SOUTH FLORIDA RESEARCH CENTER

Report SFRC-87/02

Distribution and Abundance of Fish Communities Among Selected Estuarine and Marine Habitats in Everglades National Park

NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

Everglades National Park, South Florida Research Center, P.O. Box 279, Homestead, Florida 33030

DISTRIBUTION AND ABUNDANCE OF FISH COMMUNITIES AMONG SELECTED ESTUARINE AND MARINE HABITATS IN EVERGLADES NATIONAL PARK

SFRC-87/02

Gordon W. Thayer, William F. Hettler, Jr.,
Alexander J. Chester, David R. Colby, Patti J. McElhaney

U.S. Department of Commerce
National Marine Fisheries Service, NOAA
Southeast Fisheries Center
Beaufort Laboratory
Beaufort, North Carolina 28516

1987

TABLE OF CONTENTS

LIST OF TABLES

List of Tables (Contd)

LIST OF FIGURES

List of Figures (Contd)

List of Figures (Contd)

List of Figures (Contd)

ABSTRACT

The overall objective of our juvenile study was to evaluate relative species abundance and size composition of fish communities among selected habitats in estuarine and marine waters of Everglades National Park and to provide descriptions of the habitats in which these fishes occurred. Particular emphasis was placed on spotted seatrout (Cynoscion nebulosus) and gray snapper (Lutjanus griseus). The study was divided into two subobjectives --juvenile fish associated with open water habitats and fish utilizing red mangrove prop root habitats.

The study area was subdivided into five sampling strata that included Whitewater Bay-Coot Bay, channels in Florida Bay, and three open water areas between western and eastern Florida Bay. Random sampling was conducted within these strata as well as regular periodic sampling at several selected sites. Coot Bay and eastern Whitewater Bay are characterized by low salinities and sediments with high organic content and generally low densities of Ruppia maritima and/or Halodule wrightii. Channel areas in Florida Bay generally display the highest overall standing crop and density of seagrasses composed of Thalassia testudinum, Syringodium filiforme and Halodule wrightii. The western strata of Florida Bay adjacent to the Gulf of Mexico was the most diverse in terms of seagrass composition, particularly in the northern portion, and exhibits the highest overall densities of Syringodium. The central and eastern strata are dominated by monotypic stands of Thalassia with the sparcest seagrass densities occuring in the eastern area adjacent to the Florida Keys. Here the sediment veneer is the thinnest observed in our study area.

Over 90 species of fish representing 43 families were collected during the study, and 11 species contributed to over 90% of the fish collected. Western Florida Bay and channels in Florida Bay consistently supported fish communities that were comprised of similar species and the highest densities relative to other study areas. On an areal basis, the average numerical abundance and standing crop values of fish we observed are similar to, but at the low end of, the range of several published reports of fishes in seagrass meadows. Cluster analysis demonstrated two obvious associations. One cluster was characterized by species that occurred frequently and in large numbers, and this grouping occurred primarily in channels and in northwestern Florida Bay where mixtures of Syringodium and Thalassia were prevalent. A second cluster was of low fish density stations that are generally in areas of sparce monotypic meadows of Thalassia.

Juvenile gray snapper and spotted seatrout were collected regularly, but in small numbers, during the stratified sampling phase as well as at regular sampling at Joe Kemp Key and Bradley Key. Although gray snapper were collected in western Florida Bay, they were most abundant in channels in eastern Florida Bay. This distribution is coincident with our larval sampling which found larval snapper only in the vicinity of the Florida Keys. Juvenile spotted seatrout were collected primarily in northwestern Florida Bay, and primarily in areas with mixed seagrass meadows containing Syringodium. Larval seatrout also were collected in greatest abundance in the same area, possibly suggesting only limited geographic movement of juveniles after settlement out of the plankton.

Discriminant function analyses of data from randomly sampled sites were employed in an attempt to identify those environmental characteristics most important in determining juvenile spotted seatrout and gray snapper habitat. High densities

of Syringodium and high percentages of organic matter in the sediments were particularly diagnostic of spotted seatrout habitat, while Halodule and Syringodium biomass were the most informative variables in describing gray snapper habitat, particularly when these seagrasses were present in channels. These discriminant functions were employed to classify Joe Kemp Key and Bradley Key collections as having occurred at target fish or non-target fish habitat. Target fish were collected on all occasions at Joe Kemp Key and Bradley Key and the discriminant functions developed from our stratified random sampling phase of the study classified the sampling locations at Joe Kemp Key and Bradley Key as target fish habitat on all but one occasion.

Data also are presented on the food habits of juvenile gray snapper and spotted seatrout, and on the distribution of spiny lobsters, blue and ornate crabs, and penaeid shrimp based on otter trawl collections at the randomly sampled sites. Food habit data was similar to published accounts for similar size fish. There appeared to be distinct distribution patterns of lobsters, crabs and shrimp.

The red mangrove prop roots of Whitewater Bay, Coot Bay and Florida Bay provides an extensive habitat that heretofore has not been evaluated quantitatively for fishes. A technique was developed and tested to sample these habitats quantitatively. Fishes collected from this habitat type were compared with fishes collected by trawl from the immediately adjacent seagrass habitat. The mangrove prop root habitat supported an overall greater density and standing crop of fish. Several of the species utilizing the prop root habitat are of commercial and recreational importance (e.g., mullet and gray snapper), while many are forage foods for predatory fishes. This phase of the study demonstrated that the red mangrove prop root habitat is utilized by a wide variety of fish, and that greater attention should be given to evaluating its contribution as a refuge and a source of food resources for fishes in Everglades National Park.

INTRODUCTION

There are relatively few publications addresssing the ecology of the estuarine habitats of Everglades National Park and specifically the ecology of juvenile and forage fishes. Published data on recreationally and commercially important juvenile fishery organisms in estuarine and marine waters of Everglades National Park do not provide a great deal of insight into their distribution and abundance or their preferred habitats. Recently, Odum et al. (1982), Schomer and Drew (1982) and Zieman (1982) described aspects of the ecology of south Florida estuarine areas and Florida Bay. They summarized general distributions of fishery organisms associated with mangrove-lined environments and seagrass meadows, but little quantitative information are available on juveniles. Tabb and Manning (1961, 1962) and Tabb and Dubrow (1962) provided lists of invertebrate and fish species in portions of the area as well as information on general habitats of these species. These data predate the perceived decline in harvest felt by sportfisherman (Davis 1982), and pertain primarily to Whitewater Bay, Coot Bay and western Florida Bay. Powell, et al. (1986) have described the ecology of the fish communities using several carbonate mud banks in Florida Bay, and have shown this to be a very dynamic habitat used by large numbers of fish of numerous species.

The objective of the juvenile phase of the overall Beaufort Laboratory study (see Beaufort Laboratory, 1987) was to evaluate the relative species abundance and size composition of fish communities among selected habitats in the estuarine and marine waters of Everglades National Park and to provide descriptions of the habitats sampled. We examined a variety of habitat characteristics in an attempt to discriminate their roles in structuring fish communities utilizing these habitats. Our emphasis was on four target species: gray snapper, spotted seatrout, red drum, and snook. Most of the fish we captured were species other than the target species. We include information on these fishes in this report to characterize the fish communities in selected estuarine and marine habitats of the Park. Little information was available until this report and that of Powell et al. (1986) on the relative distribution and abundance of the pelagic, shallow-water estuarine fish of the Everglades National Park, such as the clupeids, engraulids, atherinids, and belonids.

This juvenile fish phase of our study is subdivided into two subobjectives: juvenile fish associated with seagrass habitats; and fish communities utilizing red mangrove (Rhizophora mangle) prop root habitats. This latter part of our report is a combination of two manuscripts that currently are in press (see Thayer et al. 1987, In press).

I. FISH ASSOCIATED WITH SEAGRASS AND UNVEGETATED HABITATS

AREA AND METHODS

The study area sampled included open water and channel areas of southwestern Florida Bay, Coot Bay and eastern Whitewater Bay (Fig. 1), and included vegetated and unvegetated bottom. Two strategies were employed. A stratified random design with five strata was established for sampling the fish community and environmental parameters in open water and in channels. In addition, two permanent stations on carbonate banks adjacent to Joe Kemp Key and Bradley Key were sampled routinely; several other areas around Joe Kemp Key also were sampled but on an irregular basis.

Our sampling universe included eastern Whitewater Bay, Coot Bay, and Florida Bay west of a line drawn from Tavernier Creek to Madeira Bay. These boundaries were chosen based on available time and resources. Eastern Whitewater Bay, from an area northwest of Tarpon Creek to the embayment northwest of East River (Fig. 2), and Coot Bay (Fig. 3) formed a low salinity stratum (Stratum V). The remaining four higher salinity strata were located in Florida Bay. The northeastern boundary of the Florida Bay sampling area was a line from Tavernier Creek to Madeira Bay; the Park boundary formed the southeastern sampling limit; the shore from about East Cape Canal to Madeira Bay formed a boundary; and the western boundary was formed by a line from the East Cape Canal to a point on the gulf side of Ninemile Bank and then east to a point southwest of Peterson Keys (Fig. 4).

The areas sampled were designated as either open water habitats or channels and did not include the extensive carbonate mud banks characteristic of much of Florida Bay. The open water area of southwestern Florida Bay was subdivided into three approximately equal sized strata (Fig. 4) based on benthic vegetation distribution (Zieman and Fourqurean 1985) and discussions with Mr. Jim Fourqurean (Univ. Va., pers. comm.). Although variable plant biomasses were evident (Zieman and Fourqurean 1985), the overall lowest Thalassia standing crop was reported for Stratum I (east), generally intermediate standing crops for the

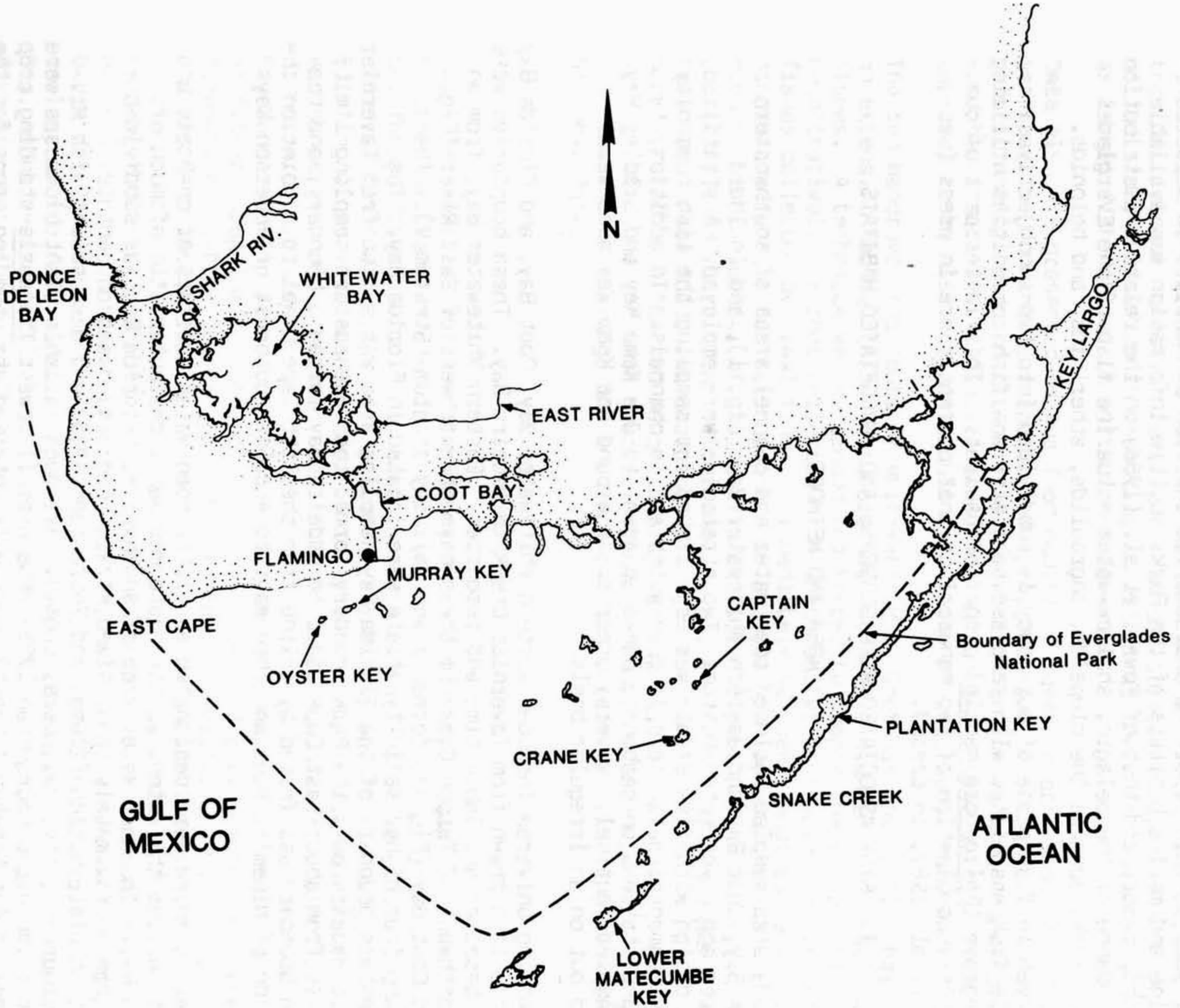


Figure 1. Diagram of the general sampling area showing Whitewater Bay, Coot Bay and Florida Bay.

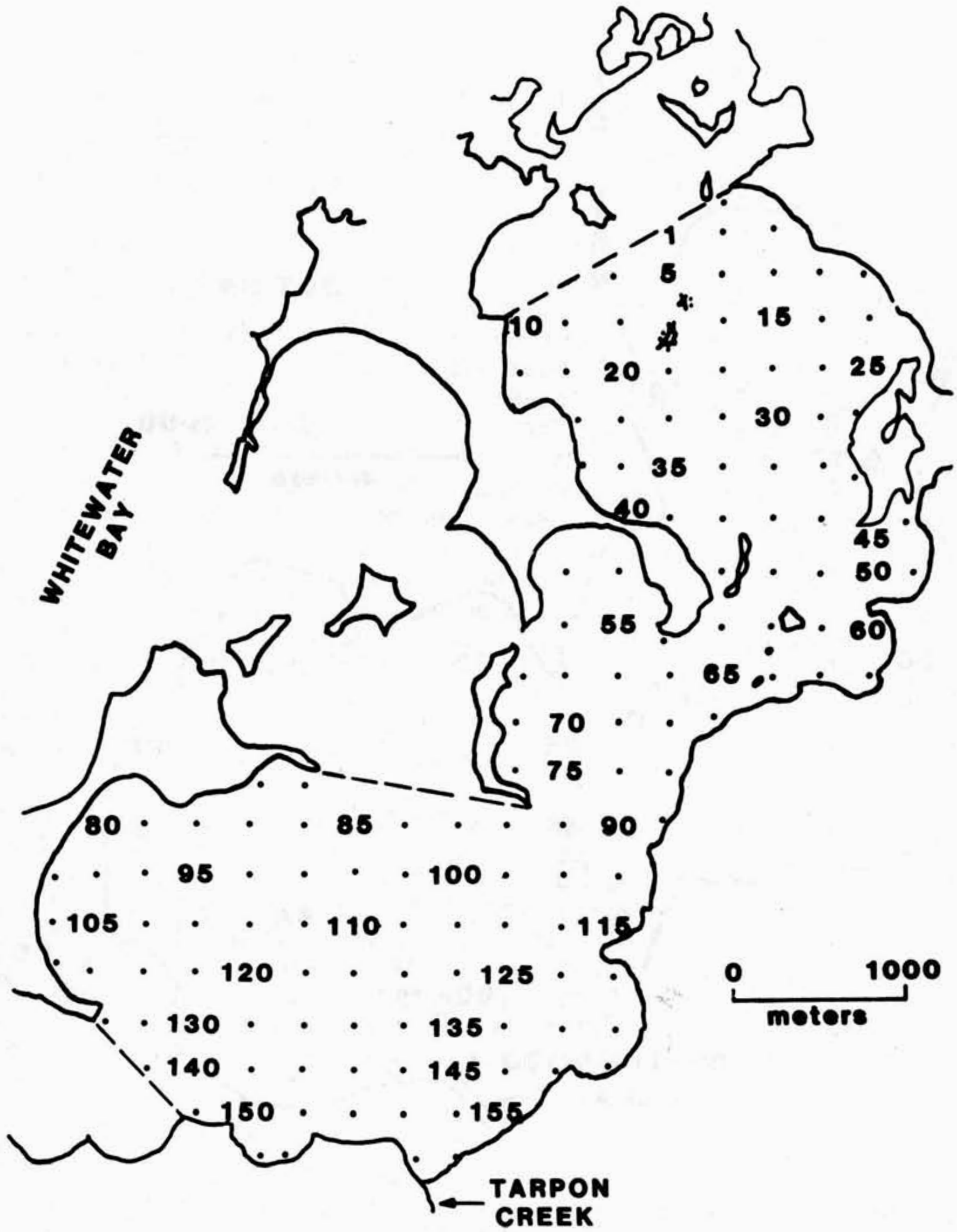


Figure 2. Diagram of the southeast section of Whitewater Bay showing sampling locations. Only every fifth station is noted, and each station represents an area approximately 400 m on a side.

