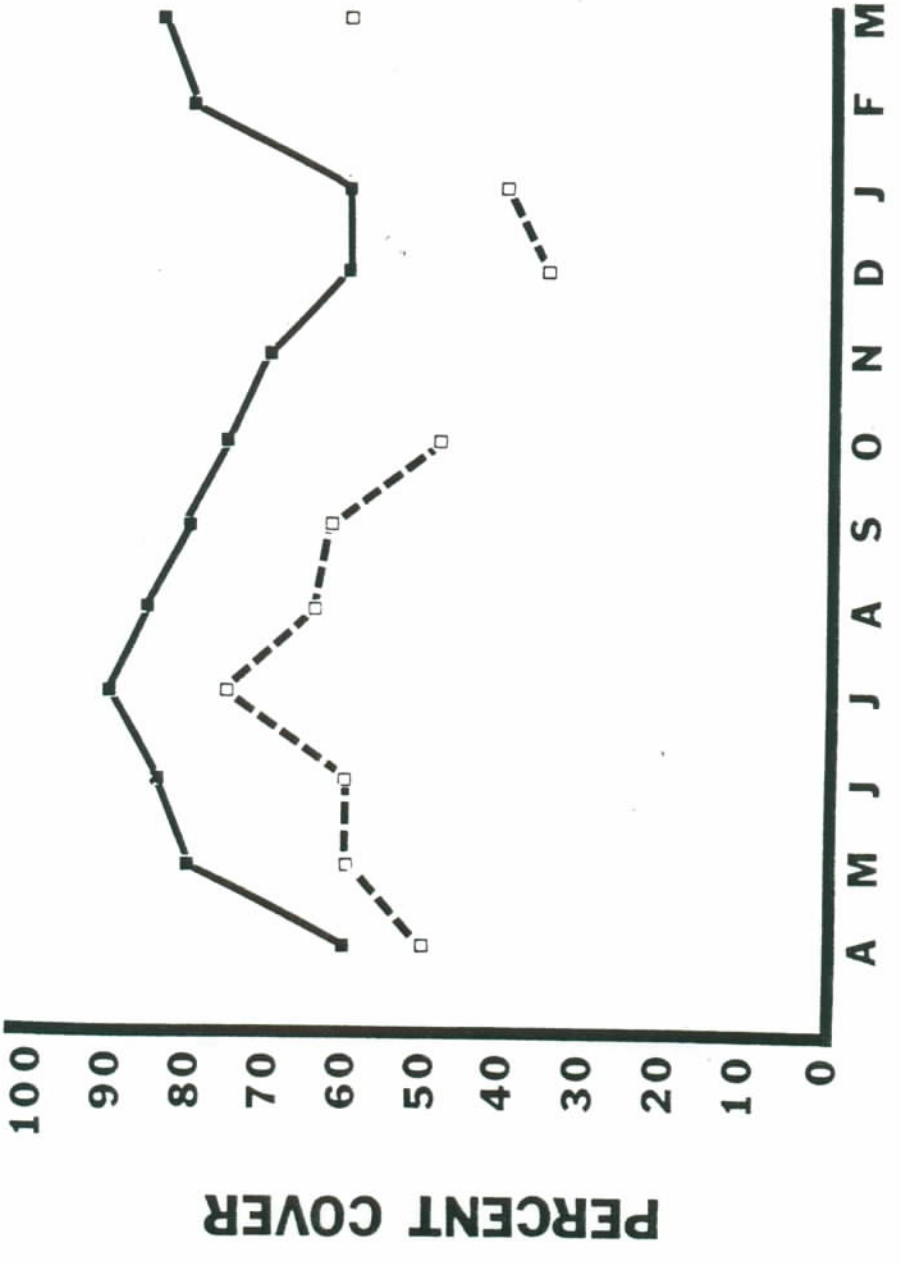
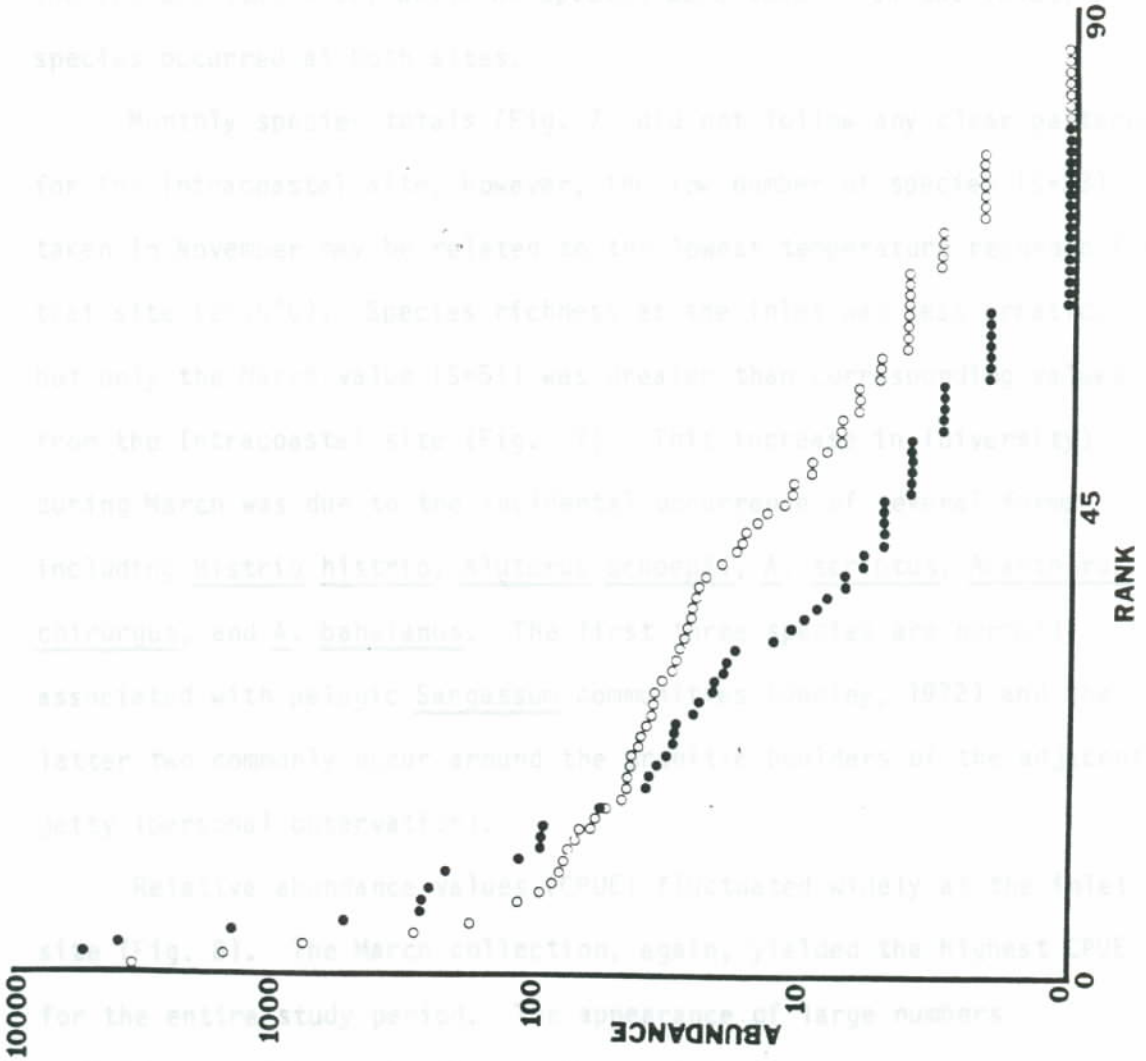

PERCENT COVER
100
90
80
70
60
50
40
30
20
10
0
A M J J A S O N D J F M
MONTHS

Figure 6. Dominance-diversity curves for each site. The ordinate is logarithmic. Inlet = (●); Intracoastal = (o).


ABUNDANCE
10000
1000
100
10
0
0
45
90
RANK

steeper slope at the inlet site, while the curve for the Intracoastal site exhibits a more even (flatter) distribution of relative abundances among the species present. A total of 107 species were collected at the Intracoastal site, while 83 species were taken from the inlet; 54 species occurred at both sites.

Monthly species totals (Fig. 7) did not follow any clear pattern for the Intracoastal site; however, the low number of species (S=23) taken in November may be related to the lowest temperature recorded for that site (21.5°C). Species richness at the inlet was less erratic, but only the March value (S=51) was greater than corresponding values from the Intracoastal site (Fig. 7). This increase in (diversity) during March was due to the incidental occurrence of several forms including Histrio histrio, Aluterus schoepfi, A. scriptus, Acanthurus chirurgus, and A. bahaianus. The first three species are normally associated with pelagic Sargassum communities (Dooley, 1972) and the latter two commonly occur around the granitic boulders of the adjacent jetty (personal observation).