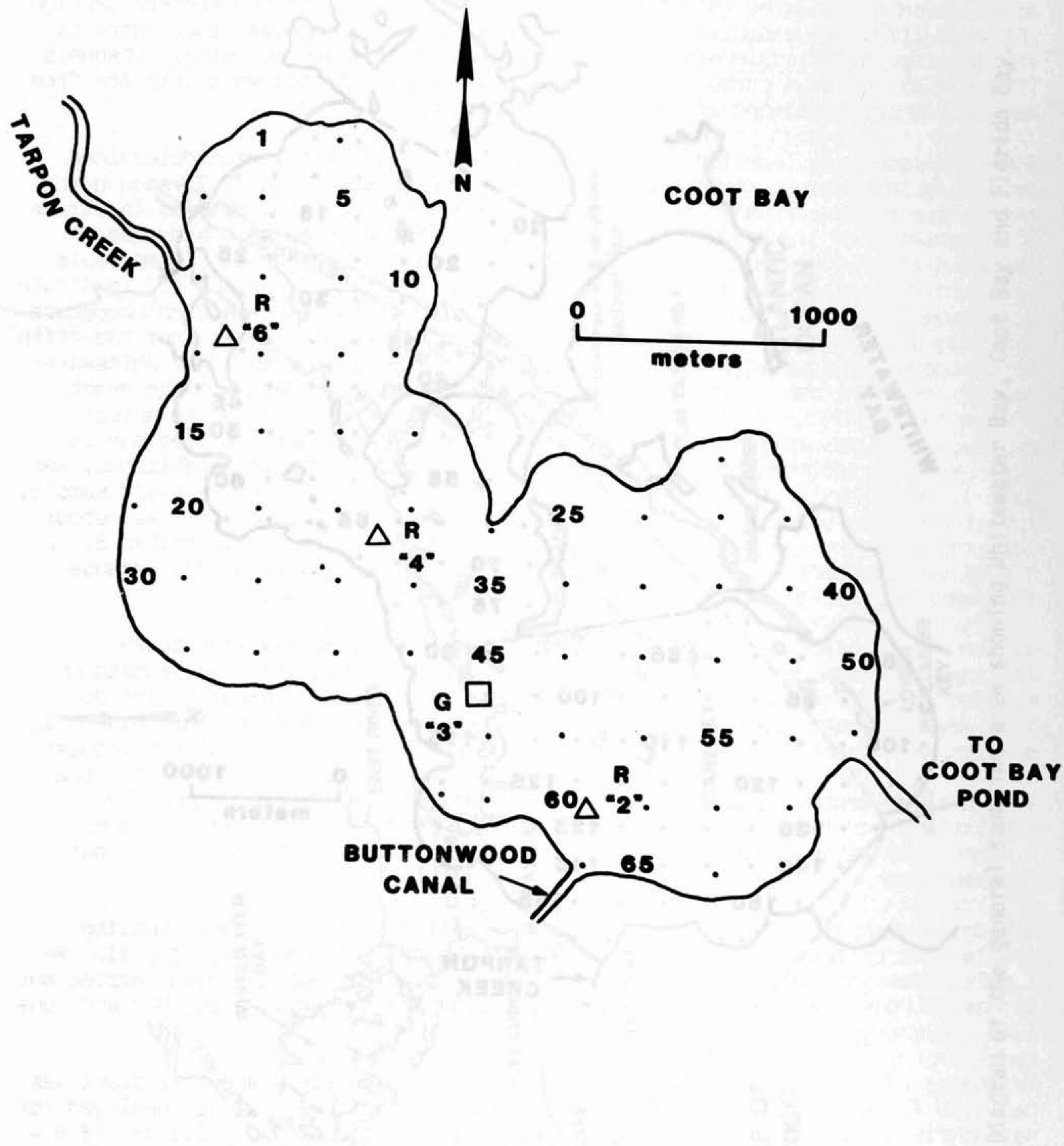


Figure 3. Diagram of Coot Bay showing location of sampling stations. Every fifth station is shown, and each station represents an area approximately 400 m on a side.

mid-portion of the area (Stratum II), and highest values in the western section (Stratum III). In establishing these strata, it was recognized that there is variability in Thalassia within each strata and from south to north. Channels (Stratum IV) between carbonate mud banks and between islands were selected from Nautical Chart-11451 and after on site inspection (Fig. 5).

Potential sampling locations within Strata I, II, III, and V were determined using a grid system. In Whitewater Bay and in Coot Bay (Figs. 2,3) each grid cell represented a square area approximately 400 m on a side, whereas in Strata I, II and III in Florida Bay (Fig. 6) each cell represented a square area approximately 1800 m on a side. There were 159 and 67 potentially sampleable cells in Whitewater Bay and Coot Bay, respectively, and 93, 98 and 107 in Strata I, II and III, respectively. Prior to each survey a random selection procedure was used to select six cells from each of the first three strata; from the fifth stratum, two were selected from Coot Bay and four were selected from Whitewater Bay. Three alternate cells also were selected for each stratum in the event that one or more of the six selected stations turned out, during the actual survey, to be unsampleable (i.e., if we were unable to reach the area due to shallow depths or the area was outside of sampling criteria we established, see below). We established a depth range of 0.5-2.3 m within which we would sample, and if the open water area fell outside the range, an alternate cell was used; this range did not pertain to channels. Prior to sampling we eliminated 8, 12 and 23 sample grids in Strata I, II, and III, respectively (Fig. 7), because they were either too shallow (< 0.5 m) or too deep (> 2.3 m).

Additional samples from the open water habitat of Florida Bay were taken routinely at both Joe Kemp Key and Bradley Key. A single area was sampled on each occasion adjacent to and to the east of the Flamingo Channel on the Joe Kemp Key carbonate mud bank (JKK #1); several other locations on this bank (Fig. 8) also were sampled periodically. Joe Kemp Key #1 was sampled at the request of Everglades National Park personnel. During our sampling we noted that the area off the western side of Bradley Key appeared to be "good target fish habitat" (i.e., had seagrass species combinations typical of where we were finding some target species), and we established a permanent station at that location.

Biological, physical and chemical data were collected (during each sampling) (Table 1) from the approximate mid-point of the randomly-chosen grid cell. We sampled fish, shrimp, crabs, vegetation, and sediment. Surveys were carried out in May, June, July, September and November 1984 and January, March, May and June 1985.

Two types of trawls were used to sample the fish community. An otter trawl was deployed for benthic fishes and crustaceans and a surface trawl was deployed for natant fishes. Both trawl types were pulled at a speed of 2.0 ± 0.2 m/s (3.5 - 4.5 knots) between two 5-m-long boats with 25-hp outboard engines. The surface trawl, without doors to open the mouth of the net, was pulled by two boats each angled about 45° away from the intended trawl transect to fish properly. For the otter trawl, which uses doors to open the net, we also used two boats to (1) increase our pulling power and speed and (2) avoid disturbing the trawl transect by the prop-wash.

Each trawl was pulled for 2 minutes in a downwind direction (except when confined to narrow channels). A floating marker, tethered to an anchor, was

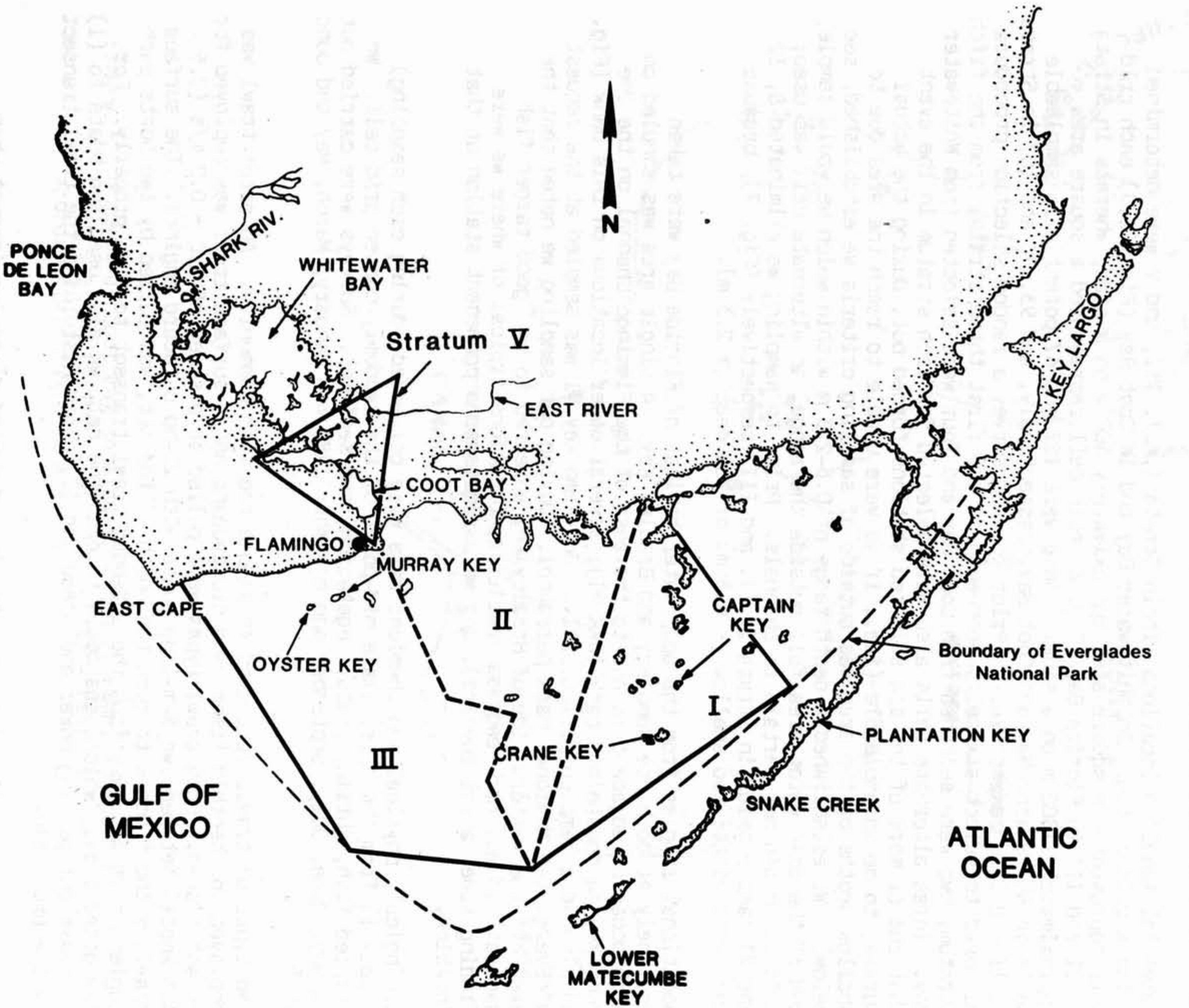


Figure 4. Diagram of Florida Bay showing the sampling area for Stratum III (west), Stratum II (mid) and Stratum I (east).

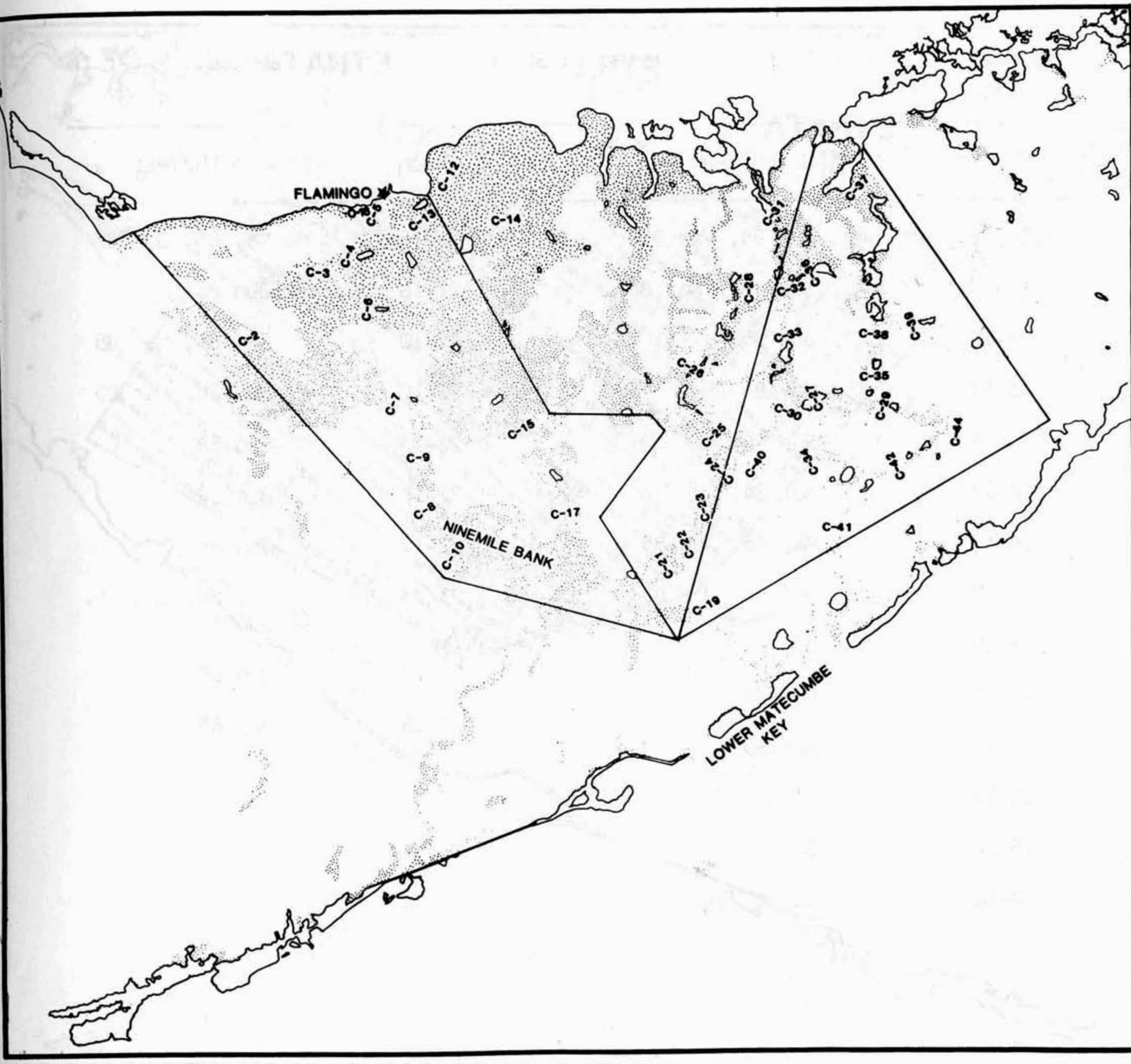


Figure 5. Diagram of Florida Bay depicting location of Channel stations (Stratum V).

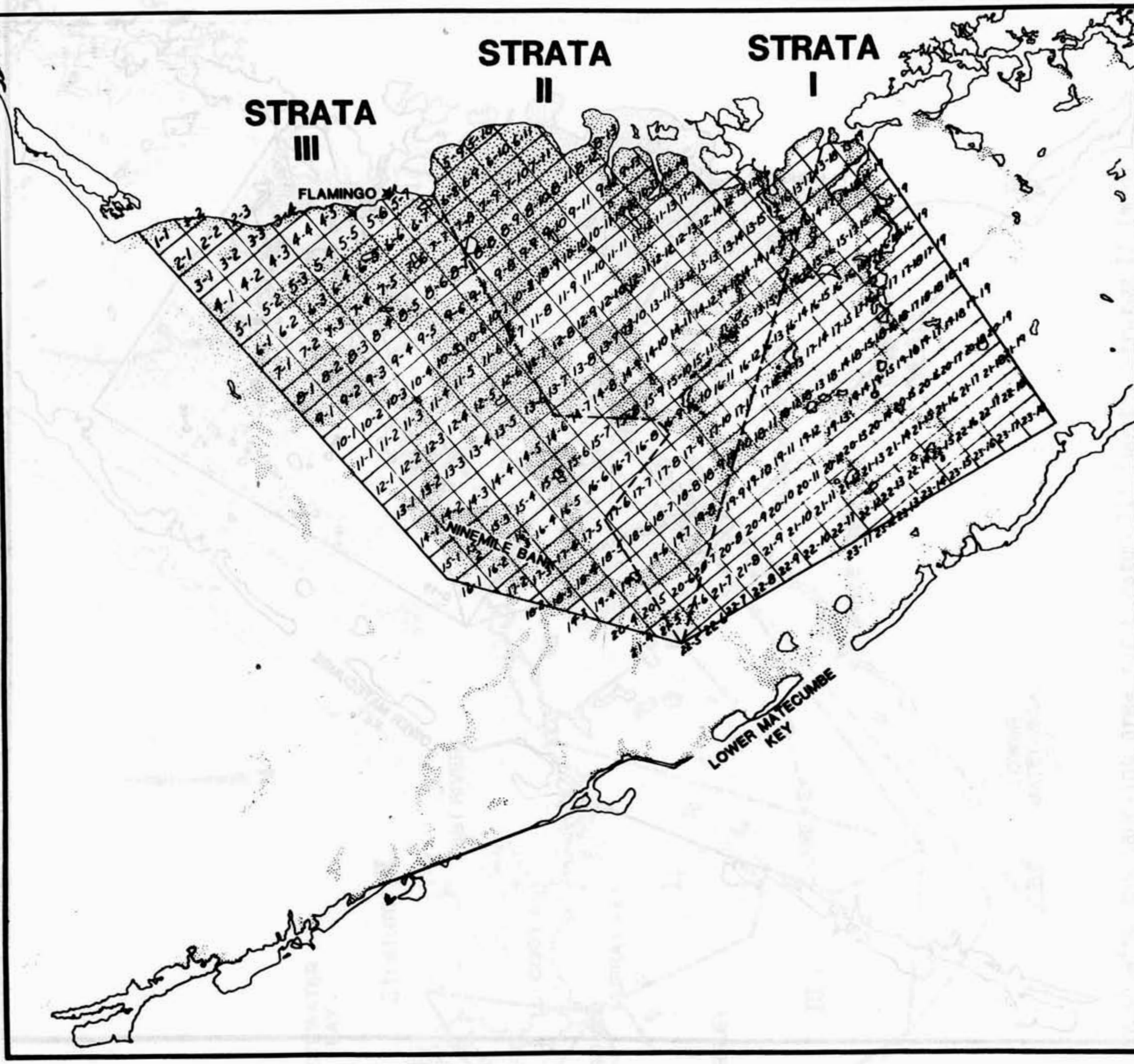


Figure 6. Diagram of Florida Bay showing the location of open water sampling stations. Each block (station) represents an area approximately 1800 m on a side.