Relative abundance values (CPUE) fluctuated widely at the inlet site (Fig. 8). The March collection, again, yielded the highest CPUE for the entire study period. The appearance of large numbers (951.3/haul) of juvenile ($\bar{X}$ SL = 30.9 mm) Lagodon rhomboides caused this abrupt increase. In the Intracoastal, relative abundance values displayed peaks during spring and fall with relatively constant values during summer and winter months.

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Figure 7. Total number of species collected each month. (-----) = Inlet; (———) = Intracoastal.

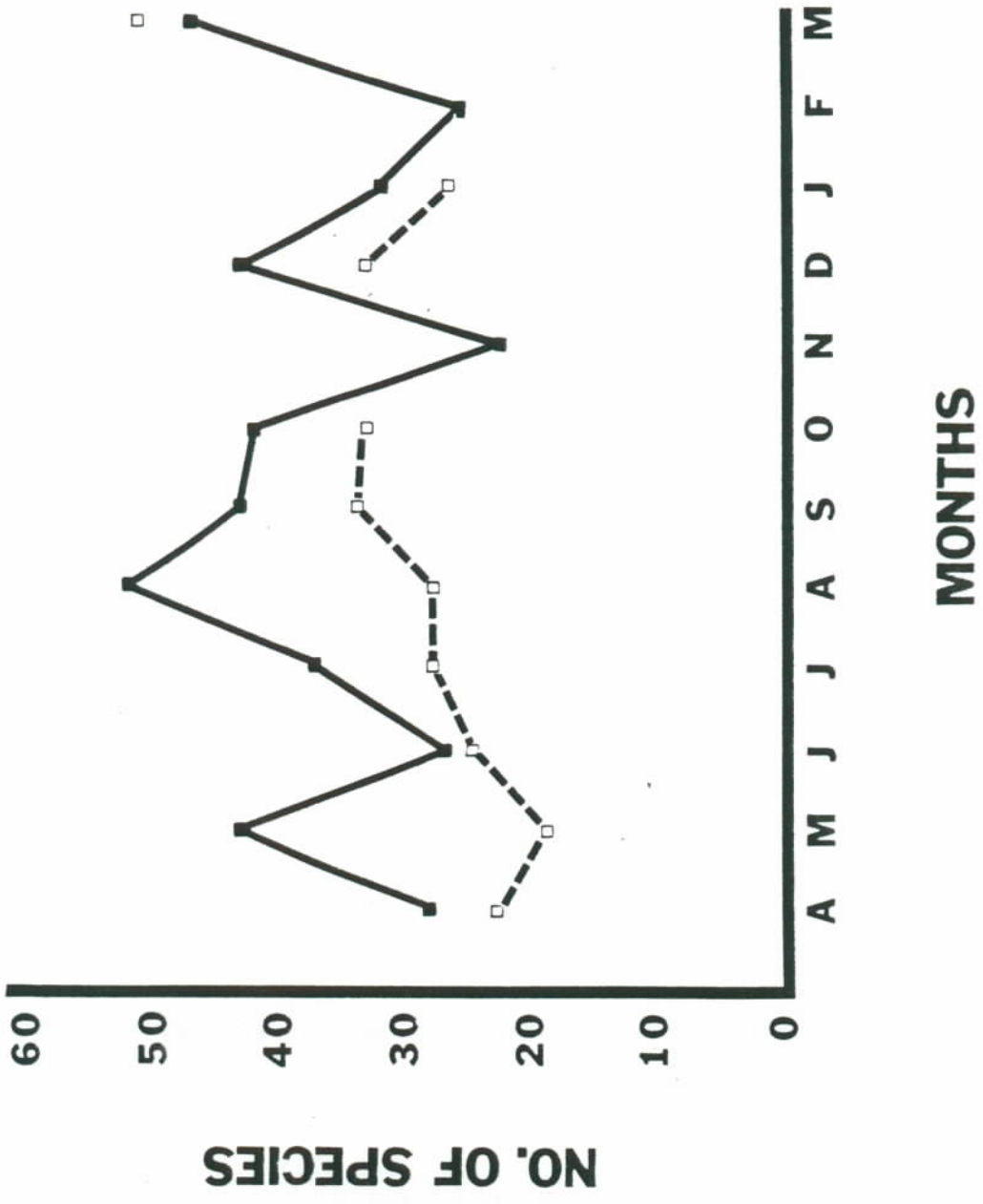
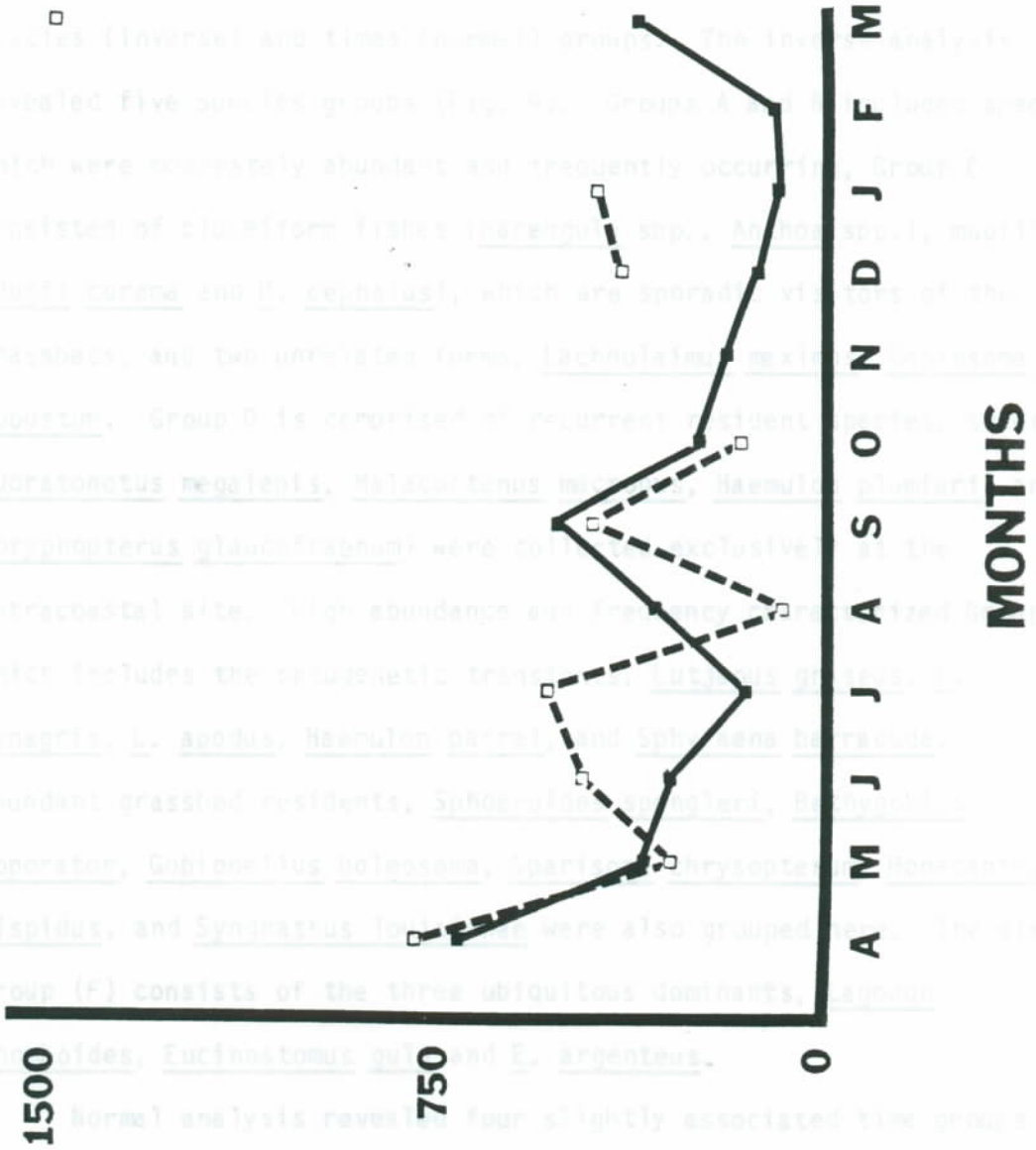

NO. OF SPECIES
60
50
40
30
20
10
0
A M J J A S O N D J F M
MONTHS

Figure 8. Monthly CPUE (fish per siene haul) at both sites. (-----) = Inlet; (———) = Intracoastal.