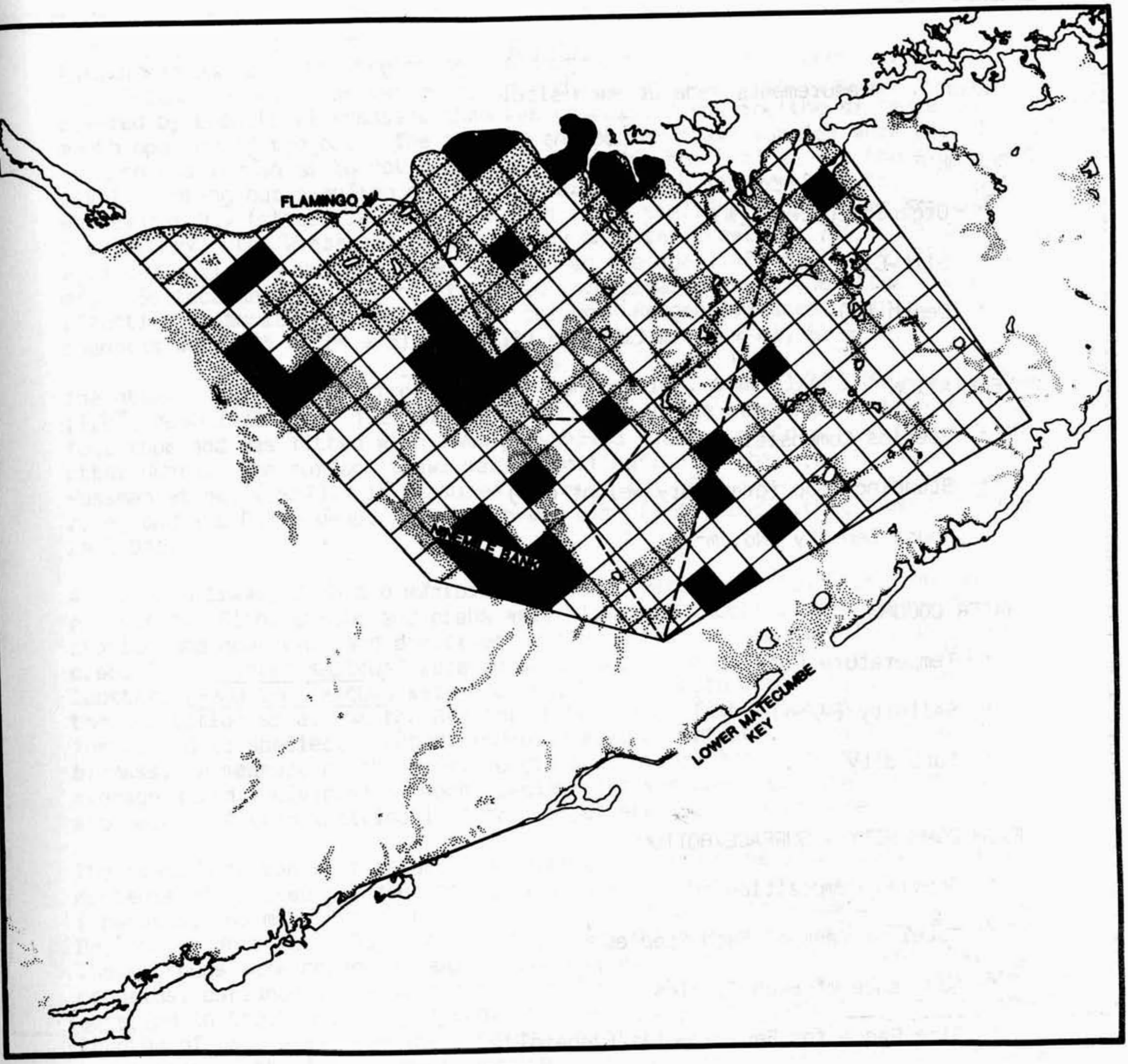


Figure 7. Diagram of Florida Bay. Darkened blocks indicate areas deemed unsampleable due to depth.

Table 1. Measurements made at each site.

SEDIMENT

- Organic Content (%)
- Silt-Clay (%)
- Depth (m)

VEGETATION

- Species Composition
- Standing Crop (grams dry weight$\cdot m^{-2}$)
- Shoot Density (No. m^{-2})

WATER COLUMN

- Temperature (°C)
- Salinity ($^{o}/oo$)
- Turbidity

FISH COMMUNITY - SURFACE/BOTTOM

- Species Composition
- Total Biomass of Each Species
- Abundance of Each Species
- Size Range for Each Species (general)

  Target Species

  - Length-frequency distribution
  - Weights of individuals
  - Stomach contents

thrown overboard at the beginning and another at the end of each tow from which the distance of each tow was measured with an optical range finder. The area covered by each trawl transect then was calculated knowing the distance and mouth opening of the net. The surface and bottom trawl samples were positioned at each station so as to not overlap and disturb the habitat for the subsequent trawl. During our sampling of non-channel areas in Florida Bay, Coot Bay and Whitewater Bay (stratified stations plus fixed stations at Joe Kemp Key and Bradley Key), the average area sampled by an otter trawl was 784 m^2 (N = 229, SE = 14 m^2) while the surface trawl covered an average 1148 m^2 (N = 223, SE = 23 m^2). Surface samples were not taken in some areas because the otter trawl effectively sampled the entire water column. Respective areas sampled in channels were 795 m^2 (N = 51, SE = 33) and 1213 m^2 (N = 41, SE = 55).

The otter trawl was made from tarred nylon netting, 6-mm (1/4") bar with a 3-mm (1/8") mesh tail bag. The net measured 3.4 m at the head rope and 3.8 m at the foot rope and was fitted with 3-mm galvanized tickler chain strung between the otter doors. The surface trawl was a modification of the net described by Massman et al. (1952). It measured 6.6 m at the head rope, 6.2 m at the foot rope, and was 0.7 m deep. Wing mesh was 6-mm (1/4") bar with a 3-mm (1/8") mesh tail bag.

After each trawl, fish and macroinvertebrates were separated from plant material collected. Fish, shrimp and crabs were placed in labelled sample bags for each station and gear type and preserved in 10% Formalin. Occasionally, large blue crabs (Callinectes sapidus) were measured and returned to the water. All lobsters (Panulirus argus) were counted, total length measured, and returned to the collection area. At the Beaufort Laboratory, fish and crustaceans were identified to species, counted, and each species wet weighed as a measure of biomass. A measure of the total length of the smallest, largest and average-sized individual of each species also was made, but the standard length and weight of each individual of the target species were measured.

The stomach contents of target fish were analyzed in the laboratory. Stomach contents of spotted seatrout and gray snapper collected in all habitats (channels, red mangrove prop roots (Part II), open water/grass beds of Florida Bay and of Whitewater Bay and Coot Bay) were identified to major groups of prey. These groups were copepods, amphipods, isopods, crustacean zoea/megalopa, penaeids, carideans, crabs, mysids, and fish; only crustaceans and fish were observed in trout and snapper stomachs. Although the number and size (maximum length) of each prey item was recorded, data analysis was reduced to a comparison of the frequency of occurrence of each major prey group in stomachs of fish in seven size classes. Gravimetric analysis was not appropriate because of a wide range of digestive decomposition and/or regurgitation caused by preservation time. For example, in some stomachs freshly ingested shrimp would appear whole and could be easily quantified, whereas in other fish stomachs, especially those captured later in the day, only remnants of shrimp body parts could be recovered.

Surface and bottom temperature and salinity were measured (YSI model 33 S-C-T meter) at each station, midway along and adjacent to each trawl line. At salinities in excess of 37 $^0/oo$ a refractometer was employed. Water samples also were taken for turbidity; unfortunately, our Monitek Nephelometer never functioned successfully during the study period, and therefore turbidities are not reported. At each station a SCUBA diver took triplicate 100 cm^2 samples

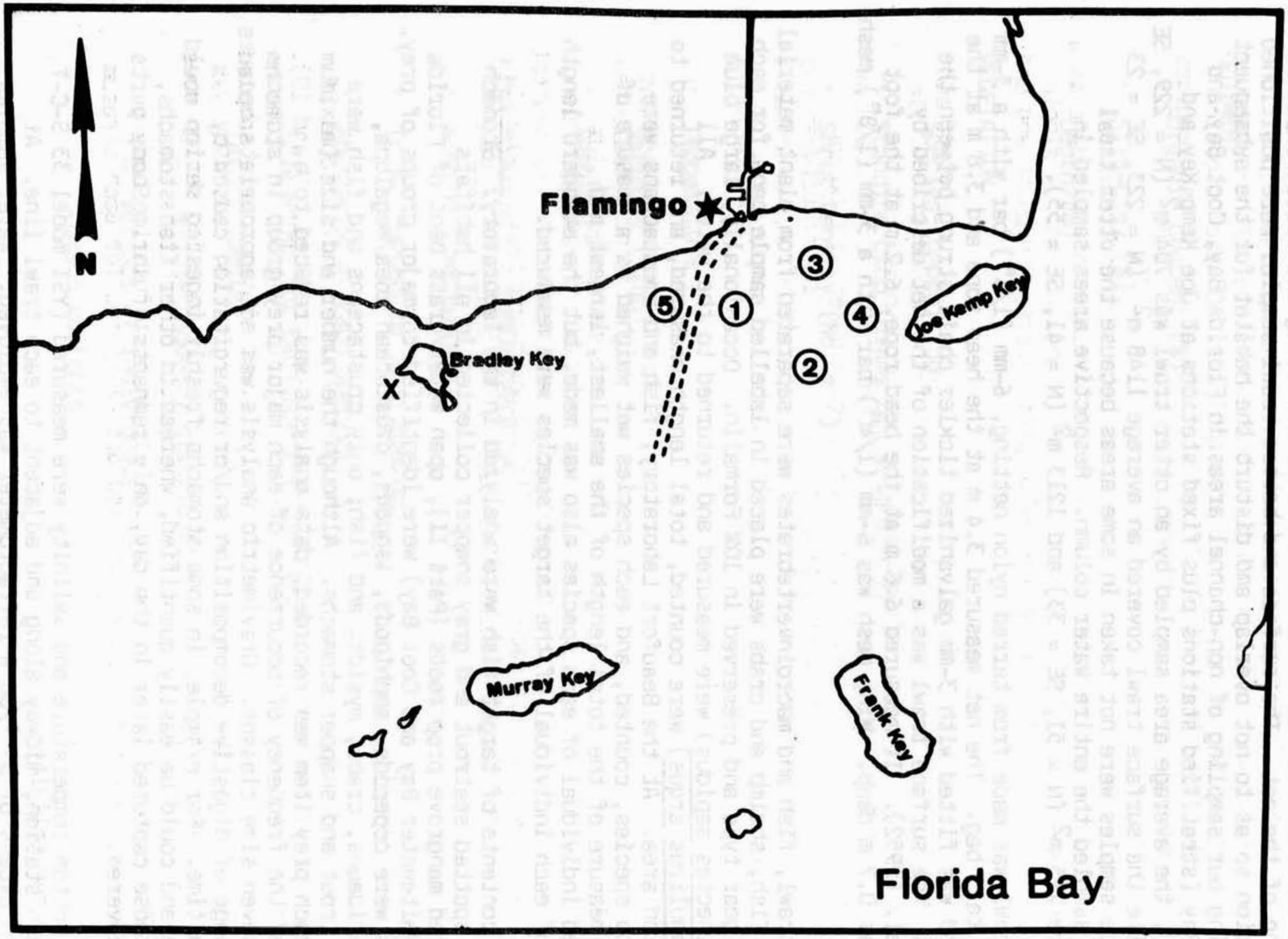


Figure 8. Diagram of area near Flamingo, FL, in Florida Bay showing location of Joe Kemp Key sampling stations and Bradley Key. Bradley Key was sampled on the west and only Joe Kemp Key Station 1 data are reported herein.

(quadrat with 10-cm sides) of vegetation plus a sample of surface sediment. For each sample, an individual on board the vessel tossed a sample quadrat over his shoulder, and where the quadrat landed above-ground vegetation was totally removed from within the quadrat frame at the sediment water interface; this was repeated two more times. Each sample was rinsed of sediment, placed in a labelled bag, and stored on ice for analyses at the laboratory. The surface sediment sample also was placed on ice for later analysis. On each occasion a marked pole was pushed into the sediment in the vicinity of one of the seagrass samples, and the depth of penetration to bedrock recorded if $\leq$ 2 m.

A different procedure was used in channels. All sampling for environmental characteristics in the channels took place prior to trawling; this was done as a safety precaution since otter trawling made channels highly turbid. A single sediment and grass sample was taken at the anticipated start, mid-point and end of a trawl.

Sediment samples were dried at 65°C, and then analyzed for organic content and percent silt-clay. Pulverized and weighed subsamples were placed in a muffle furnace at 500°C for 24 h and the loss of weight taken as a measure of organic content. The remaining sediment was weighed and wetted using saturated sodium hexametaphosphate solution, and wet sieved. Material retained on 4.00 mm (shell) and 0.063 mm (sand) sieves were redried, and the difference between the initial total dry weight and the sum of these two size fractions was taken as a measure of silt-clay content. This procedure is a modification from the American Society for Testing and Materials (1963).

The plant samples were kept chilled until seagrasses were sorted at the laboratory. Individual short shoots of each seagrass species were counted and separated from any belowground material that may have been accidently collected. To remove carbonate, epiphytes and sediment, the shoots were rinsed in 10% phosphoric acid until effervesence ceased and then rewashed in seawater. The plant material was dried at 80°C to a constant weight and weighed to the nearest 0.001 g. Data were averaged for each sample site for each species: <u>Thalassia testudinum</u>, <u>Syringodium filiforme</u>, <u>Halodule wrightii</u>, and <u>Ruppia maritima</u>.

RESULTS AND DISCUSSION

<u>Description of Environmental Characteristics of Strata</u>

During the nine monthly sampling visits to Everglades National Park a total of 264 stations were occupied, several on more than one occasion (Figs. 9 and 10). Table 2 provides information on the stations in each strata that were sampled on each occasion. A total of 35, 40, 41, 31 and 50 different stations were sampled in Stratum I, II, III, IV, and V, respectively, representing 41%, 46%, 49%, 79% and 22% of the sampleable area in each stratum. Thus, this sampling design does provide an extensive geographic basis upon which to describe habitats and fishery organisms of the study area, and Florida Bay in particular. Summary data for the habitat characteristics we measured are presented for each stratum in Table 3.