NO./ UNIT EFFORT
1500
750
0
A M J J A S O N D J F M
MONTHS

Numerical classification, using B (Pinkham and Pearson, 1976) as an index of similarity, was employed in an attempt to discern temporal changes in species composition and abundance. A two-way coincidence table (Table 2) was constructed from simultaneous classification of species (inverse) and times (normal) groups. The inverse analysis revealed five species groups (Fig. 9). Groups A and B included species which were moderately abundant and frequently occurring, Group C consisted of clupeiform fishes (Harengula spp., Anchoa spp.), mugilids (Mugil curema and M. cephalus), which are sporadic visitors of the grassbeds, and two unrelated forms, Lachnolaimus maximus, Gobiosoma robustum. Group D is comprised of recurrent resident species; several (Doratonotus megalepis, Malacoctenus macropus, Haemulon plumieri, and Coryphopterus glaucofraenum) were collected exclusively at the Intracoastal site. High abundance and frequency characterized Group E, which includes the ontogenetic transients, Lutjanus griseus, L. synagris, L. apodus, Haemulon parrai, and Sphyraena barracuda. Abundant grassbed residents, Sphoeroides spengleri, Bathygobius soporator, Gobionellus boleosoma, Sparisoma chrysopterum, Monacanthus hispidus, and Syngnathus louisianae were also grouped here. The sixth group (F) consists of the three ubiquitous dominants, Lagodon rhomboides, Eucinostomus gula and E. argenteus.

Normal analysis revealed four slightly associated time groups. These were Group 1: (April, May, June, July), Group 2: (November, December, January, March), Group 3: (February), and Group 4: (August, September, October).

TABLE 2

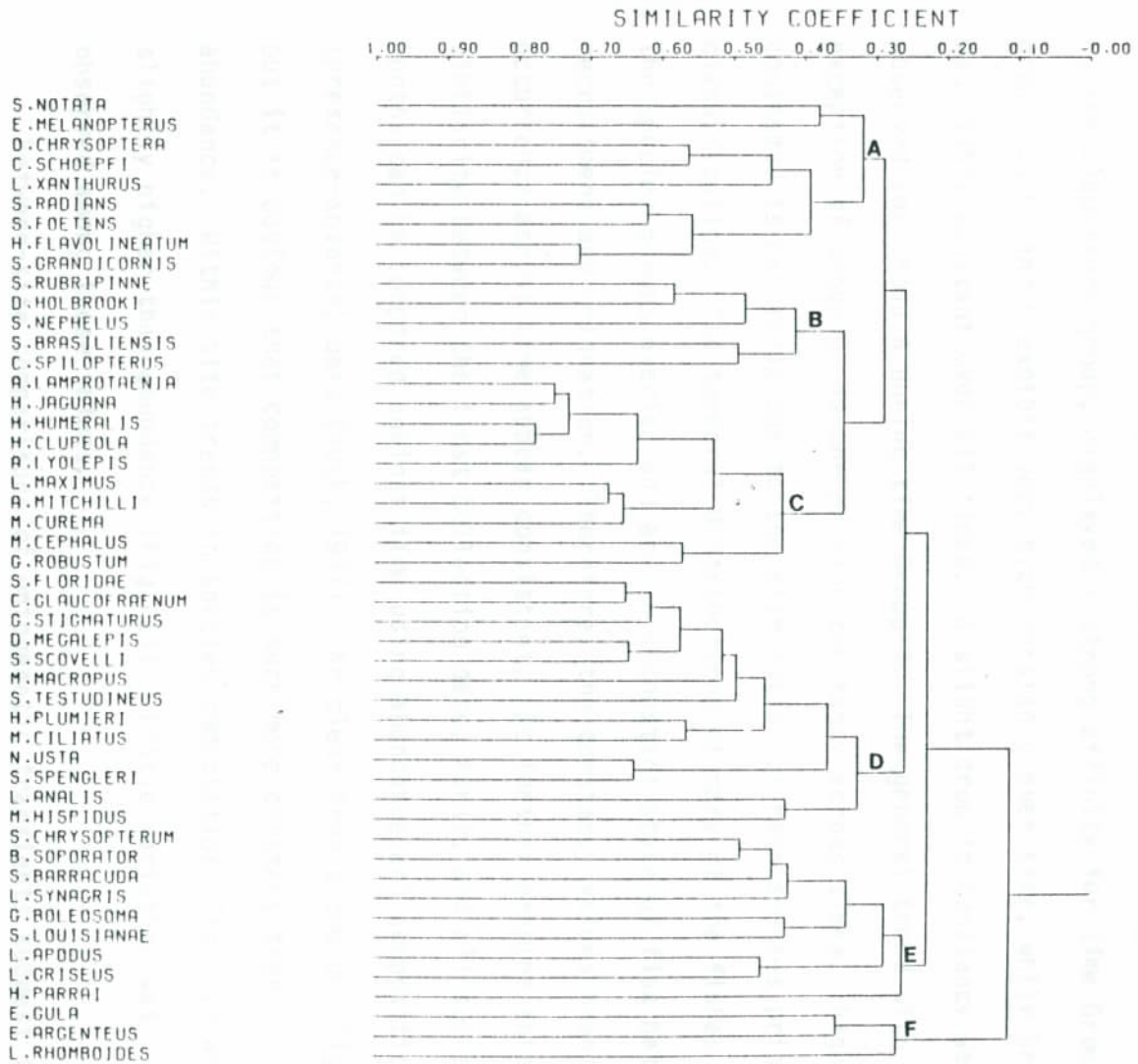
TWO-WAY COINCIDENCE TABLE COMPARING CLASSIFICATIONS FOR MONTH AND SPECIES ASSOCIATIONS. FOUR TIME GROUPS (1-4) ARE COMPARED AGAINST SIX SPECIES GROUPS (A-F).

SPECIES GROUP	TIME GROUP											
	1				2				3			4
Group A												
Strongylura notata	1	3	13	4	3		1	4	2			11
Eucinostomus melanopterus	6	30		3			1					6
Orthopristis chrysoptera	87	2	5	4		448			23	7	6	
Chilomycterus schoepfi	1	2	11	3		2			9	1		
Leiostomus xanthurus	1	24	8	9			107		2	2	2	
Sparisoma radians		7		1				6	2	5	4	
Synodus foetens	2	5	11	3				23	6	4	4	
Haemulon flavolineatum	5	11	33					2	3	5	1	2
Scorpaena grandicornis	4	8						5	5	4	4	2
Group B												
Sparisoma rubripinne	1	1	1				1		21		3	
Diplodus holbrooki	2		1	22				14				
Sphoeroides nephelus	1	1	1			2	2		1			
Scorpaena brasiliensis			1		2	2	9	5				
Citharichthys spilopterus		7	1	1		1	7	2	4		1	
Group C												
Anochoa lamprotaenia									1		87	5
A. lyolepis								2			28	
A. mitchilli								2	4		1	1
Harengula humeralis									31		19	
H. jaguana									1		191	
H. clupeola		1							1034		65	
Mugul curema					5		5	4		1	1	1
M. cephalus					3		3	1	2	13		

TABLE 2 - Continued

SPECIES GROUP	TIME GROUP 1				2				3			4
Group D												
Syngnathus floridae	4	3			1	2	5	31	9	8	4	
Coryphopterus glaucofraenum	2	2			1	4	1	10	4	12	8	
Gobionelles stigmaturus	5	3				19	1	19	4	5	2	
Doratonotus megalepis	2	4			3		2	6	4	4	3	
Syngnathus scovelli	2	3			2	11	4	5	3	2	4	2
Malacoctenus macropus	2				4	2	4	5	8	10	8	1
Sphoeroides testudineus	3	2	10		4	5	47	4	12	8	4	
Haemulon plumieri	3	1	5		3	1	11			10	4	2
Monacanthus ciliatus	2	2	1		8		12		8	16	4	
Nicholsina usta	3	1	5	1		8	11	5	8	11		1
Group E												
Sphoeroides spengleri	3	3	3	1		1	10	46	1	5		1
Lutjanus analis	7	7	1	3	8	13	2		9	20	8	
Monacanthus hispidus	2	3	2	4		18	4	347	7	39	2	3
Sparisoma chrysopterum	3	15	4	6	10	8	13	3	33	37	7	2
Bathygobius soporator	19	13	16	4		10	42	43	37	41	15	1
Sphyraena barracuda		41	19	4	2	3	8	34	59	13	10	2
Lutjanus synagris	47	4	28	20	1	1	1	2	20	4	31	2
Gobionellus boleosoma	25	27		1	2	121	17	5	30	15	3	3
Syngnathus louisianae	11		7	2	5	47	25	18	18	12	2	8
Lutjanus apodus	14	4	51	2	1	1	1	2	20	4	31	2
Lutjanus griseus	69	12	32	4	2	2	1	3	126	29	28	
Haemulon parrai	2	23	7	10	8			11	142	42	67	1
Group F												
Encinostomus gula	323	1049	126	600	55	320	963	291	891	392	145	206
E. argenteus	89	141	53	283	37	557	156	282	97	4	316	
Lagodon rhomboides	3589	239	1371	495	15	326	70	2785	28	29	43	22

Figure 9. Results of inverse analysis of species by months matrix. A-F represent species groups.