Temperature and Salinity

Water temperature was similar among strata. A typical seasonal cycle was observed with minimum values in winter and maximum values in July and September

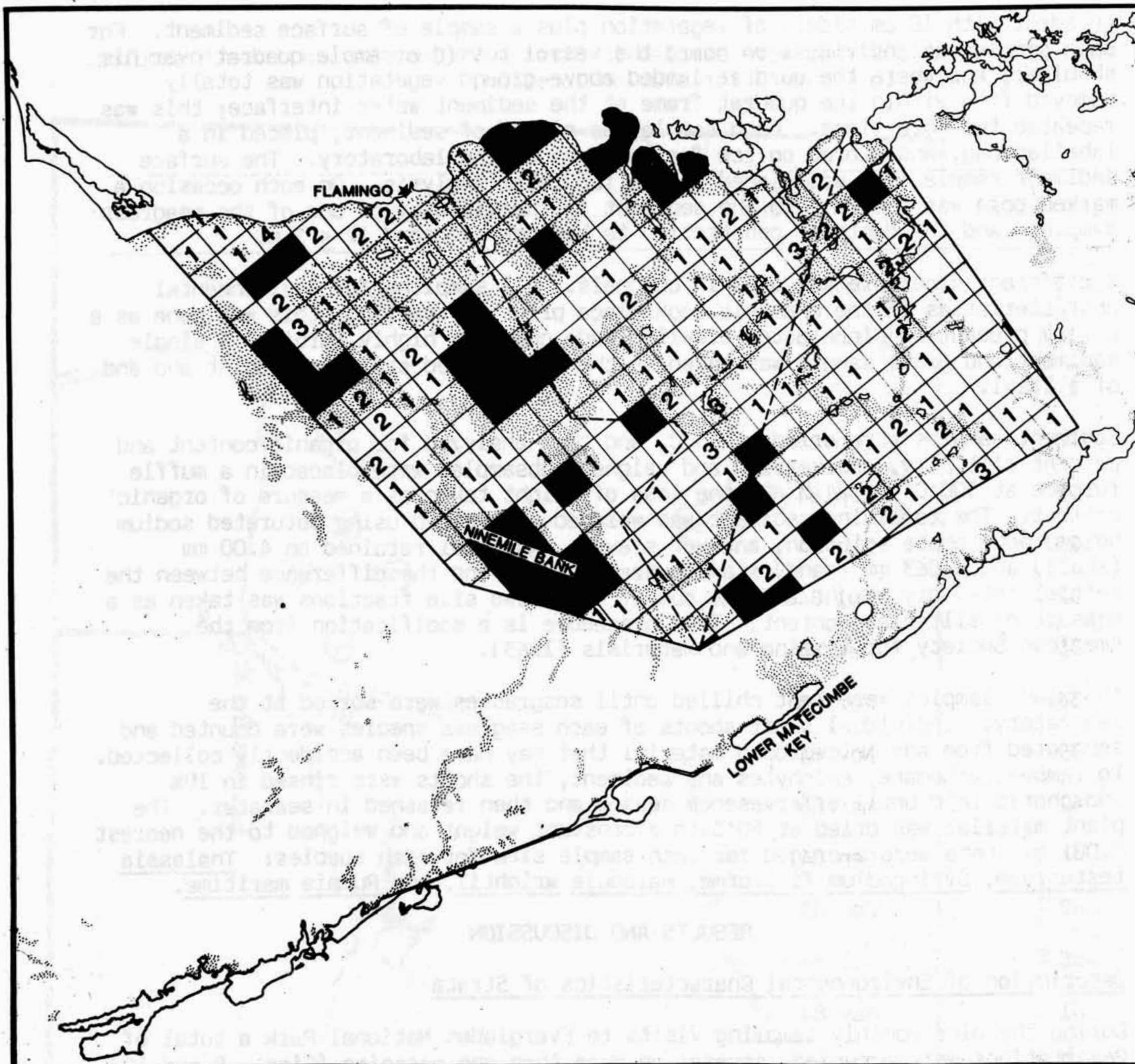


Figure 9. Diagram of sampling areas in Florida Bay. Number within a block indicates the number of times that station was sampled. Blocks lacking numbers were not sampled.

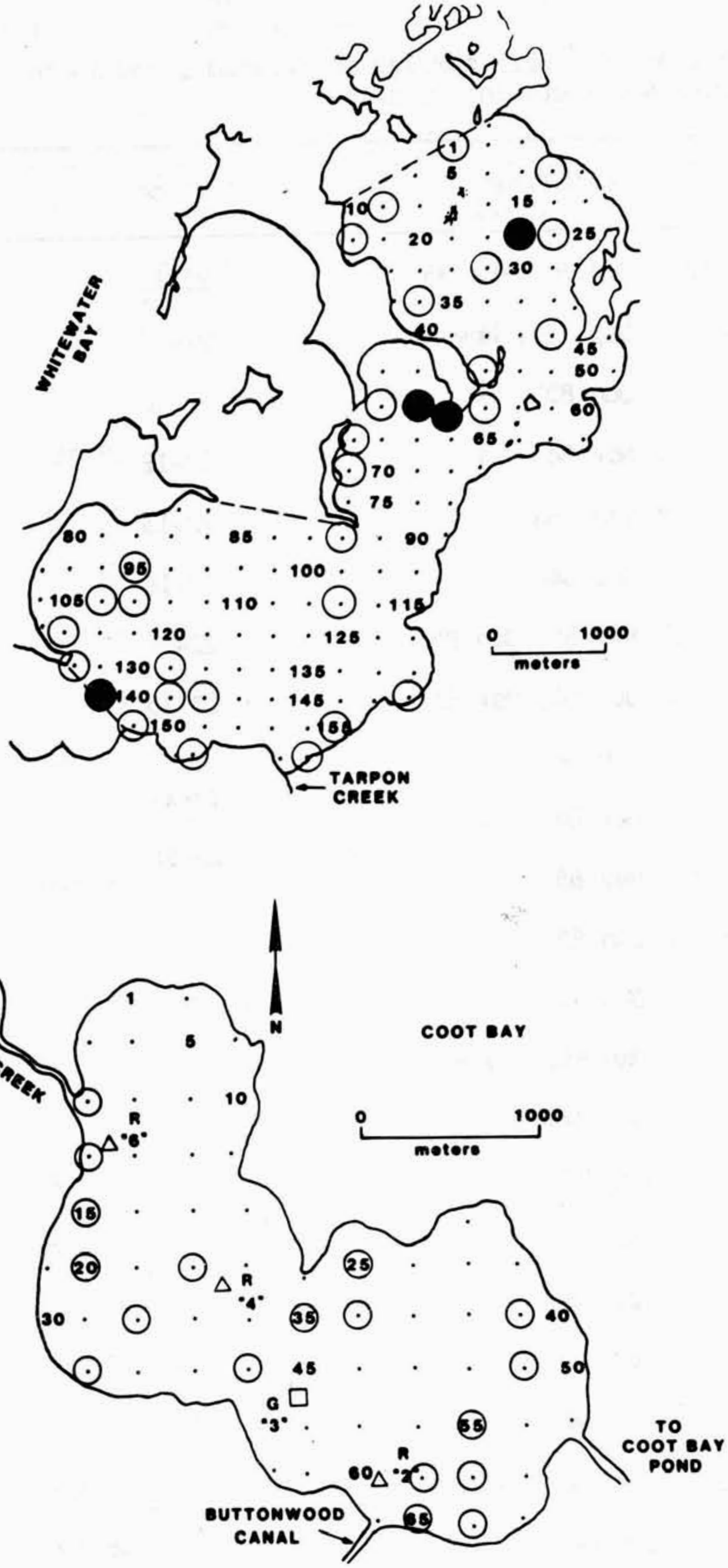


Figure 10. Diagram of Whitewater Bay (upper) and Coot Bay (lower). Stations with open circles were sampled once while darkened circles indicate stations sampled twice.

Table 2a. Stations that were sampled in Stratum I and month sampled. Refer to Figure 6 for station location.

Station	Month/Year	Station	Month/Year
14-16	Jul 84, Mar 85	21-15	May 85, Jun 85
14-17	Sep 84, Nov 84	21-16	Jun 84
14-19	Jun 85	22-10	Sep 84, Mar 85
15-17	Nov 84	22-12	Nov 84, Mar 85
16-14	Sep 84	22-13	Sep 84
16-15	Jul 84	22-16	Jun 84
16-17	May 85, Jun 85	22-17	Jan 85
16-18	Jul 84, Mar 85	23-15	Nov 84, Jan 85, Jun85
16-19	Jun 84	23-17	Jun 85
17-12	Nov 84	23-18	May 85
17-16	May 85		
18-13	Jan 85		
18-14	Jun 84		
18-16	Jan 85, May 85		
18-18	Jul 84		
19-12	Mar 85		
19-16	Jun 85		
20-9	Mar 85		
20-12	Sep 84		
20-13	Nov 84		
20-14	Jun 84, May 85		
20-15	Jun 84		
20-19	Jan 85		
21-8	Jul 84, Sep 84		
21-12	Jul 84, Jan 85		

Table 2b. Stations that were sampled in Stratum II and month sampled. Refer to Figure 6 for station location.

Station	Month/Year	Station	Month/Year
5-9	Sep 84	14-15	May 84, Jul 84, Mar 85
7-10	May 84, Jun 84	15-9	Sept 84, Nov 84
8-9	Jun 84	15-10	Jul 84
8-10	Jun 85	15-11	Jul 84
10-8	Mar 85	15-12	Jun 85
10-9	May 85	15-13	May 85
10-11	Jun 84	15-14	May 85
11-10	Sep 84	16-10	Sep 84, Jan 85, Jun 85
11-12	May 84	17-7	Jan 85
12-8	May 85	17-9	Jun 84, Mar 85, Jun 85
12-10	May 85, Jun 85	17-11	Nov 84
12-12	Nov 84	18-9	Jul 84
12-13	Sept 84	19-5	Jan 84
12-14	May 84, Jan 85	19-6	Jun 84
12-15	Mar 85	20-7	Sep 84
13-8	Jan 85		
13-9	Jul 84		
13-12	Mar 85		
13-13	Nov 84		
13-17	Jun 84, Mar 85		
14-8	Jan 85		
14-9	Nov 84		
14-10	Jul 84		
14-13	Jun 85		
14-14	Nov 84		

Table 2c. Stations that were sampled in Stratum III and month sampled. Refer to Figure 6 for station location.

Station	Month/Year	Station	Month/Year
1-2	Sep 84	10-4	May 85
2-1	Jun 84	11-1	Jan 85, Jun 85
2-2	Jun 84	11-2	Nov 84
3-2	Nov 84	12-1	Jun 85
3-3	Jun 84, Jul 84, Jan 85, Jun 85	12-2	Jan 85
4-4	May 84, Jul 84	12-3	Jul 84
5-2	May 84, Jul 84	13-1	May 85
5-5	Sep 84, Jun 85	13-3	Mar 85
5-6	Mar 85, May 85	13-4	Nov 84
6-2	Sep 84, Jan 85, Jun 85	14-3	Jun 84
6-3	May 85	14-5	Nov 84
6-4	Jun 85	15-4	Sep 84
6-6	Mar 85	15-6	Mar 85
6-7	Nov 84	16-8	May 85
7-3	Nov 84	19-3	May 85
7-4	May 84	19-4	Jul 84
8-3	May 85		
8-7	May 84		
9-1	Mar 85		
9-2	Jun 84, Mar 85		
9-3	Jan 85		
9-4	Sep 84, Jan 85		
9-5	Sep 84		
10-2	Jun 84, Jul 84		
10-3	May 84		

Table 2d . Stations that were sampled in Stratum IV and month sampled. Refer to Figure 5 for station location.

Channel	Month/Year	Channel	Month/Year
2	Jun 85	24	Sep 84
3	May 84	26	Jul 84
5	Jan 85	27	May 84, Mar 85
6	Jun 84	29	Jan 85
7	Mar 85	31	May 84, Jun 85
8	Nov 84, Jun 85	32	Jun 85
9	Jul 84	33	Jun 84, Jul 84, Nov 84
12	Jul 84	34	Sep 84, Jan 85, May 85
13	Mar 85	35	Sep 84, Jan 85
14	Nov 84	37	May 85
16	Mar 85	38	Jul 84, Nov 84, Jun 85
17	Jun 84	39	Mar 85
19	May 85	40	Nov 84, Jan 85, May 85
21	Jun 84, Jan 85	41	Sep 84, Jun 85
22	May 85, Jun 85	44	Jun 84, Sep 84, Mar 85
23	Jul 84, Sep 84, Nov 84, May 85		

Table 2e. Stations that were sampled in Stratum V (Whitewater Bay) and month sampled. Refer to Figure 2 for station location.

Station (WWB)	Month/Year	Station	Month/Year
1	May 84	141	Jun 85
8	Mar 85	142	Jan 85
11	Jul 84	148	Mar 85
18	Jun 85	149	May 85
23	May 84, Jun 84	155	Nov 84
24	Sep 84	157	Jun 85
29	Sep 84	159	May 85
34	May 84		
44	Sep 84		
47	Nov 84		
54	Nov 84		
55	Jul 84, Jan 85		
56	Jun 84, Mar 85		
57	May 84		
61	Nov 84		
69	Jun 84		
88	May 85		
95	May 85		
106	Jul 84		
107	Mar 85		
113	Jan 85		
117	Jun 84		
128	Jun 85		
131	Jan 85		
139	Jul 84, Sep 84		

Table 2f . Stations that were sampled in Stratum V (Coot Bay) and month sampled. Refer to Figure 3 for station location.

Station (CB)	Month/Year
7	May 85
11	Jun 85
15	May 85
20	Jun 85
22	Sep 84
25	Jun 84
32	Jul 84
35	May 84
36	Mar 85
39	Nov 84
41	Mar 85
44	Sep 84
49	Jan 85
55	Jul 84
61	May 84
62	Jun 84
65	Nov 84
66	Jan 85

(Table 4). Slightly greater differences in the average maximum and minimum water temperatures occurred in stratum I (12.5°C) and stratum II (14.7°C) than elsewhere in our sampling area (10.1-11.6°C) (Table 3). This probably is a reflection of the shallowness and generally low water exchange that occurs in the eastern and central sections of Florida Bay (see Schomer and Drew 1982).

There was a significant difference in mean salinity among strata, and also with season (ANOVA, $p < 0.05$). Coot Bay and Whitewater Bay (Stratum V) had significantly lower salinities ($\bar{x}$ = 17.2 o/oo; Table 3) than did the remaining strata ($\bar{x}$ = 36.0 o/oo; Table 3) ($p < 0.001$). This difference supported our initial decision to separate the sampling area into two salinity zones. Coot Bay maintained a slightly higher salinity (18.8 o/oo) than did Whitewater Bay (16.9 o/oo) during our period of study. In general, all strata displayed lowest salinity between September and March and higher salinities during the remainder of the year (Table 4).

In Florida Bay, the largest extremes in salinity were encountered in the interior subenvironment (Strata I and II). In Stratum I there was a maximum recorded range for stations of 21 o/oo during the year. Wide seasonal ranges in the interior region are common (Shomer and Drew 1982), and apparently are related to restricted circulation. It is possible that water control structures along the northern portion of Everglades National Park exacerbate the normal salinity extremes in this area by manipulations of deficits and excesses of freshwater inflow to the area. Stations in Stratum II displayed less of a range (17.0 o/oo), from 28 o/oo in November to 45.0 o/oo in May. Within Stratum III, near the Gulf of Mexico, the range was 16.0 o/oo, from 24 o/oo in September to 40.0 o/oo in June. The range in salinity extremes was least (12 o/oo) for the channels (Fig. 5).

Silt-Clay and Organic Content of Sediments

The silt-clay and organic content of surface sediments reflect the overall hydrology and depositional characteristics of the environment. Both parameters also are influenced by the presence and density of seagrasses, in part because seagrasses modify hydrodynamic and depositional characteristics of flowing water (Fonseca et al. 1983; Fonseca and Fisher 1986) and because they are a source of organic matter. We found a great deal of variability among sampling stations in both silt-clay and organic matter content of the sediments, and a weak correlation between the two parameters ($r = 0.397$, $p < 0.001$). The weakness of this relationship was surprising since many studies in estuarine areas have demonstrated a strong relationship (Kenworthy et al. 1982; Chester et al. 1983). Our observation may be a reflection of the large extents of seagrass meadows and the generally low current regimes characteristic of Florida Bay, Coot Bay and Whitewater Bay (Tabb and Dubrow 1962; Shomer and Drew 1982). In general, low currents would result in a generally reduced flushing of allochthonous organic matter from the meadows, while a combination of low current circulation and extensive meadows would result in silt-clay being filtered from the overlying water near the leading edge of a meadow as it moves over the meadow. In addition, land drainage is primarily from the mainland lying to the north, and there are generally low currents in that area. Thus, material probably settles out close to shore. Therefore, a great deal of inorganic matter may be added along the mainland border, while in the grass meadows large quantities of seagrass organic matter may be added to the sediments with little added silt-clay inorganic particle sizes.

Table 3. Mean values for environmental and biological variables that were measured during 1984 and 1985 in Whitewater Bay, Coot Bay and Florida Bay. Data are presented as mean stratum values (see Text for strata locations.

Parameter	Stratum				
	I	II	III	IV	V
Temperature (°C)	26.7	26.7	26.7	27.0	27.1
Salinity (o/oo)	36.2	36.5	35.2	36.2	17.2
Organic matter (%)	8.5	14.5	15.3	12.4	18.4
Silt-Clay (%)	54.1	47.0	60.2	62.9	58.8
Sediment depth (m)	0.6	0.9	1.1	0.9	0.5
Water depth (m)	1.7	1.3	1.5	1.5	1.4
Thalassia shoots (No/m^2)	514	878	594	657	0
Thalassia standing crop (gdw/m^2)	58.6	203.2	154.4	184.8	0
Halodule shoots (No/m^2)	21	146	282	988	396
Halodule standing crop (gdw/m^2)	0.1	3.5	7.0	22.4	4.4
Syringodium shoots (No/m^2)	0	0	843	221	0
Syringodium standing crop (gdw/m^2)	0	0	59.9	19.3	0
Ruppia shoots (No/m^2)	0	0	0	0	431
Ruppia standing crop (gdw/m^2)	0	0	0	0	3.9

Table 4. Average monthly temperature and salinity values for each strata.

Year	Month	Stratum I		Stratum II		Stratum III		Stratum IV		Stratum V	
		·C	o/oo	·C	o/oo	·C	o/oo	·C	o/oo	·C	o/oo
1984	5			29.6	40.2	28.0	36.8	26.9	38.0	28.1	18.5
	6	27.9	36.5	28.1	39.0	28.0	38.0	29.0	37.5	25.6	19.7
	7	30.9	37.7	31.4	40.2	29.9	36.5	29.7	39.0	31.4	19.7
	9	29.7	33.7	29.8	33.0	30.3	30.0	29.4	34.7	29.7	13.3
	1	26.8	29.5	26.4	29.7	26.6	32.5	26.8	31.0	26.3	9.5
1985	1	18.4	35.8	17.7	38.0	20.2	35.5	19.0	37.0	20.6	11.2
	3	24.0	31.2	22.7	31.2	22.2	32.5	23.9	31.5	20.6	16.5
	5	28.3	41.8	26.7	38.4	29.2	35.9	29.3	38.7	32.3	21.5
	6	28.0	43.5	29.3	40.5	25.1	39.2	29.0	39.5	29.1	24.8

Our data on silt-clay and organic matter in the sediments suggest that Whitewater Bay, Coot Bay and Florida Bay are depositional environments. The mean silt-clay content of Florida Bay ranged from 47.0% to 62.9%, and for Coot Bay and Whitewater Bay it averaged 54.1% (Table 3). The central portion of Florida Bay (Stratum II) had the lowest mean value (47%) while the channel stations (stratum IV) had the highest silt-clay levels (63%). There was a difference among strata (ANOVA, $p < 0.05$), and a SNK range procedure indicated the differences were between these two strata alone. The Coot Bay-Whitewater Bay had silt-clay levels intermediate to but not different from Stratum I and III in Florida Bay. The high silt-clay levels of the channels were surprising but may be due to the fact that most channels sampled do not have high current flows and have relatively high densities of seagrasses (see later) that help to retain this particle size. The origin of this silt-clay material in the channels is unknown.

A discernable pattern was observed in the distribution of silt-clay content in Florida Bay (Fig. 11) but not in Coot Bay or Whitewater Bay (Fig. 12). In Florida Bay, silt-clay values generally exceeding 55% were prevalent in a band along the northern and northeastern boundary (Fig. 11). The high silt-clay area to the north encompasses the northern subenvironment (Schomer and Drew 1982) but extends into Florida Bay to a greater extent than the boundary drawn for this subenvironment. These high values probably are a direct result of land drainage.

With the exception of the eastern portion of Florida Bay (Stratum I), average organic levels generally exceeded 10%. There was a significant difference (ANOVA, $p < 0.001$) among strata with the eastern portion of Florida Bay displaying the lowest overall level (8.5%) and sediments of the Coot Bay-Whitewater Bay stratum having the highest mean organic matter content (18.4%). Strata II, III and IV were similar and significantly different from stratum I (SNK, < 0.05). There was a great deal of variability in data among stations (Fig. 13) with no discernable seasonal trends. We believe that the variability in part resulted from the variable densities and species of seagrasses in the habitats from which the sediment samples were taken.

The high levels of organic matter in the sediments of Coot Bay and Whitewater Bay probably result largely from decay of mangrove leaves, with some contribution by <u>Ruppia maritima</u> and <u>Chara hornmanni</u>, while seagrasses are the major contributor to the organic levels in Florida Bay. Sampling and stable carbon and nitrogen analyses by Harrigan (1986) support this suggestion. The relatively low organic content of Stratum I sediments is coincident with areas of lowest overall seagrass density and biomass (Table 3) and will be discussed later.

General patterns of distribution of sediment organic content were evident in Florida Bay (Fig. 14) but not in Coot Bay and Whitewater Bay (Fig. 15). Sediments having organic levels $\leq$ 15% were present primarily in the eastern and northeastern portion of Florida Bay and between Flamingo, East Cape and the western tips of Dildo Key Bank and First National Bank. Comparatively, high sediment organic levels (> 15%) exist in the western and northwestern portion of the bay (Fig. 14). We believe that these patterns in Florida Bay probably are a function of seagrass density and distribution. The area of $\leq$ 15% organic carbon generally occurs in areas of relatively low standing crops of seagrasses while the region having > 15% organic carbon has relatively high above-ground seagrass biomasses.

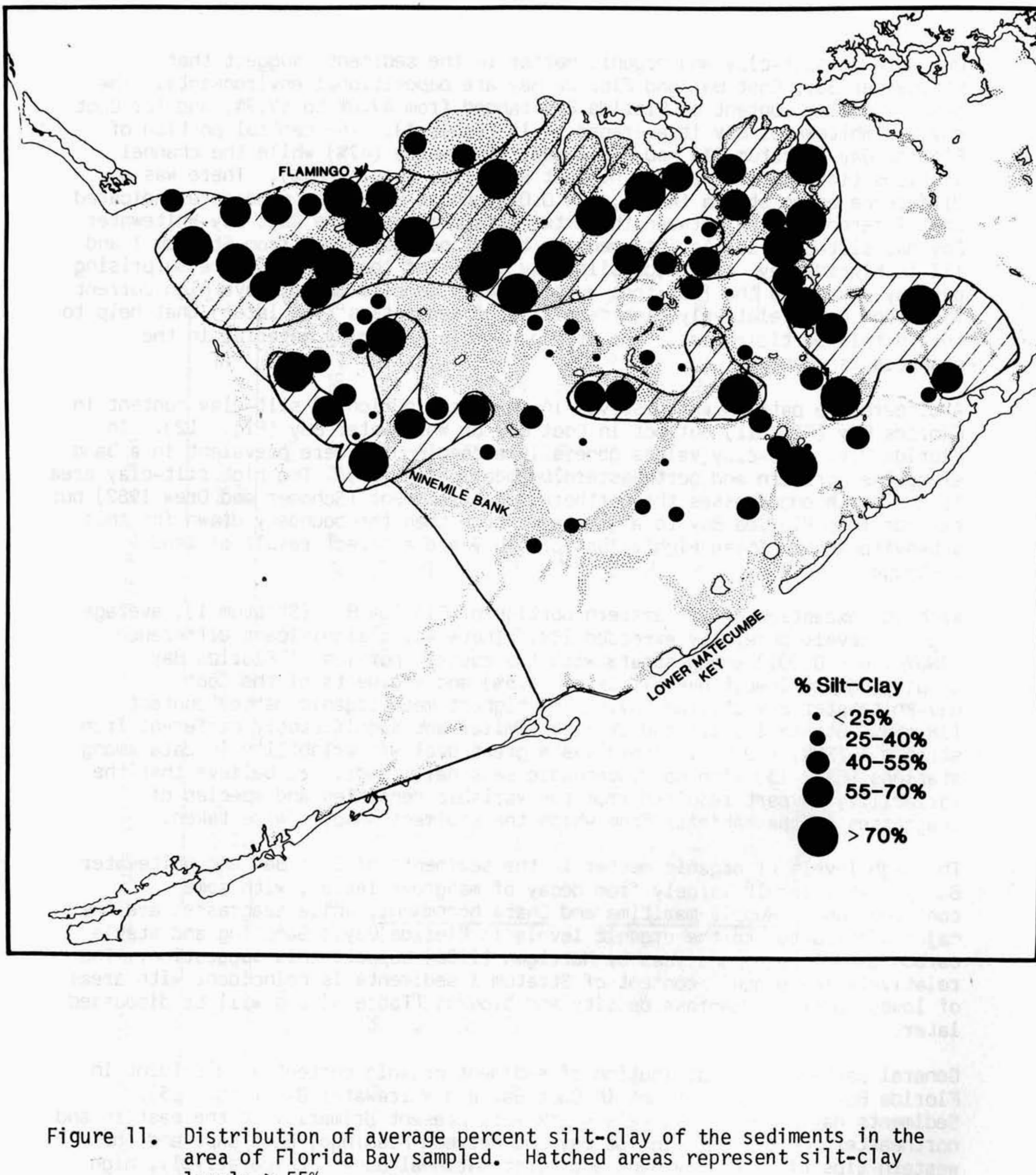


Figure 11. Distribution of average percent silt-clay of the sediments in the area of Florida Bay sampled. Hatched areas represent silt-clay levels ≥ 55%.

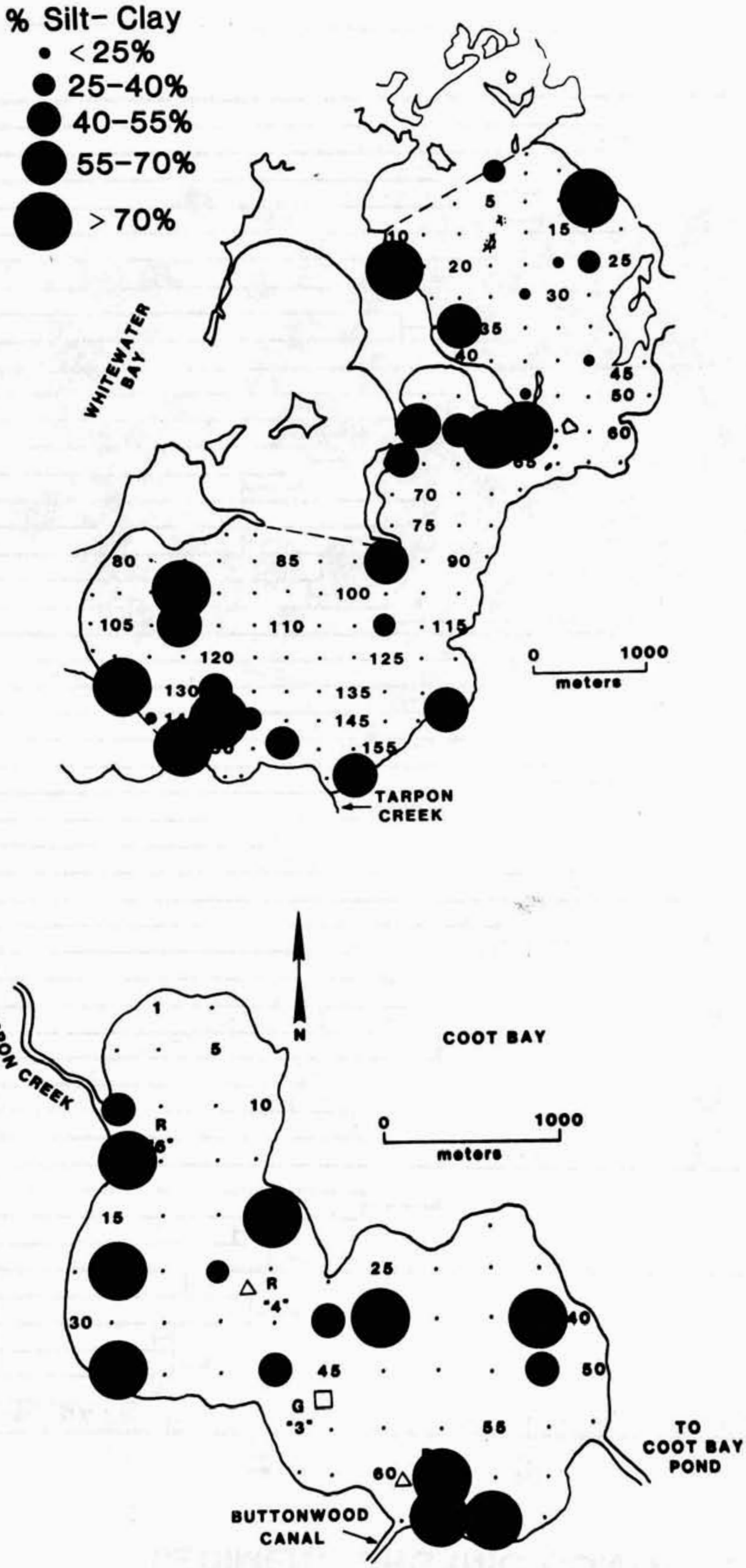


Figure 12. Distribution of average percent silt-clay content of the sediments of eastern Whitewater Bay (upper) and Coot Bay (lower).

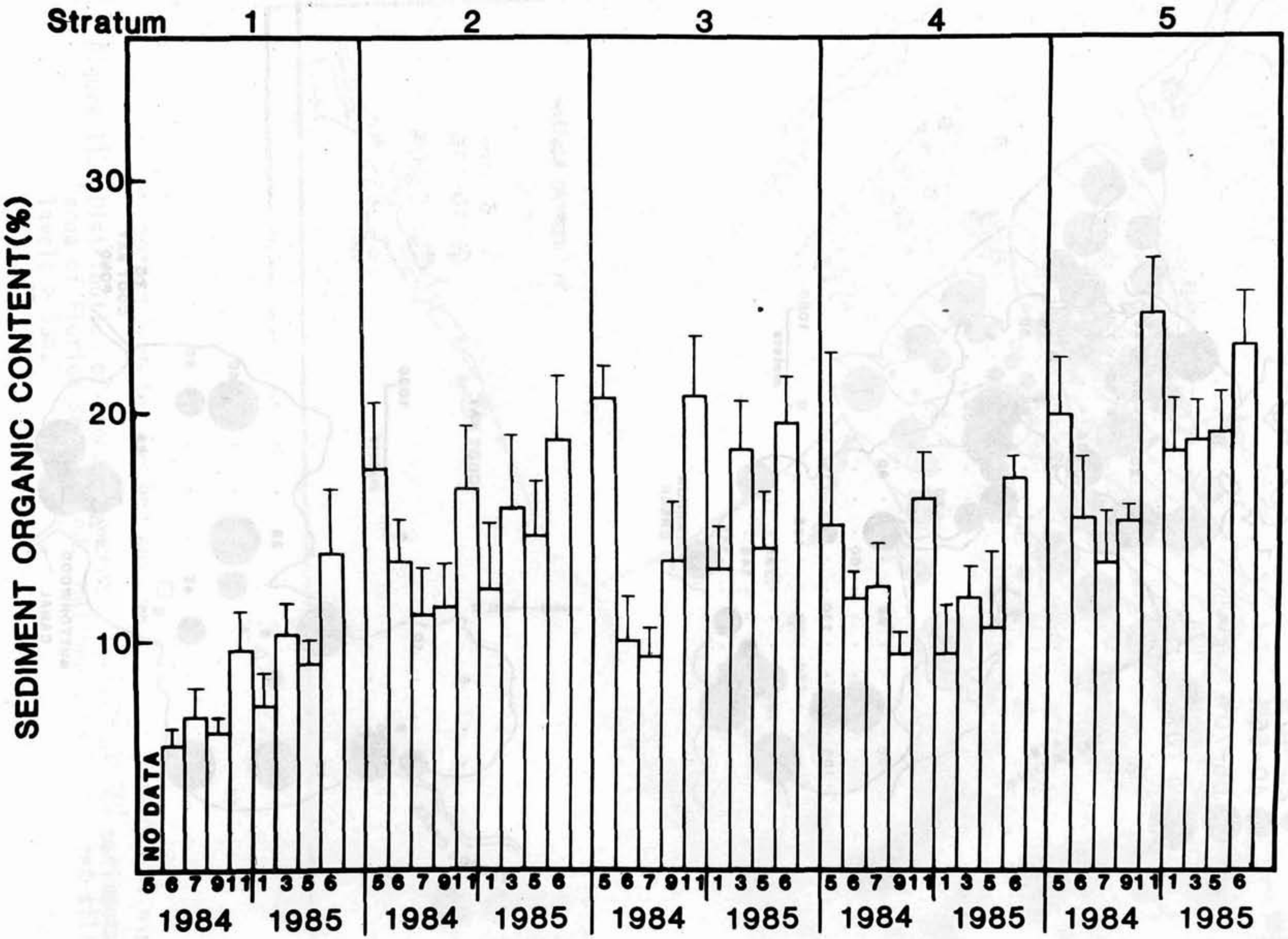


Figure 13. Average monthly sediment organic content (%) for each stratum during the study period. Months are designated by number. Vertical bar represents upper limit of range.