SIMILARITY COEFFICIENT
1.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 -0.00
S.NOTATA
E.MELANOPTERUS
D.CHRYSOPTERA
C.SCHOEPFI
L.XANTHURUS
S.RADIANS
S.FOETENS
H.FLAVOLINEATUM
S.GRANDICORNIS
S.RUBRIPINNE
D.HOLBROOKI
S.NEPHELUS
S.BRASILIENSIS
C.SPILOPTERUS
A.LAMPROTAENIA
H.JAGUANA
H.HUMERALIS
H.CLUPEOLA
A.LYOLEPIS
L.MAXIMUS
A.MITCHILLI
M.CUREMA
M.CEPHALUS
G.ROBUSTUM
S.FLORIDAE
C.GLAUCOFRAENUM
G.STIGMATURUS
D.MEGALEPIS
S.SCOVELLI
M.MACROPUS
S.TESTUDINEUS
H.PLUMIERI
M.CILIATUS
N.USTA
S.SPENGLERI
L.ANALIS
M.HISPIDUS
S.CHRYSOPTERUM
B.SOPORATOR
S.BARRACUDA
L.SYNAGRIS
G.BOLEOSOMA
S.LOUISIANAE
L.APODUS
L.GRISEUS
H.PARRAI
E.GULA
E.ARGENTEUS
L.RHOMBOIDES
A
B
C
D
E
F

Constancy analyses contributed to the interpretation of the qualitative relation of species groups to time groups (Fig. 10). Group C, the clupeiform group, displayed a strong affinity for time Group 4. groups D, E, and F exhibit very high constancy over time, while Group B was highly constant over all times. A slight drop in constancy was observed for Group A during time Group 3. The general trend with the exception of Group C, is one of high constancy across times. High constancy is partially due to the elimination of rare species prior to classification. The temporal distributions of many of the fishes in the species groups overlap and are in a constant state of flux between recruitment and emigration. Therefore, the constancy values based on occurrence across time appear consistent. To further examine this, similarity between the first collection date, April, and all successive months can be compared against time using abundance and compositional (presence-absence) data (Heck, 1977). No clear trends emerge (Fig. 11) but it is obvious that composition is much more constant than abundance. Within site trends in species composition (Fig. 12) were slightly higher than abundance (Fig. 13). Little variation was observed among these values.

Between-site comparisons of ontogenetic transients suggest that some of the incoming recruits have specific habitat preferences which may determine settling and subsequent survival of the young stages. For example, the lane snapper (Lutjanus synagris) was taken at both sites, including young of the year (15-20 mm SL) which first arrived in September and October. Young (15-20 mmSL) gray snappers (Lutjanus

Figure 10. Constancy of co-occurrence between species groups and time groups.

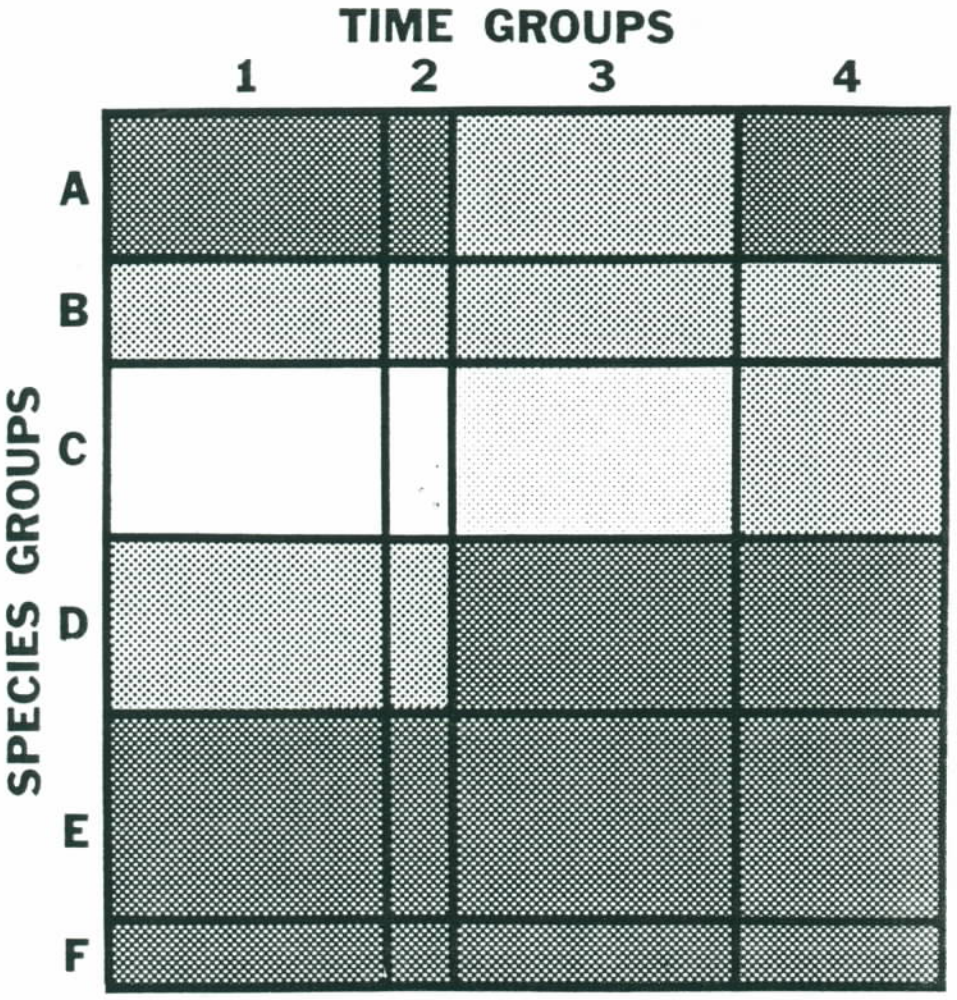

TIME GROUPS
1
2
3
4
SPECIES GROUPS
A
B
C
D
E
F
very high ≥0.7
high ≥0.5
moderate ≥0.3
low ≥0.1

Figure 11. Similarity (B) between the first collection month (April) and each succeeding month. Based on combined data sets. (———) = Abundance; (-----) = Presence-absence.