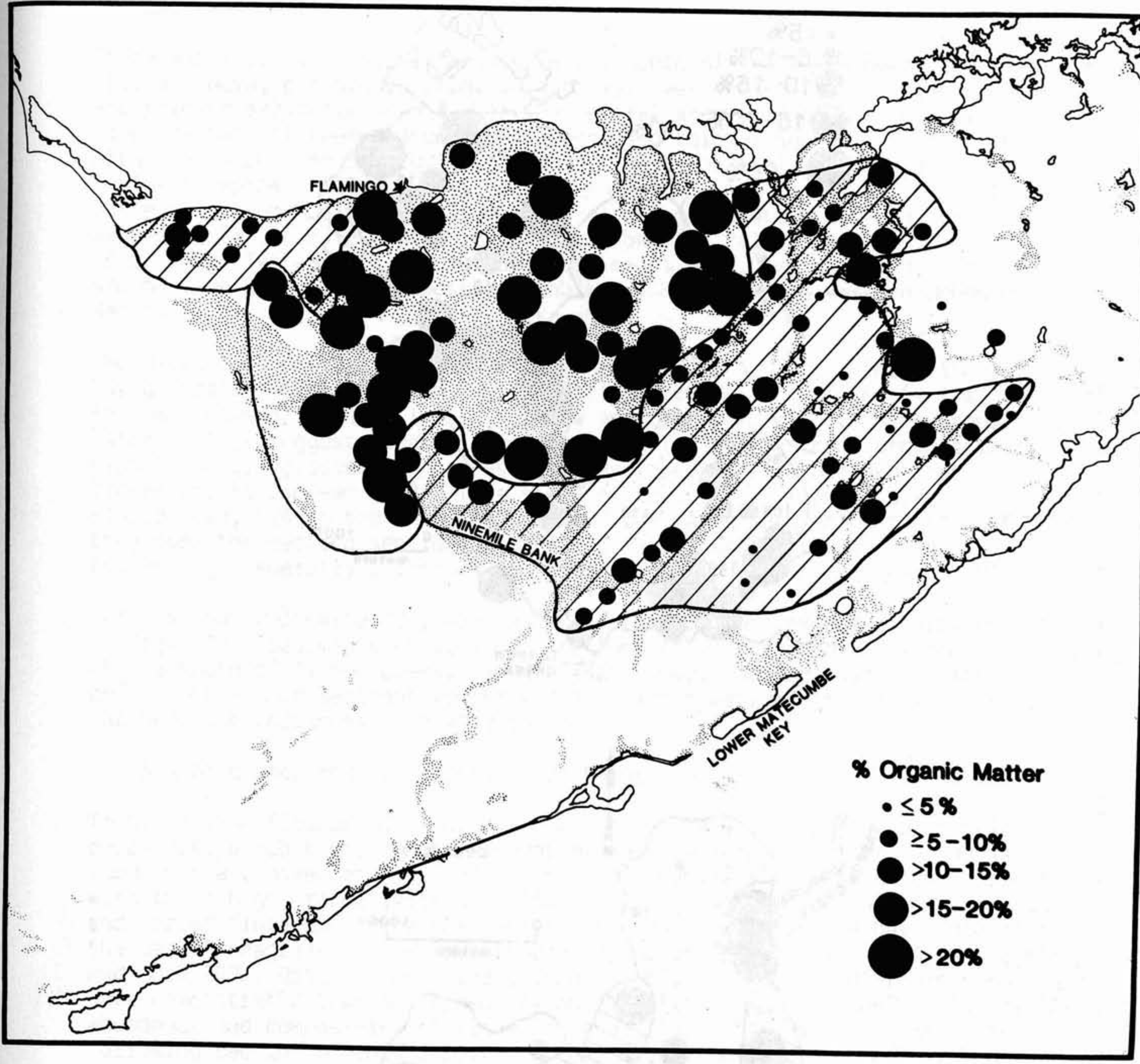


Figure 14. Distribution of average sediment organic matter in Florida Bay.

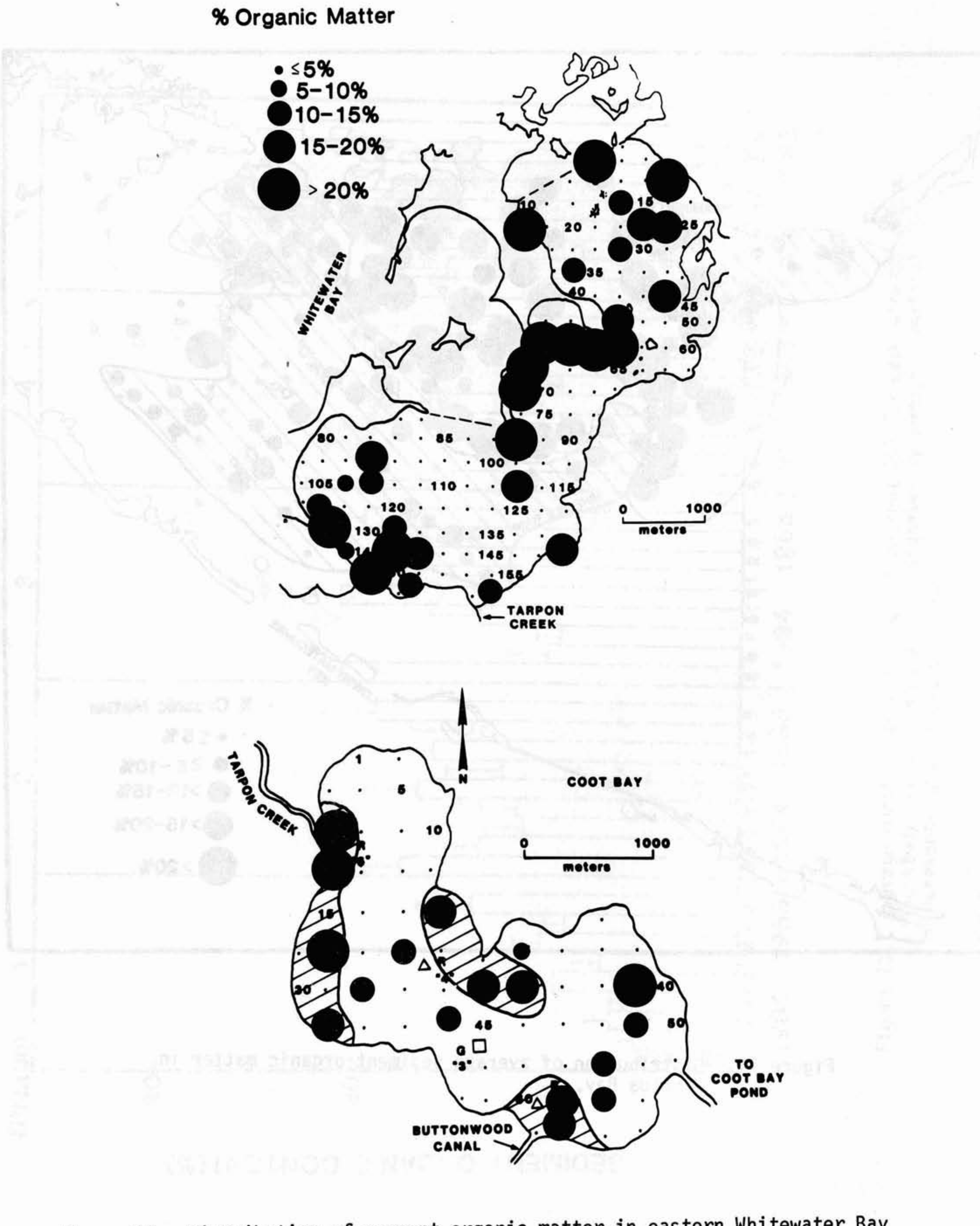


Figure 15. Distribution of percent organic matter in eastern Whitewater Bay (top) and Coot Bay. Hatched area represents ≥ 15% organic matter.

Sediment Depth

There was a significant difference in the depth of sediments among the five strata (ANOVA, $p < 0.001$) (Fig. 16 and 17). Western Florida Bay (Stratum III) had thicker sediments than either the central area (II) or the channels (IV) sampled; both of these latter areas possessed thicker sediment veneers than either Stratum I or Stratum V (Table 3). Western Florida Bay generally had sediment depths > 1.0 m while the eastern portion had depths $\leq$ 1.0 m. This western stratum has extensive, well developed carbonate mud banks. Thick sediments (> 1.0 m) extend into the basin between Calusa Keys and Corinne Key (Fig. 16). Two pockets of shallower sediments ($\leq$ 1.0 m) occurred in the area around Blue Bank and southwestern Rabbit Key Basin and in western Johnson Key Basin.

The distribution of sediments less than and greater than 1 m thick in Florida Bay generally coincided with the respective distribution of low (< 15%) and high (> 15%) sediment organic levels and low and high seagrass standing crops (see later). This suggests that, if seagrasses influence sediment organic levels significantly, grasses are not as well developed in the shallower sediments. Zieman and Fourqurean (1985) in a study of the distribution of seagrasses in Florida Bay, also noted that the western area had a much thicker sediment depth than does the eastern section. Our values and areas of various sediment thicknesses generally coincide with those of Zieman and Fourqurean (1985).

Coot Bay and Whitewater Bay had sediments that did not exceed a thickness of 1.5 m (Fig. 17). Sediments at Coot Bay stations only exceeded a thickness of 1.0 m at the mouth of Tarpon Creek. In Whitewater Bay, the northeast section had a consistently thin sediment veneer < 0.2 m, while many of the remaining stations had sediment thicknesses of >0.2 to 0.4 m.

Standing Crop and Shoot Density of Seagrasses

To be of significance as a nursery area, a habitat must provide protection from predators, a substrate for attachment of sessile stages, or a rich and varied food source (Thayer et al. 1978). Seagrass habitats fulfill these criteria with their high productivity and blade densities as well as the normally rich and varied flora and fauna that occur. Numerous publications have documented the use of seagrass meadows by fishery organisms (e.g., Adams 1976, Weinstein and Heck 1979, Orth and Heck 1980, Stoner 1982, Weinstein and Brooks 1983), and have demonstrated that plant density and species composition can influence the abundance and composition of fishes that utilize a seagrass habitat. The following section of this report provides a description of the distribution, abundance and biomasses of seagrasses we collected during our sampling program. Data are analyzed in conjunction with previously discussed environmental parameters. Data are later utilized in our discussion of fish communities to describe interrelations among fishes, and specifically target species, and habitat variables.

The distribution, abundance and species composition of the seagrasses differed among strata and, generally, there was high variability among stations in any single strata. The initial premise upon which we based our subdivision of areas into two major regions, i.e., Coot Bay-Whitewater Bay and Florida Bay, was that, because of the greatly different salinity regimes of the two areas, seagrass composition and possibly fishery communities would differ. The further subdivision of open water areas in Florida Bay into three strata was based on

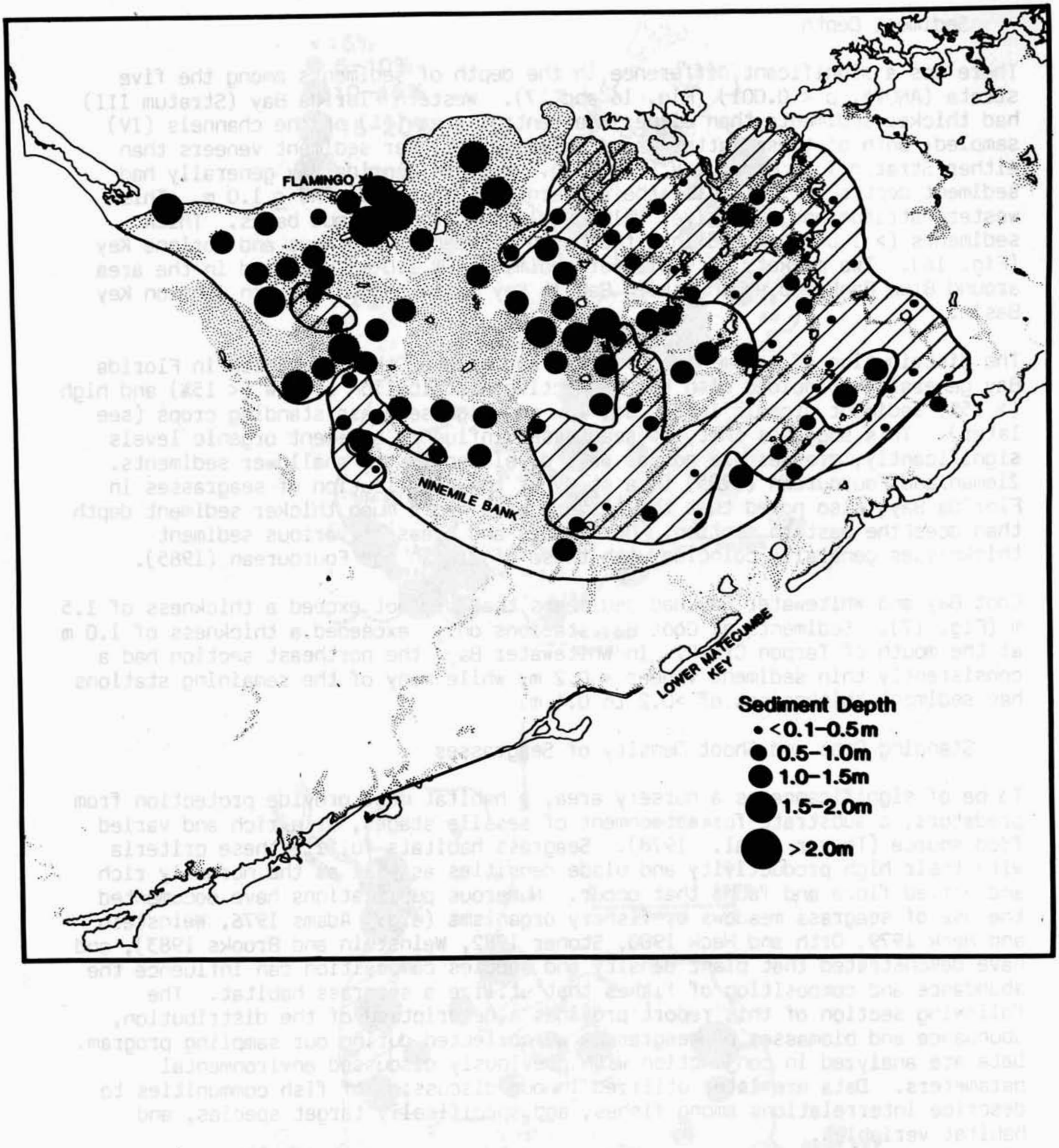


Figure 16. Distribution of ranges in sediment thickness at Florida Bay sampling stations. Hatched area represents sediments ≤ 1.0 m thick.

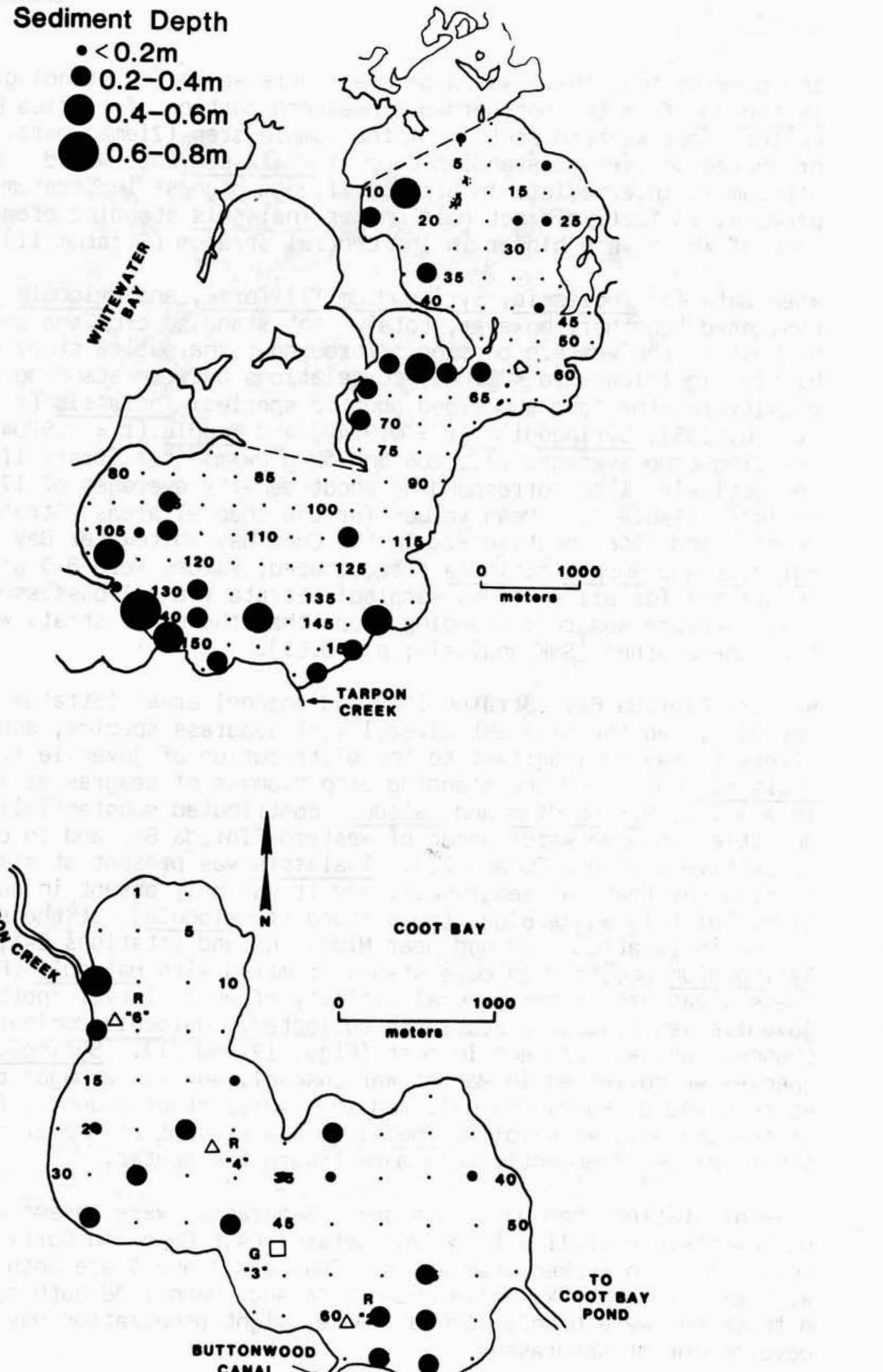


Figure 17. Distribution of ranges in sediment thickness in eastern Whitewater Bay (upper) and Coot Bay (lower) sampling stations.

the premise that there was a general increase in the standing stock of Thalassia testudinum from the northern-northeastern portion of Florida Bay to the western-southwestern section of the sample area (Zieman pers. comm.). We had projected an average standing crop of Thalassia that would be lowest in Stratum I, intermediate in Stratum II, and highest in Stratum III. This premise, in fact, did not hold up for Thalassia standing crop or shoot numbers, both of which were higher in the central stratum (Stratum II) (Table 3).