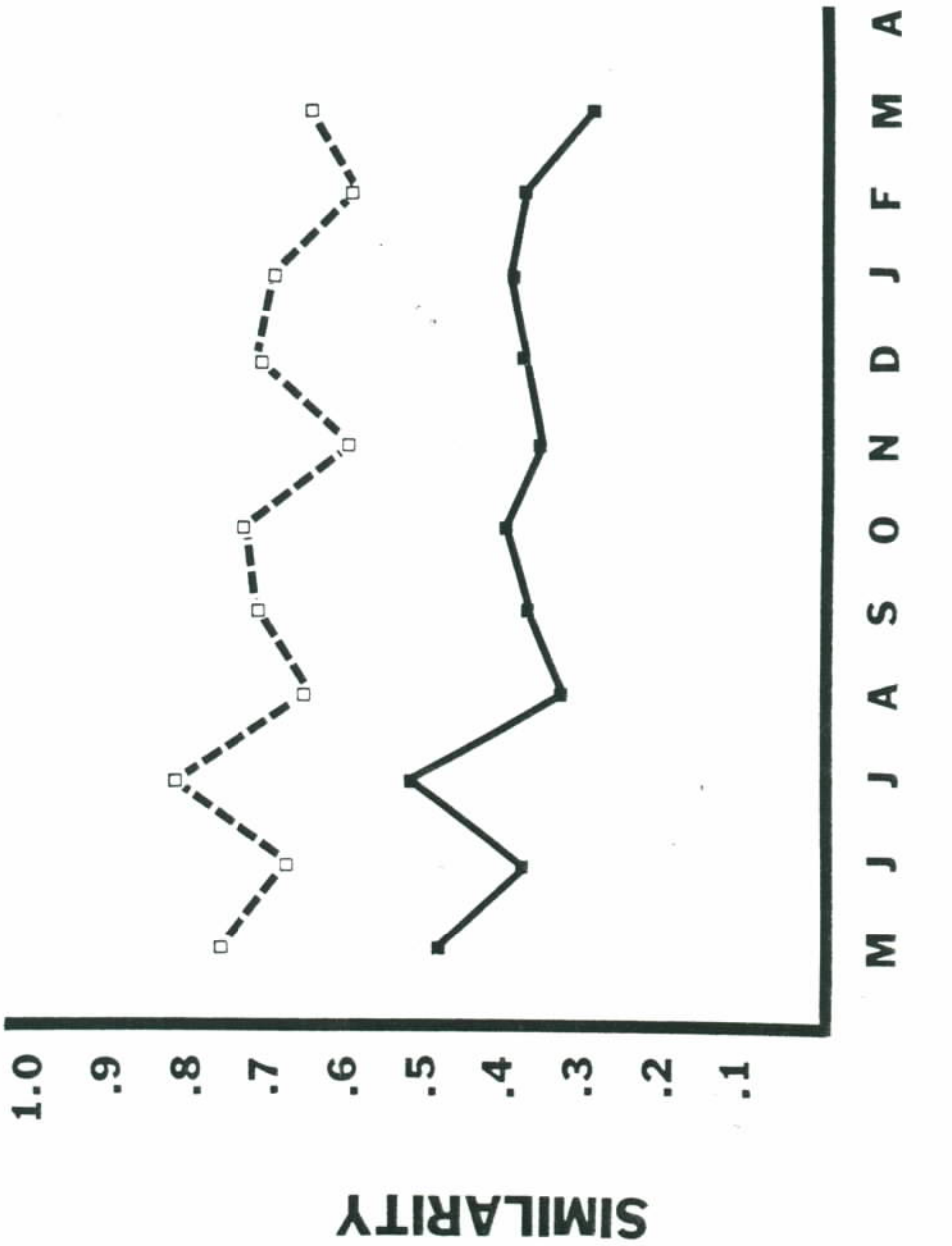

SIMILARITY
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
M J J A S O N D J F M A
MONTHS

Figure 12. Similarity (B) between the first collection month and succeeding months using presence absence data. (-----) = Inlet; (———) = Intracoastal.

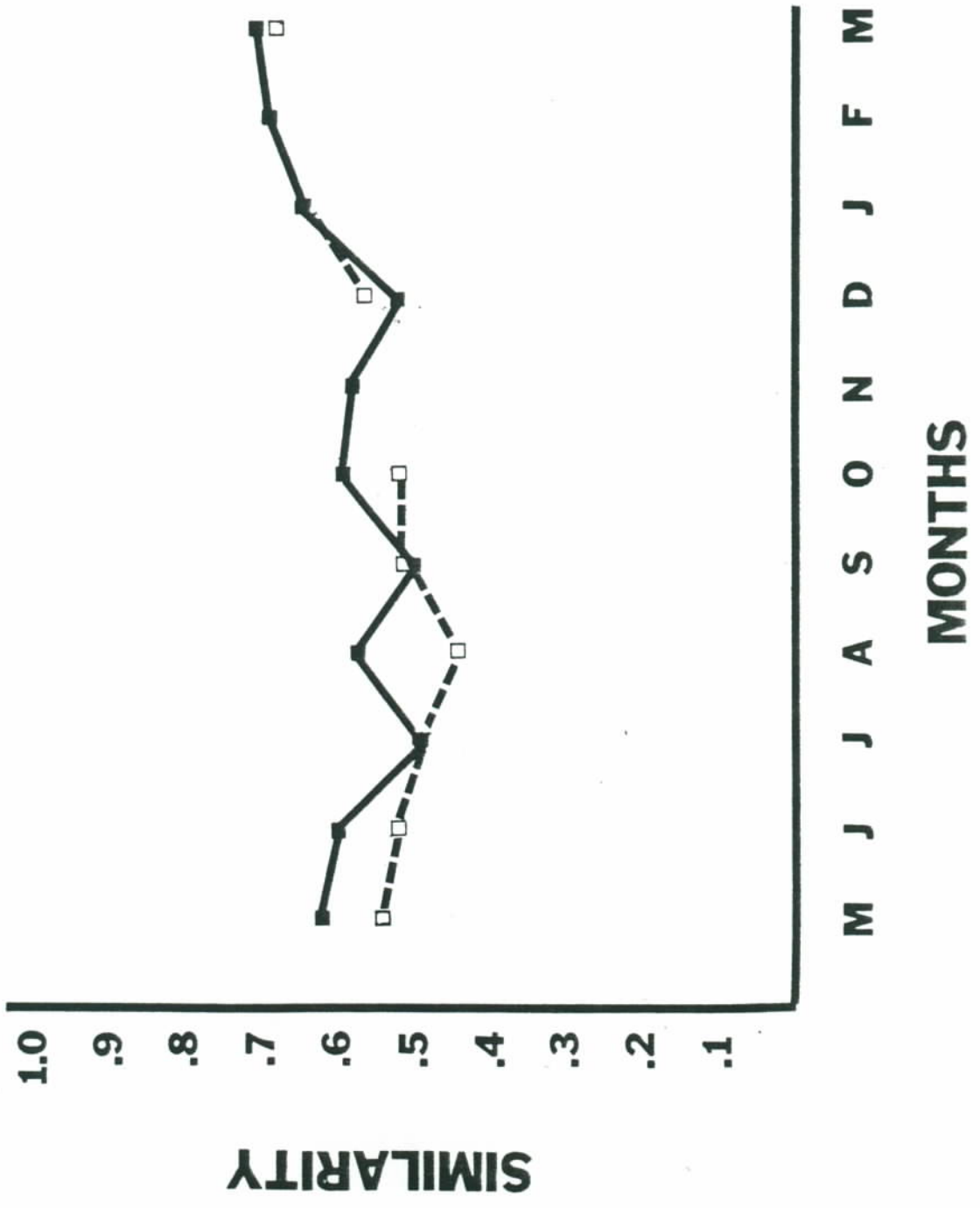
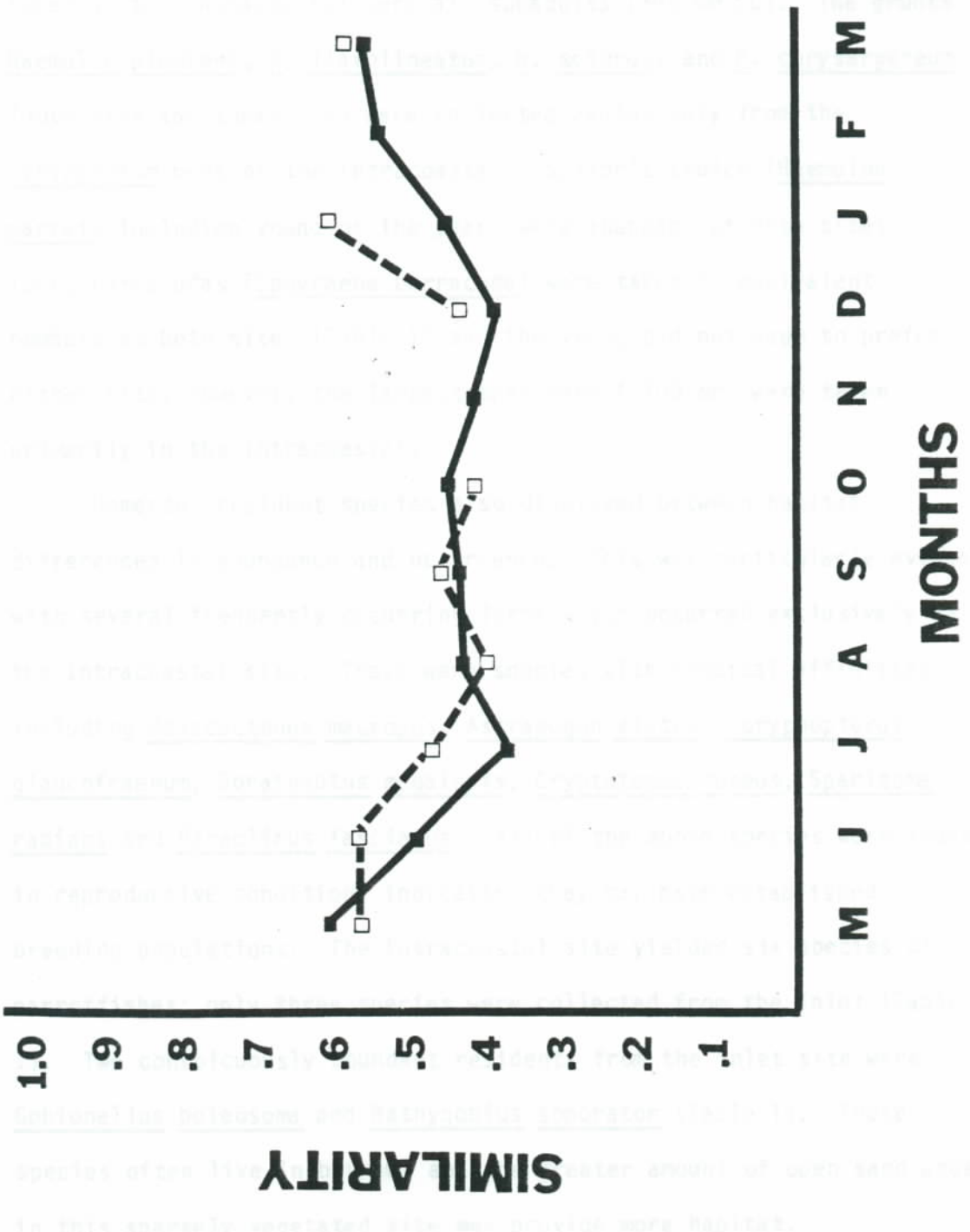

SIMILARITY
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
M J J A S O N D J F M
MONTHS

Figure 13. Similarity (B) between the first collection month and succeeding months using relative abundance data. (-----) = Inlet; (———) = Intracoastal.