When data for Thalassia, Syringodium filiforme, and Halodule wrightii were evaluated together, however, total plant standing crop and shoot density were highest in the western portion. Throughout the entire study area there were highly significant ($p < 0.001$) correlations between standing crop and shoot density for the four submerged aquatic species: Thalassia ($r = 0.7891$), Halodule ($r = 0.9188$), Syringodium ($r = 0.9142$) and Ruppia ($r = 0.9804$). Total seagrass standing crop averaged 221, 206 and 59 g $dw \cdot m^{-2}$ for Strata III, II, and I, respectively, with corresponding shoot density averages of 1719, 1024 and $535 \cdot m^{-2}$ (Table 3). Mean values for the channel areas (Stratum IV) were 230 g $dw \cdot m^{-2}$ and 1866 $shoots \cdot m^{-2}$. In the Coot Bay-Whitewater Bay stratum, where Halodule and Ruppia maritima predominated, values were 8.3 $g \cdot m^{-2}$ and 431 $shoots \cdot m^{-2}$ for all stations sampled. Strata V and I possessed significantly lower average seagrass standing crops than the other strata which did not differ from one another (SNK analysis; $p < 0.05$).

Western Florida Bay (Stratum III) and channel areas (Stratum IV) throughout the bay displayed the greatest diversity of seagrass species, and this plant species diversity may be important to the distribution of juvenile fishes. Although Thalassia dominated the standing crop biomass of seagrasses in Florida Bay (Fig. 18 and 19), Syringodium and Halodule contributed substantially to shoot densities in open water areas of western Florida Bay and in channels, respectively (Figs. 20 and 21). Thalassia was present at almost every site in Florida Bay that had seagrasses, and it was only absent in our samples near Gibby Point in Snake Bight (pure stand of Halodule), at the entrance to Sandy Key Basin (station 5-2) and near Middle Ground (stations 2-1, 3-2) where Syringodium occurred in pure stands or mixed with Halodule (Figs. 18 and 20). These areas are in the general vicinity of where larval spotted seatrout and juvenile seatrout were routinely collected. Halodule dominated several of the channels and was present in most (Figs. 19 and 21). Syringodium was the only species we collected in Man of War Channel, and was a major component of the eastern end of Rocky Channel, and in several other channels (Fig. 21). In many of the channels we sampled, Thalassia was present at one or both ends while the other species frequently were more toward the center.

Several stations had no seagrasses. Seagrasses were absent along the northwestern shoreline (Fig. 20) between East Cape and Curry Key. Four channels (Fig. 21) also lacked seagrasses. Channels 3 and 5 are both high current areas with exposed bedrock, while channel 16 and channel 38 both had sediments about 1 m thick but were highly turbid. Here, light penetration may limit the development of seagrasses.

The largest seagrass standing crops that we sampled in Florida Bay coincided with relatively thick sediments characterized by elevated levels of organic matter (Figs. 14 and 16), suggesting that seagrasses tend to grow most luxuriously in deeper sediments. There were significant ($p < 0.001$) relations between total standing crop or shoot number and sediment organic content $\geq$ 15%,

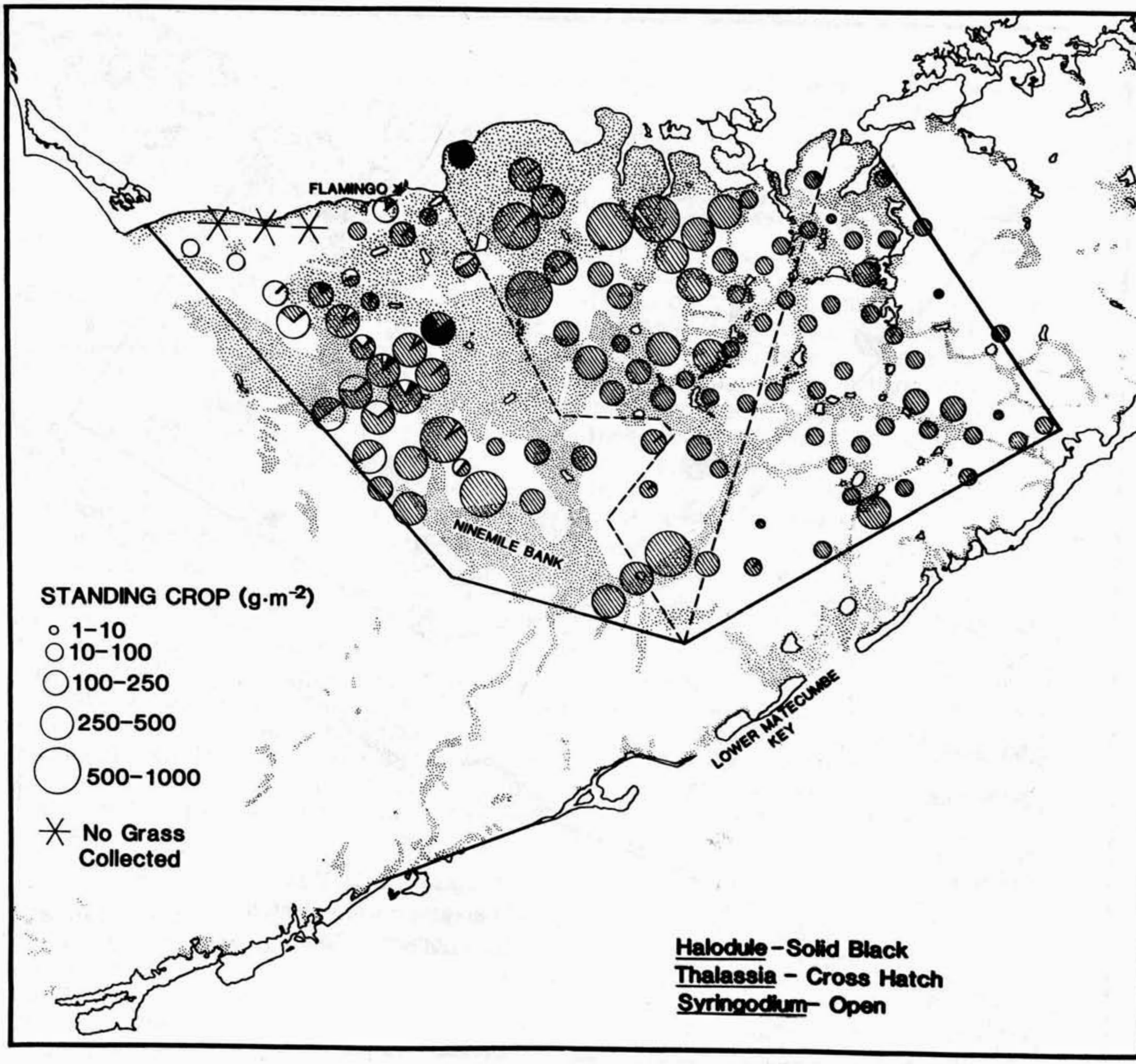


Figure 18. Distribution of seagrass standing crop ranges in Florida Bay. Hatched represents Thalassia testudinum, solid represents Halodule wrightii and open represents Syringodium filiforme.

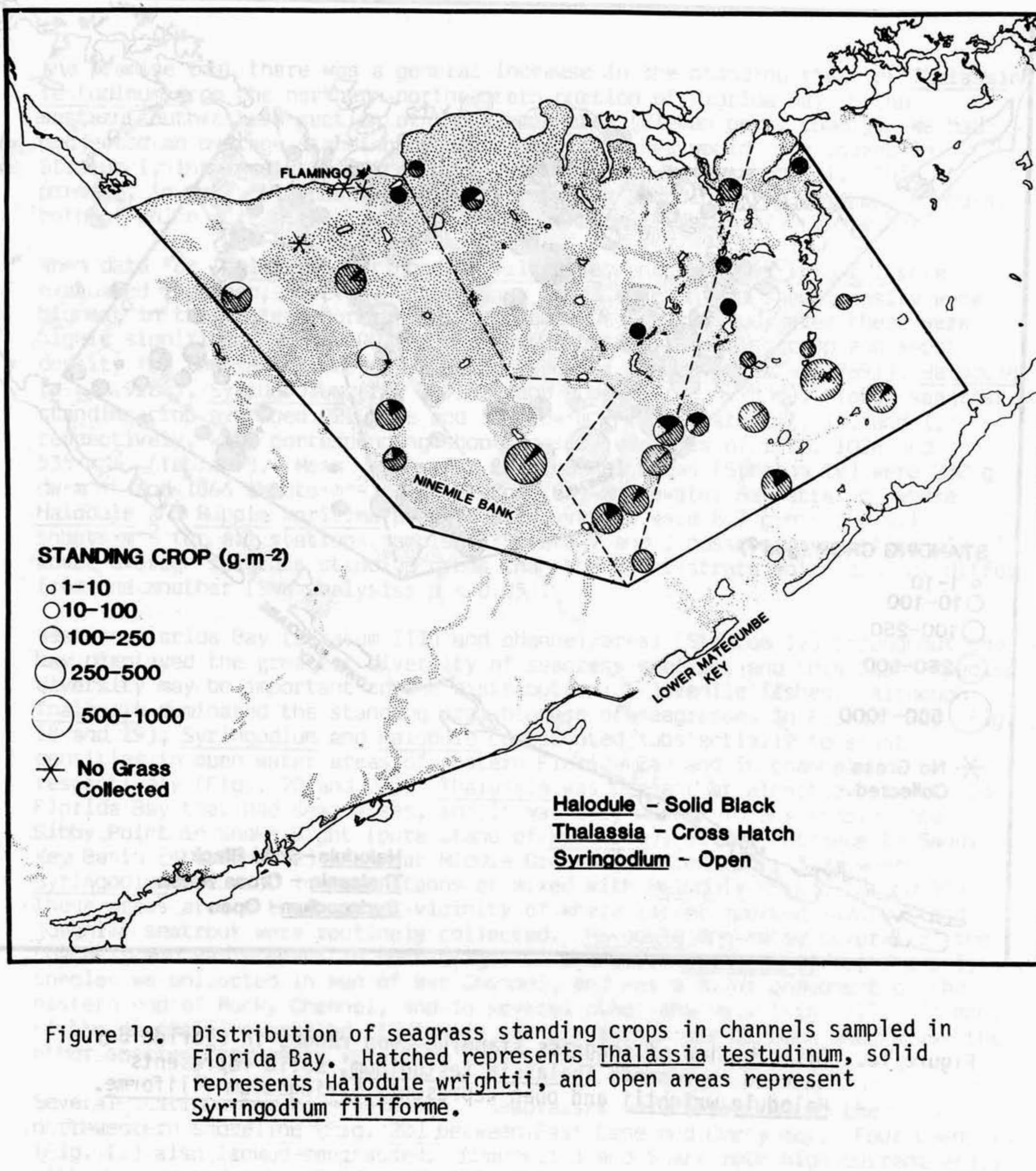


Figure 19. Distribution of seagrass standing crops in channels sampled in Florida Bay. Hatched represents Thalassia testudinum, solid represents Halodule wrightii, and open areas represent Syringodium filiforme.

although the correlations were not remarkable, $r = 0.5154$ and 0.4723 ($N = 105$), respectively. The overall shallowest veneer of sediment and lowest organic levels generally corresponded and occurred throughout Stratum I. Here, seagrass standing crops normally were $\leq 50\ g \cdot m^{-2}$. This stratum had a significantly lower ($p < 0.001$) overall standing crop of Thalassia ($59\ g \cdot m^{-2}$) than did the other areas in Florida Bay, while the remaining non-channel strata had high levels of organic matter and relatively deep sediments.

Zieman and Fourqurean (1985), in their analysis of the seagrasses of Florida Bay, observed a generally increasing trend of Thalassia standing crop in a northwesterly direction from the Florida Keys to the mainland. We observed a trend for increasing seagrass standing crops in a similar direction from the Florida Keys only in the central stratum (Stratum II) (Fig. 18). In eastern Florida Bay (Stratum I), 13 of the 35 stations sampled had standing crop values $> 50\ g \cdot m^{-2}$. These stations are not in the northern portion of this stratum, but instead are either south of Crane Keys or form an arc from Ramshorn Shoal to Captain Key and then to Calusa Key Basin and Black Betsy Key (Fig. 18). In western Florida Bay (Stratum III), standing crop levels we observed were higher in Blue Bank Basin, southeastern Johnson Key Basin, and western Rabbit Key Basin than in the area to the west between Sandy Key Basin, Frank Key, Flamingo and East Cape. An area south of Barnes Key also had a relatively high standing crop of Thalassia ($490\ g \cdot m^{-2}$). Thus, the trend observed by Zieman and Fourqurean (1985) in Thalassia standing crops was not as evident in our study. This disparity may be a reflection of the stratified random sampling design we used and the fact that all seagrass samples were taken from the approximate center of each grid cell; triplicate samples taken, however, were similar and we believe give an accurate picture of plant characteristics at the stations sampled. There was a general trend for total seagrass shoot density to increase in a northerly direction in Stratum III, and this was due to the presence of Syringodium and Halodule.

Channel areas near the Florida Keys generally had higher seagrass standing crops than did channels on the north and northwestern portion of Florida Bay. In the northern portion of Florida Bay, only the channels leading from Johnson Key Basin had high standing crops. In the eastern portion, however, channels between Cross Bank, Bob Allen Keys, Panhandle Key and Barnes Key contained a high abundance of seagrass, and normally had more than one seagrass species present (Fig. 19).

Whitewater Bay and Coot Bay had the lowest overall abundances of seagrasses of the areas sampled. During the period of study, Halodule was the predominant species collected in Whitewater Bay (Figs. 22 and 23) where it had a mean standing crop of $6.0\ g \cdot m^{-2}$ and shoot density of $534 \cdot m^{-2}$. Lowest densities were in the northern portion of the sample area. Ruppia maritima also was present in Whitewater Bay, with an average standing crop of $3.4\ g \cdot m^{-2}$ and a shoot density of $366 \cdot m^{-2}$. The northeast portion had a very large Ruppia population in March 1985, when there was a shoot density of $8700 \cdot m^{-2}$ with a standing crop of 77 $g \cdot m^{-2}$. Other stations sampled in this northern portion either had low quantities of Halodule in sediment pockets among the bedrock, or were void of vegetation. Many stations in Coot Bay also were devoid of seagrasses (Fig. 22), and, where seagrasses were present, Ruppia was most prevalent. Ruppia had a mean standing crop of $5.3\ g \cdot m^{-2}$ and shoot density of $636 \cdot m^{-2}$ for the stations sampled. Halodule, which also was present, had a mean standing of $1.3\ g \cdot m^{-2}$ and a shoot density of $109 \cdot m^{-2}$.