SIMILARITY
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
M J J A S O N D J F M
MONTHS

griseus) were collected at the inlet site only. The fewer specimens taken at the Intracoastal were all subadults (>80 mm SL). The grunts Haemulon plumieri, H. flavolineatum, H. sciurus, and H. chrysargereum (juveniles and subadults) were collected exclusively from the Syringodium beds of the Intracoastal. Sailor's choice (Haemulon parrai) including young of the year, were abundant at both sites. Young barracudas (Sphyraena barracuda) were taken in equivalent numbers at both sites (Table 1) and the young did not seem to prefer either site; however, the largest specimens (>100 mm) were taken primarily in the Intracoastal.

Demersal resident species also displayed between habitat differences in abundance and occurrence. This was particularly evident with several frequently occurring forms which occurred exclusively at the Intracoastal site. These were species with tropical affinities, including Malacoctenus macropus, Astrapogon alutus, Coryphopterus glaucofraenum, Doratonotus megalepis, Cryptotomus roseus, Sparisoma radians and Paraclinus fasciatus. All of the above species were found in reproductive condition, indicating they may have established breeding populations. The Intracoastal site yielded six species of parrotfishes; only three species were collected from the inlet (Table 1). Two conspicuously abundant residents from the inlet site were Gobionellus boleosoma and Bathygobius soporator (Table 1). These species often live in burrows and the greater amount of open sand area in this sparsely vegetated site may provide more habitat.

Table 3 provides a brief summary of recruitment within the grassbeds. March and September had the highest number of species with young of the year (10 and 7, respectively) present, It should be noted that this table is incomplete due to limitations in sampling gear and identification problems with postlarval forms (i.e., Eucinostomus and Sparisoma spp.).

The only significant correlation between biotic variables (abundance and species richness) and the environmental variables were at the Intracoastal site. Spearman's rank correlation coefficient indicated significant correlations between temperature and species number ($n=12$; $r_s=.615$; $p=.05$) and temperature and abundance ($n=12$; $r_s=.741$; $p=.01$).

TABLE 3

PRESENCE OF NEWLY RECRUITED YOUNG OF SELECTED SPECIES OVER TIME

	A	M	J	J	A	S	O	N	D	J	F	M
Lagodon rhomboides											X	X
Haemulon parrai					X	X				X	X	
H. flavolineatum					X	X					X	
H. sciurus											X	
Orthopristis chrysoptera								X		X		
Lutjanus griseus				X		X						X
L. apodus				X		X						
L. analis							X					
Ocyurus chrysurus				X							X	X
Sphyraena barracuda					X	X					X	X
Synodus foetens						X						
Bairdiella chrysoura												X
Lactophrys trigonus												X
Nicholsina usta						X		X		X		
Sparisoma chrysopterum								X		X		
Scorpaena grandicornis							X				X	
Eucinostomus spp.	X			X			X		X	X		X
Monacanthus hispidis												X
Caranx hippos												X
C. bartholomaei												X
Lacholaimus maximus								X				
TOTAL SPECIES	1	0	0	4	3	7	3	4	1	5	6	10

DISCUSSION

The ichthyofaunal composition of the Indian River Lagoon presents an interesting zooegraphical situation. Christensen (1965) reported northern distributional records for many tropical species from the Jupiter area. Many of these records were extended north to the Ft. Pierce-Sebastian region by Gilmore (1977) and Gilmore et al. (1981). Studies on the northern portion (e.g., Merritt Island) of the Indian River Lagoon show the fish fauna to be impoverished when compared with southern sections (Schooley, 1977; Mulligan and Snelson, 1983; Snelson, 1983). Successive loss of tropical forms in a northerly direction, coupled with the infusion of Carolinean elements, demonstrates the transitional nature of the eastern Florida fish fauna (Briggs, 1974; Gilmore et al. 1981). While sufficient comparable data are not yet available, there is apparently a north-south gradient in relative abundances of many species within the lagoon. Several tropical species (i.e., Haemulon flavolineatum, Lutjanus apodus, Doratonotus megalepis) were more abundant in the present study than reported by Jones et al. (1975) for the Ft. Pierce region. Gilmore and Hastings (1983) list 54 species which exhibit disjunct east Florida-Caribbean distributions. That is, they are rare or absent from the Gulf of Mexico (the West Florida shelf in particular) but commonly found along the eastern coast

of Florida. This pattern indicates that latitudinal comparisons (e.g., Weinstein and Heck, 1979) between Caribbean and Florida grassbed faunas should also consider the east coast of Florida.

Species reported from the Jupiter Inlet area are qualitatively more similar to Panamanian grassbeds (Weinstein and Heck, 1979) than those of Apalachee Bay in the Gulf of Mexico (Livingston, 1975). The connection between eastern Florida and the Caribbean is maintained by the Florida Current, which transports planktonic propagules in a northerly direction.

Three new additions to the fish fauna of the Indian River lagoon were contributed by the present study: Trinectes inscriptus, Chilomycterus antillarum and Micrognathus criniger. The latter two forms have been reported from North Carolina (Burgess et al. 1980) but T. inscriptus may represent a northern range extension.

Jones et al. (1975) found the numbers of species collected from grassbeds located near ocean inlets to be higher than at more inland sites. From a grassbed station near Jupiter Inlet, Christensen (1965) reported the greatest number of species collected during his survey of many habitats. Inlet stations undoubtedly benefit from the oceanic influence provided by these passages. Snelson (1983) has recently described the three primary factors responsible for the north-south gradient of species richness found within the Indian River Lagoon as latitude and climate, habitat diversity, and ocean access. Proximity of the Florida current, which is closer at Jupiter than to the other inlets, certainly enhances the ocean access factor through

stabilization of environmental variables (e.g., temperature, salinity, clarity) and input of recruits.

Determinants of community structure on a local scale require closer examination of the life history patterns of the inhabitants of the grassbeds. The ontogenetic grassbed transients (e.g., Lutjanus spp., Haemulon spp., and Sphryaena barracuda) are spawned on offshore reefs, some possibly hundreds of kilometers away. Some inshore species (e.g., Lagodon rhomboides, Eucinostomus spp., and Sphoeroides testudineus) appear to spawn in nearshore oceanic waters. Therefore, continuous arrival (recruitment and immigration) and loss (emigration and mortality) of such species should exert pronounced effects on population dynamics within the grassbed fish assemblages. Sale (1980) contended that temporally variable patterns of arrival and loss contribute to the maintainence of high local diversity in non-equilibrium patch reef fish communities. Despite variations in recruitment and loss, other workers (Smith, 1978; Smith and Tyler 1972; Gladfelter et al., 1980; Anderson et al., 1981) have postulated that fine subdivision of available resources by potential competitors is the primary determinant of community structure in reef fishes and that such assemblages are at or near equilibrium. If community structure is regulated by stochastic aspects of recruitment, species composition and numbers are expected to be unpredictable over time (Sale, 1977), while predictability should characterize a deterministic (regulated by biotic interactions) assemblage (cf., Grossman, 1982).

Temporal consistency in species occurrence (Fig. 10) was

generally high with the exception of the clupeiform group (Group C). Also, similarity (B) between the first collection period and succeeding months (Fig. 11) displayed low values for abundance ($\bar{x}$=.39) but relatively high values for presence-absence ($\bar{x}$=.79). Within-site trends of composition and abundance were not high (Fig.); again, species composition is more consistent over time than corresponding relative abundances. The abundance values were affected by arrival and loss as well as sampling error. The temporal fidelity exhibited by the clupeiform group is not unexpected since these forms, especially members of the genera Anchoa and Harengula, travel in large heterotypic schools (Daly, 1970). These aggregations, which often include juvenile carangids (Decapterus punctatus and Selar crumenopthalmus), are not considered regular members of the grassbed fauna, but their sporadic mass occurrence affects the ecology of resident species in some interactive fashion. Fish communities often contain certain core species which are consistently present in particular habitats (Smith, 1978). Heck (1977) noted the presence of such core species in macroinvertebrate communities inhabiting Panamanian seagrass beds. The species comprising groups D, E, and F are possible core species here, in terms of temporal consistency.

Critical to understanding the recruitment process and its effects on population dynamics of inshore grassbed fishes is a knowledge of spawning time and place, as well as predominant circulation patterns. The northerly flow of the Florida current is not always evident along the southeastern coast of Florida. Due to the meandering nature of

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Critical to understanding the recruitment process and its effects on population dynamics of inshore grassbed fishes is a knowledge of spawning time and place, as well as predominant circulation patterns. The northerly flow of the Florida current is not always evident along the southeastern coast of Florida. Due to the meandering nature of

this current, the western edge is often displaced horizontally (east or west) for 1-3 km. Such displacements can cause current reversals and counterclockwise spinoff gyres (Lee and McGuire, 1973). If the local reef fishes spawned during current reversals to assure a net movement of zygotes inshore (also depending on prevailing winds) it would lend support to Johannes' (1978) hypothesis that some species aggregate to spawn at particular periods or locations when prevailing circulation patterns would favor the return of the young to the parental locality. When the Florida current is displaced to the east, tidal currents are the primary agents of coastal circulation (Lee and McGuire, 1973); therefore, species spawning in nearshore waters would increase chances of having their propagules transported to the nearest inlet by the incoming tide. The Florida current undoubtedly transports larvae from distant, southern spawning grounds and, if the edge of the current is displaced to the west, the likelihood of inshore transport would be increased. However, it would appear that the numerically dominant reef species taken in the samples were spawned on adjacent reefs (e.g., Lutjanus synagris, L. griseus, Sphyraena barracuda and Haemulon parrai). Of the offshore reef spawners, it is not entirely clear how juvenile survivorship is related to preference for inshore habitat such as grass beds. For example, Lutjanus synagris, the most abundant lutjanid in the samples, is also found as juveniles on adjacent nearshore reefs (pers. obs.), while young Lutjanus griseus are only found in inshore habitats, primarily seagrass beds (Starck and Schroeder, 1970). Some haemulids also do not utilize inshore nursery

areas; Haemulon aurolineatum was represented by a single specimen in the collections, but it concurrently reached high juvenile densities on nearshore reefs (pers. observ.). Other species with reef affinities Abudefduf saxatilis, Pomacentrus leucostictus, Hypoplectrus unicolor, and Serranus subligarus collected in the grassbeds are undoubtedly the fortuitous consequence of dispersal. There is insufficient life history information available to determine whether Aulostomus maculatus or Fistularia tabacaria fall into this category or not. The above species were taken primarily at the Intracoastal site, where environmental conditions are apparently suitable for their growth and survival. The unique environmental conditions of the Intracoastal Waterway are a result of continual tidal exchange of oceanic water and absence of direct fluvial discharge. Constancy of these factors is also manifested by the presence of particular stenohaline invertebrates such as Lytechinus variegatus, Diadema antillarum, Holothuria sp., and Oculina sp. While the recruitment data presented here are not complete, there is an increase in March (Table 2). Munro et al. (1973) found reproductive peaks for Jamaican reef fishes during February, March, and April. The arrival of some species such as Lagodon rhomboides corresponds with peak reproductive periods reported from other localities (Caldwell, 1957). Unfortunately, there are few available data on the reproductive ecology of local fishes, leaving these speculations open until such information is gathered.

Small demersal species, such as apogonids, gobiids, syngnathids, and clinids, exhibit low fecundity and some degree of postzygotic

parental care (Barlow, 1981). Consequently, this mode of reproduction coupled with morphological constraints restricts their distribution because of limited dispersal capabilities. Most of these species must have colonized the area initially as waif recruits from more southern regions. Once established, the resident populations are probably responsible for continued recruitment. A case in point is Coryphopterus glaucofraenum, considered the most eurytopic species of a predominantly reef dwelling genus (Bohlke and Robins, 1960) but not reported from seagrass collections in the Florida Keys (Springer and McErlean, 1962) or Biscayne Bay (Low, 1973; Sogard, 1982). In reef habitats, C. glaucofraenum is common in sandy or rubble patches (Longley and Hildebrand, 1941). Christensen (1965) reported this species from the Intracoastal Waterway and it was frequently taken during this study, including gravid females. A similar pattern of colonization and subsequent establishment is also probable for Astrapogon alutus, Malacoctenus macropus, and Doratonotus megalepis. Populations of these these species may not be directly dependent on allochthonous larval recruitment to ensure their persistence.

Regardless of origin, the larvae that actually enter the inlet are likely to settle over preferred substrates. Habitat selection by the recruits, coupled with differential predation, may determine the observed between-site differences in species composition and abundance (Williams and Hatcher, 1983; Weinstein and Brooks, 1983). Certain reef fishes are known to be quite proficient at selecting suitable or preferred settlement sites (Williams, 1980; Williams and Sale, 1981;

Barlow, 1981). While similar information does not exist for seagrass fishes, Martin and Cooper (1981) found different fish assemblages associated with pure stands of Thalassia and Syringodium, suggesting some degree of habitat selection. The occurrence and abundance of some species taken exclusively at the Intracoastal site may be the result of habitat selection by the incoming propagules.

Recent evidence points towards habitat complexity as the most significant factor in determining local and latitudinal differences in species richness in seagrass communities (Heck and Orth, 1980; Weinstein and Heck, 1979; Weinstein and Brooks, 1983). The Intracoastal site was certainly more complex in terms of cover and biomass of seagrasses. This site also contained greater amounts of drift macroalgae, which adds considerable refuge for some fishes (Kulczycki et al., 1981; Stoner and Livingston, 1980) as well as supporting numerous invertebrates (Gore et al., 1981). The role of vegetation density on predator success and prey refuge has been confirmed experimentally (Nelson, 1979; Heck and Thoman, 1981). Increased plant biomass might also explain the greater abundance and occurrence of scarids at the Intracoastal site. Grazing activity of scarids can have significant effects on energy transport and local algal biomass; however, the actual role of herbivory in the present system is unknown (Heck, 1979; Ogden, 1980). Additional heterogeneity may be introduced to the habitat by patchiness within the seagrass bed (Heck and Orth, 1980). Interspersion of sandy patches was observed at both sites. Sandy areas, which were much smaller but more frequent at the

Intracoastal site, may be of considerable importance to resident fishes. Visual observations (with snorkeling gear) at the Intracoastal site indicate that Orthopristes chrysoptera, Lagodon rhomboides, Eucinostomus gula, E. argenteus, Haemulon sciurus, H. plumeri, Leiostomus xanthurus, and Caranx bartholomaei forage for benthos within these sandy patches. Therefore, the nearby grassy stands may serve more as refugia from predators than as a source of invertebrate prey items for these species. Sand patches are also inhabited by demersal fishes such as gobiids, bothids, synodontids, and, occasionaly, opisthognathids. The greater area of sand at the inlet site may explain the abundance of sediment-foraging Eucinostomus spp. and the fossorial gobies (Gobionellus boleosoma and Bathygobius soporator) observed there. Central to the habitat heterogeneity hypothesis (Weinstein and Heck, 1979; Heck, 1979; Orth and Heck, 1980) is the presence of contiguous coral reefs in species-rich tropical grassbeds. Exchange of species between the two habitats resulted in higher richness values for the seagrass beds in such areas. There are no diurnal exchanges between coral reefs and Jupiter grassbeds, but many of the species associated with reef-seagrass interfaces in the Carribean (e.g., haemulids, lutjanids, scarids) are taken here.

Prior to man's intervention, Jupiter Inlet was subjected to the vagaries of coastal sediment dynamics. That is, as a result of littoral sand transport, often amplified by storms, the inlet was periodically closed, sometimes resulting in a complete transition from marine to freshwater biotas within the lagoon (Dubois, 1965;

Christensen, 1965; Vines, 1970). The proposed role of unpredictable availablity of recolonizable space (via disturbance) in determining fish community structure (Sale, 1977, 1979; Bonshack and Talbot, 1980) makes these closures and subsequent reopenings of great interest. Fish assemblages occupying lagoonal habitats might have reached different stable points (Sutherland, 1974) following each recolonization episode. Species composition within particular habitats may have depended on order of initial settlement by propagules and were maintained through certain priority effects (Schulman et al., 1983). Jupiter Inlet was last closed from 1942-1947 and has since been maintained by dredging operations (Dubois, 1965; Christensen, 1965). Conceivably, in the absence of such paroxysms, present-day fish communities could be fairly stable in terms of species composition.

Most attempts at elucidating community organizations in fishes end without pinpointing precise causal mechanisms. This is partly due to the difficulty of conducting controlled experiments in natural communities and the fact that such communities are governed by a multifarious array of biological and physical factors. In Jupiter Inlet, the local hydrographic regime is the underlying factor responsible for seagrass growth (McPherson et al. 1982) and conditions promoting colonization by fishes and invertebrates. The overall lack of strong statistical correlations among environmental and biotic variables need not imply that such effects are not important. Individual populations are in a constant state of flux between arrival and loss. As a result of this the frequency of many species remains

high while population densities fluctuate with recruitment. Long term investigations of estuarine fish populations by Livingston et al. (1975) indicate that while annual cycles were quite variable, the overall trend exhibited considerable temporal constancy which was interpreted as stability. However, a single year's study is probably insufficient to draw any conclusions regarding stability or equilibrium within local populations. The importance of the critical habitat approach to conservation and management of inland waters is demonstrated here, and the fact that grassbed habitats cannot be viewed in general terms, despite their proximity, also has implications for mitigation procedures. Lagoonal grassbeds near Jupiter Inlet, despite their limited areal coverage, support diverse assemblages of fishes, including a greater proportion of tropical species than would have been predicted (Weinstein and Heck, 1979) in the absence of contiguous coral reefs.

APPENDIX A

APPENDIX A
Species List (All names follow Robins et al., 1980)

(Collection methods: S=Seine; P=Pushnet; C=Castnet; H=Handnet)

	S	P	C	H
Torpedinidae				
Narcine brasiliensis (Olfers)	X			
Dasyatidae				
Dasyatis sayi (LeSueur)	X			
D. sabina (LeSueur)	X			
Myliobatidae				
Aetobatus narinari (Euphrasen)				
Rhinoptera bonasus (Mitchill)	X			
Muraenidae				
Gymnothorax moringa (Cuvier)	X			
Ophichthidae				
Myrophis punctatus Lutken	X			
Clupeidae				
Harengula clupeola (Cuvier)	X		X	
H. humeralis (Cuvier)	X		X	
H. jaguana Poey	X		X	
Opsithonema oglinum (Lesueur)	X		X	
Sardinella aurita Valenciennes	X		X	
Engraulidae				
Anchoa cayorum (Fowler)	X			
A. cubana (Poey)	X			
A. lamprotaenia Hildebrand	X			
A. lyolepis (Evermann and Marsh)	X			
A. mitchilli (Valenciennes)	X			
A. nasuta Hildebrand and Carvalho	X			
Synodontidae				
Synodus foetens (Linnaeus)	X	X	X	
Ariidae				
Arius felis (Linnaeus)				
Antennariidae				
Histrio histrio (Linnaeus)	X	X		
Belonidae				
Strongylura notata (Poey)	X		X	
S. timucu (Walbaum)	X		X	
Cyprinodontidae				
Cyprinodon variegatus (Lacepede)	X			
Fundulus grandis Baird and Girard	X			
Atherinidae				
Hypoatherina harringtonensis (Goode)	X			
Aulostomidae				
Aulostomus maculatus Valenciennes	X			

	S	P	C	H
Fistulariidae				
Fistularia tabacaria Linnaeus	X	X		
Syngnathidae				
Cosmocampus brachycephalus (Poey)		X		
Hippocampus erectus Perry	X	X		
H. zosterae Jordan and Gilbert				
Micrognathus criniger (Bean and Dresel)		X		
Syngnathus dunckeri Metzelaar	X			
S. floridae (Jordan and Gilbert)	X	X		
S. louisianae Gunther	X	X		
S. scovelli (Evermann and Kendall)	X	X		
S. springeri Herald	X			
Centropomidae				
Centropomus undecimalis (Bloch)	X		X	
C. parallelus Poey	X			
Serranidae				
Diplectrum formosum (Linnaeus)	X			
Epinephelus morio (Valenciennes)		X		
Hypoplectrus unicolor (Walbaum)			X	
Mycteroperca bonaci (Poey)		X		
M. microlepis (Goode and Bean)	X			
Serranus subligarius (Cope)		X		
Apogonidae				
Astrapogon alutus (Jordan and Gilbert)	X	X		
A. puncticulatus (Poey)	X	X		
Carangidae				
Caranx bartholomaei Cuvier	X		X	
C. crysos (Mitchill)	X		X	
C. hippos (Linnaeus)	X			
C. latus Agassiz	X			
Oligoplites saurus (Schneider)	X			
Selar crumenophthalums (Bloch)	X			
Selene vomer (Linnaeus)	X			
Trachinotus falcatus (Linnaeus)	X		X	
T. carolinus (Linnaeus)	X		X	
Lutjanidae				
Lutjanus analis (Cuvier)	X	X	X	
L. apodus (Walbaum)	X	X	X	
L. griseus (Linnaeus)	X	X	X	
L. jocu (Schneider)	X			
L. synagris (Linnaeus)	X	X	X	
Ocyurus chrysurus (Bloch)	X	X		
Lobotidae				
Lobotes surinamensis (Bloch)	X			
Gerreidae				
Diapterus auratus Ranzani	X			

	S	P	C	H
Eucinostomus argenteus Baird	X	X	X	
E. gula (Quoy and Gaimard)	X	X	X	
E. lefroyi (Goode)	X			
E. melanopterus (Bleeker)	X	X		
Gerres cinereus (Walbaum)	X	X		
E. jonesi Gunther	X	X		
Haemulidae				
Haemulon aurolineatum Cuvier	X			
H. chrysargyreum Gunther	X	X		
H. flavolineatum (Desmarest)	X	X		
H. melanurum (Linnaeus)	X			
H. parrai (Desmarest)	X	X	X	
H. plumieri (Lacepede)	X	X	X	
H. sciurus (Shaw)	X	X	X	
H. striatum (Linnaeus)	X			
Orthopristis chrysoptera (Linnaeus)	X	X	X	
Sparidae				
Archosargus probatocephalus (Walbaum)			X	
Calamus arctifrons Goode and Bean	X			
Diplodus holbrooki (Bean)	X	X		
Lagodon rhomboides (Linnaeus)	X	X	X	
Sciaenidae				
Bairdiella chrysoura (Lacepede)	X	X	X	
Cynoscion nebulosus (Cuvier)	X	X		
Leiostomus xanthurus Lacepede	X		X	
Sciaenops ocellatus (Linnaeus)	X			
Mullidae				
Pseudopeneus maculatus (Bloch)	X			
Ephippidae				
Chaetodipterus faber (Broussonet)	X	X		
Pomacentridae				
Abudefduf saxatilis (Linnaeus)	X			
Pomacentrus luecostictus Muller and Troschel	X			
Labridae				
Doratonotus megalepis Gunther	X	X	X	
Halichores bivittatus (Bloch)	X			
Hemipteronotus splendens (Castelnau)	X			
Scaridae				
†*Cryptotomus roseus* Cope	X	X		
Nicholsina usta (Valenciennes)	X	X	X	
Sparisoma chrysopterum (Bloch and Schneider)	X	X	X	
S. radians (Valenciennes)	X	X		
S. rubripinne (Valenciennes)	X	X	X	
Scarus coeruleus (Bloch)	X	X		
Mugilidae				
Mugil cephalus Linnaeus	X		X	

	S	P	C	H
Balistes capriscus Gimelin	X	X		
Monacanthus ciliatus (Mitchill)	X	X	X	
M. hispidus (Linnaeus)	X	X	X	
M. setifer Bennett		X		
Ostraciidae				
Lactophrys trigonus (Linnaeus)	X	X	X	
L. quadricornis (Linnaeus)	X	X		
Tetradontidae				
Sphoeroides nephelus (Goode and Bean)	X	X	X	
S. spengleri (Bloch)	X	X	X	
S. testudineus (Linnaeus)	X	X	X	
Diodontidae				
Chilomycterus antillarum Jordan and Rutter	X			
C. schoepfi (Walbaum)	X	X		
Diodon holocanthus Linnaeus	X	X		

* Smith-Vaniz, W.F. and P.L. Colin, MS refer to this as *O. robinsi*.

† *Cryptotomus* from florida probably represent a distinct continental species. C.R. Robins personal comm.

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SPECIES RICHNESS, ABUNDANCE AND OCCURRENCE OF GRASSBED FISHES FROM JUPITER INLET, FLORIDA

by

David B. Snyder

This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Walter R. Courtenay, Jr., Department of Biological Sciences and has been approved by the members of his supervisory committee. It was submitted to the faculty of the College of Science and was accepted in partial fulfillment of the requirements for the degree of Master of Science.

SUPERVISORY COMMITTEE:

Walter R. Courtenay, Jr.
Thesis Advisor

Allen Mark

Jeffrey N. Taylor

Sheldon Dobkin

Walter R. Courtenay, Jr.
Chairperson, Department of Biological Sciences

Sheldon Dobkin
Dean, College of Science

Dean for Advanced Studies

Date