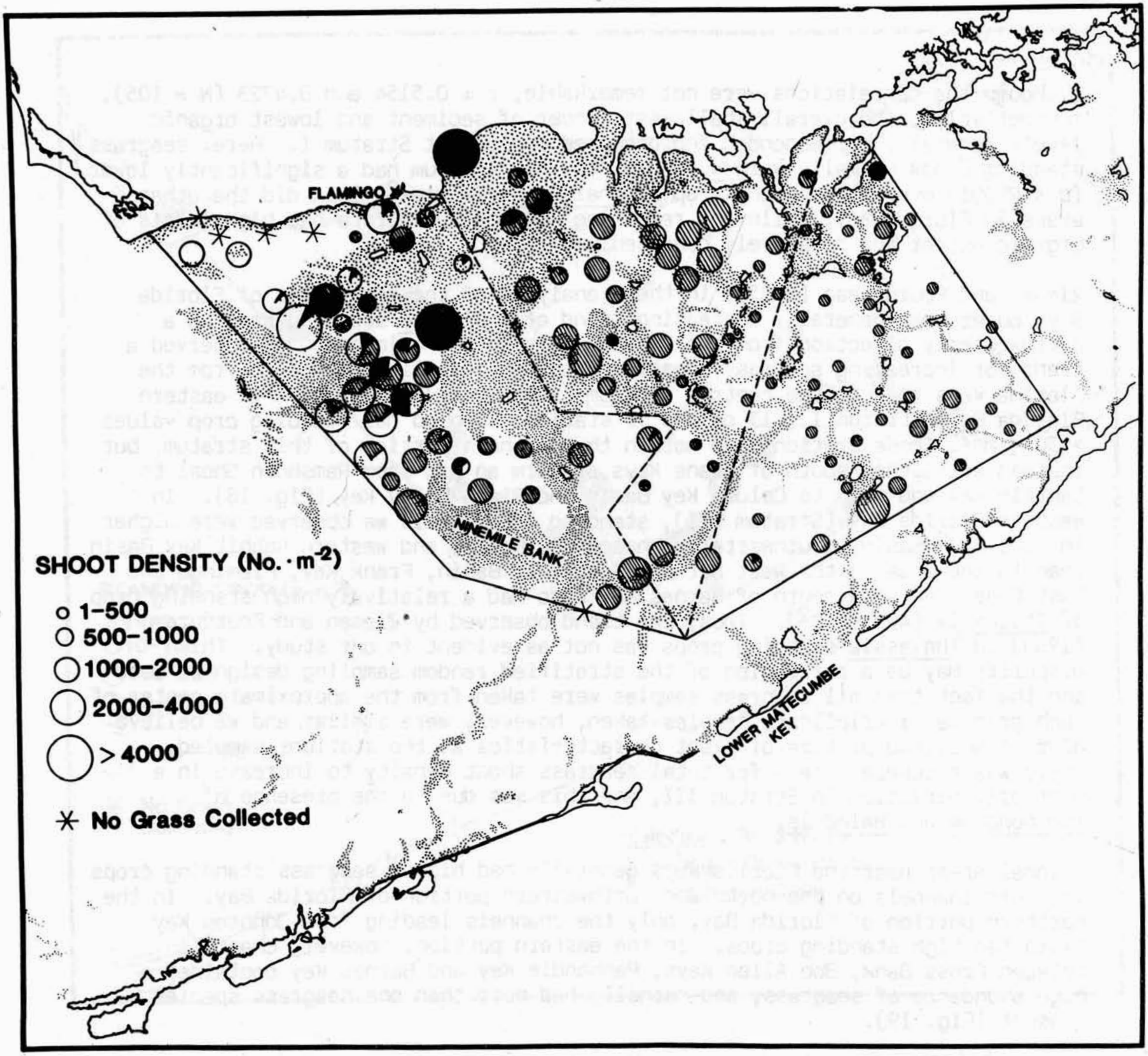


Figure 20. Distribution of seagrass shoot density in Florida Bay. Hatched areas represent Thalassia testudinum, solid represents Halodule wrightii, and open represents Syringodium filiforme.

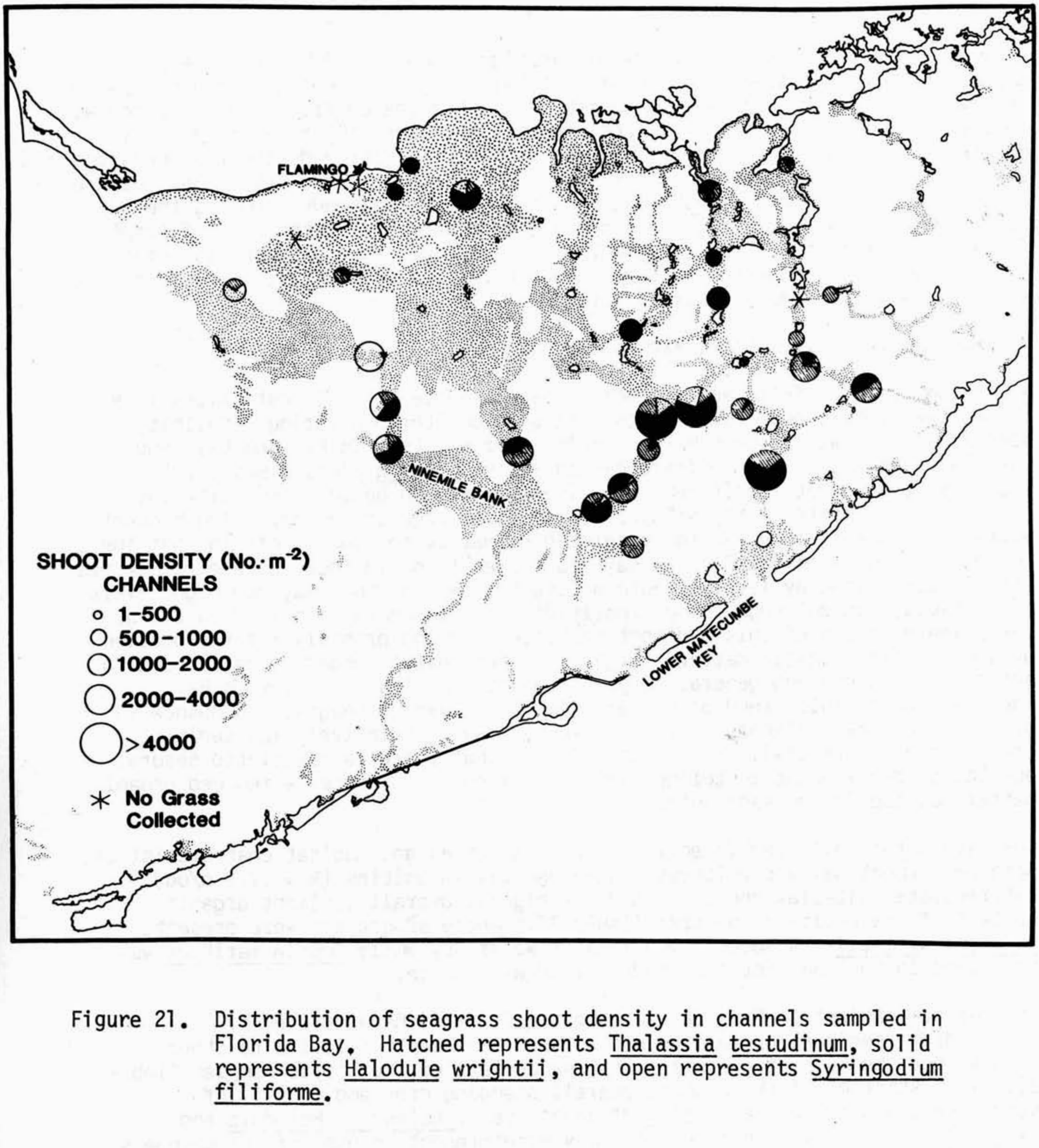


Figure 21. Distribution of seagrass shoot density in channels sampled in Florida Bay. Hatched represents _Thalassia testudinum_, solid represents _Halodule wrightii_, and open represents _Syringodium filiforme_.

In March 1984, with the assistance of Everglades National Park personnel, we mapped the bottom characteristics of Coot Bay. A grid of concentric arcs spaced approximately 100 m apart was established. With guidance from a person using a theodolyte system on shore, a bottom sample was taken with a clam rake every minute or 100 m along the arc. The boat was kept in motion during the operation and one investigator identified the rake contents and recorded the data. Figure 24 is a diagram of Coot Bay showing the results of this study. During the period May 1984 - June 1985, Chara had expanded its area to the east of Tarpon Creek to cover most of that embayment. This alga also had expanded to cover large extents of the bottom in the northeast portion of the bay, so much so that we were unable to sample several stations.

Summary of Environmental Variables

Water temperatures followed a typical seasonal cycle with highest values in May through September, and lower values during autumn through spring. Salinity was significantly lower in Coot Bay and Whitewater Bay than in Florida Bay, and there were no significant differences in salinity among Florida Bay strata. There was a weak but significant positive correlation between the silt-clay content of sediments of the study area and their organic content. The highest silt-clay contents appeared to be related primarily to land runoff in that the northern boundary of the Florida Bay study area from Flamingo to Madeira Bay had the highest silt-clay levels. Both Whitewater Bay and Coot Bay had high levels of silt-clay content suggesting depositional environments with land runoff as the primary source of this sediment particle size and probably a large portion of the sediment organic matter. Organic matter levels tended to correspond to sediment thickness and general seagrass density, at least in Florida Bay. There was an overall trend of comparatively low overall seagrass abundance in areas of shallow sediments (< 1 m thickness) having relatively low sediment organic content (< 15%). These data suggest that there is restricted seagrass population development in thinner veneer sediments and hence, a reduced organic matter buildup in the sediments.

The five strata differed in environmental variables and habitat characteristics. Stratum V (Coot Bay and Whitewater Bay) had low salinities ($\bar{x}$ = 17.2 o/oo), intermediate silt-clay contents, and the highest overall sediment organic content of the entire study area (Table 3). Where seagrasses were present, Halodule wrightii was more common in Whitewater Bay while Ruppia maritima was prevalent in Coot Bay for the study period as a whole.

The channel habitat in Florida Bay (Stratum IV) was characterized by intermediate sediment organic levels and sediment depth relative to other strata, but the highest overall silt-clay content of the strata sampled (Table 3). This stratum had the highest overall standing crop and density of seagrasses, and all three species of seagrasses (Thalassia, Halodule and Syringodium) we collected in Florida Bay were present in many of the channels. Halodule was more prevalent in this stratum than elsewhere. Channels in the southeastern and southwestern portion of the bay tended to have higher densities of seagrasses than channels sampled elsewhere.

Stratum III represented an open water, non-channel area of western Florida Bay which has the most direct exchange of water with the Gulf of Mexico. This area is characterized by extensive carbonate mud banks, and our sampling did not include these banks. The sediments of this area generally had high silt-clay

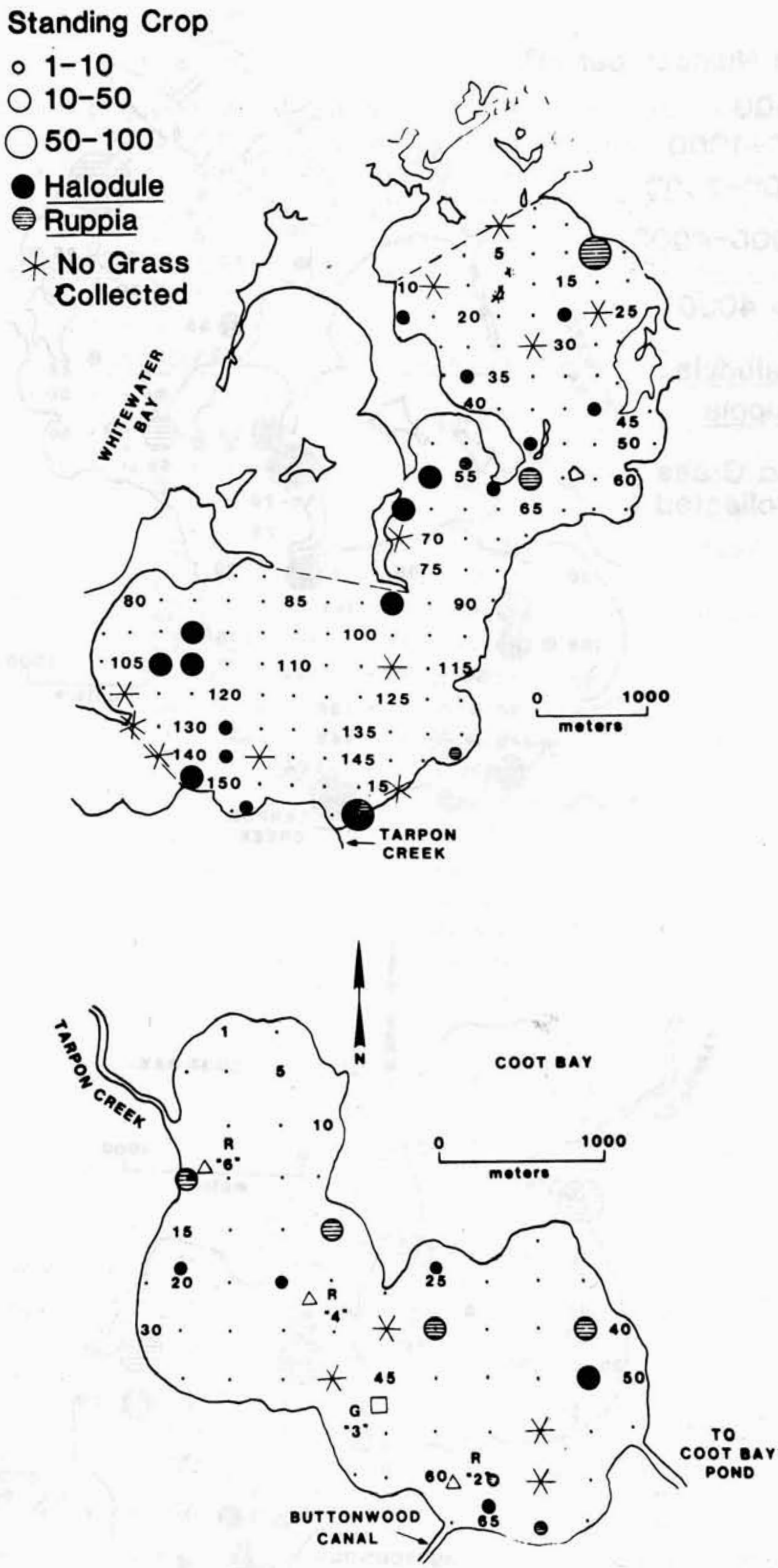


Figure 22. Ranges of seagrass standing crop in eastern Whitewater Bay (upper) and Coot Bay (lower).

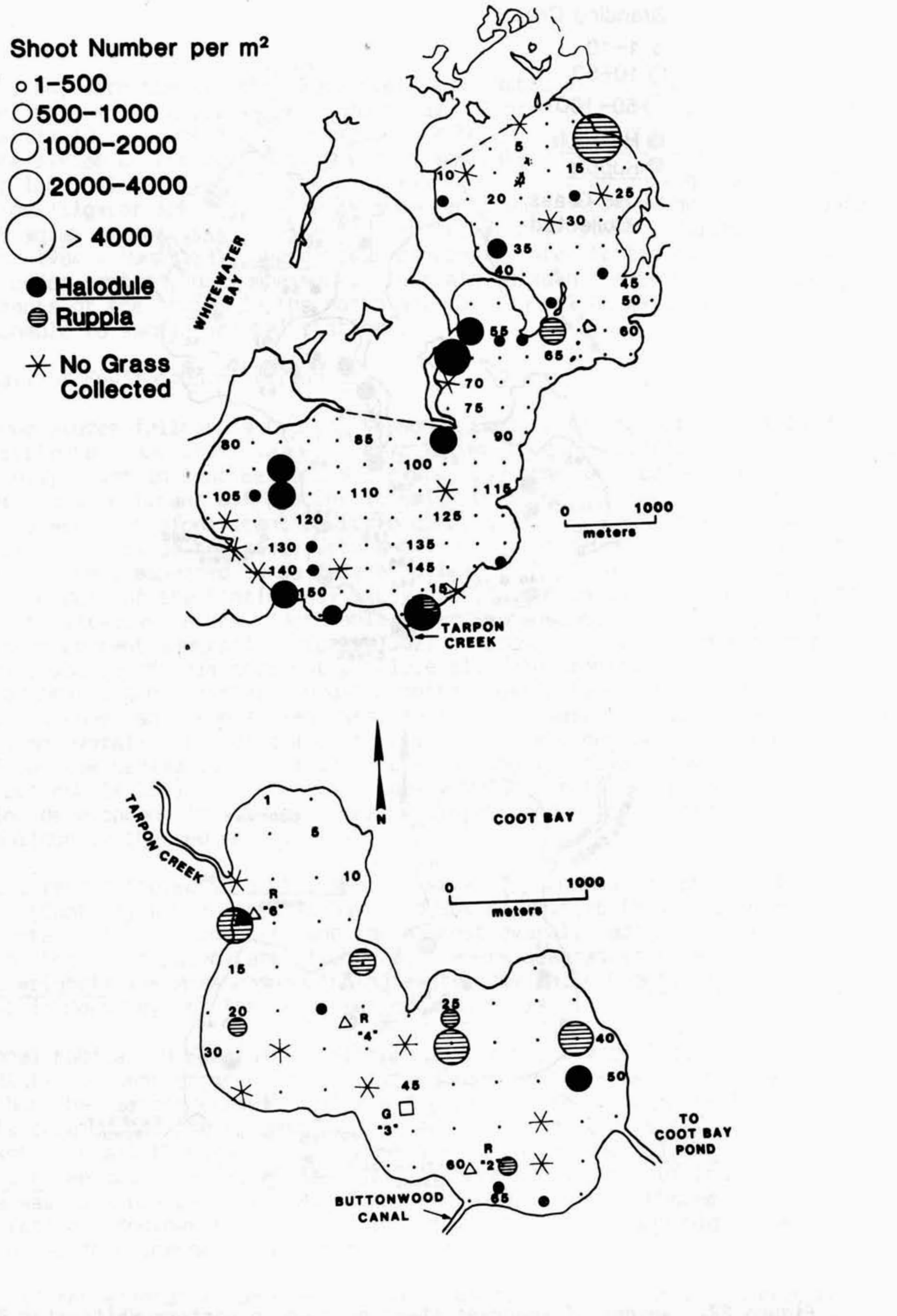


Figure 23. Ranges of seagrass shoot density in eastern Whitewater Bay (upper) and Coot Bay (lower).

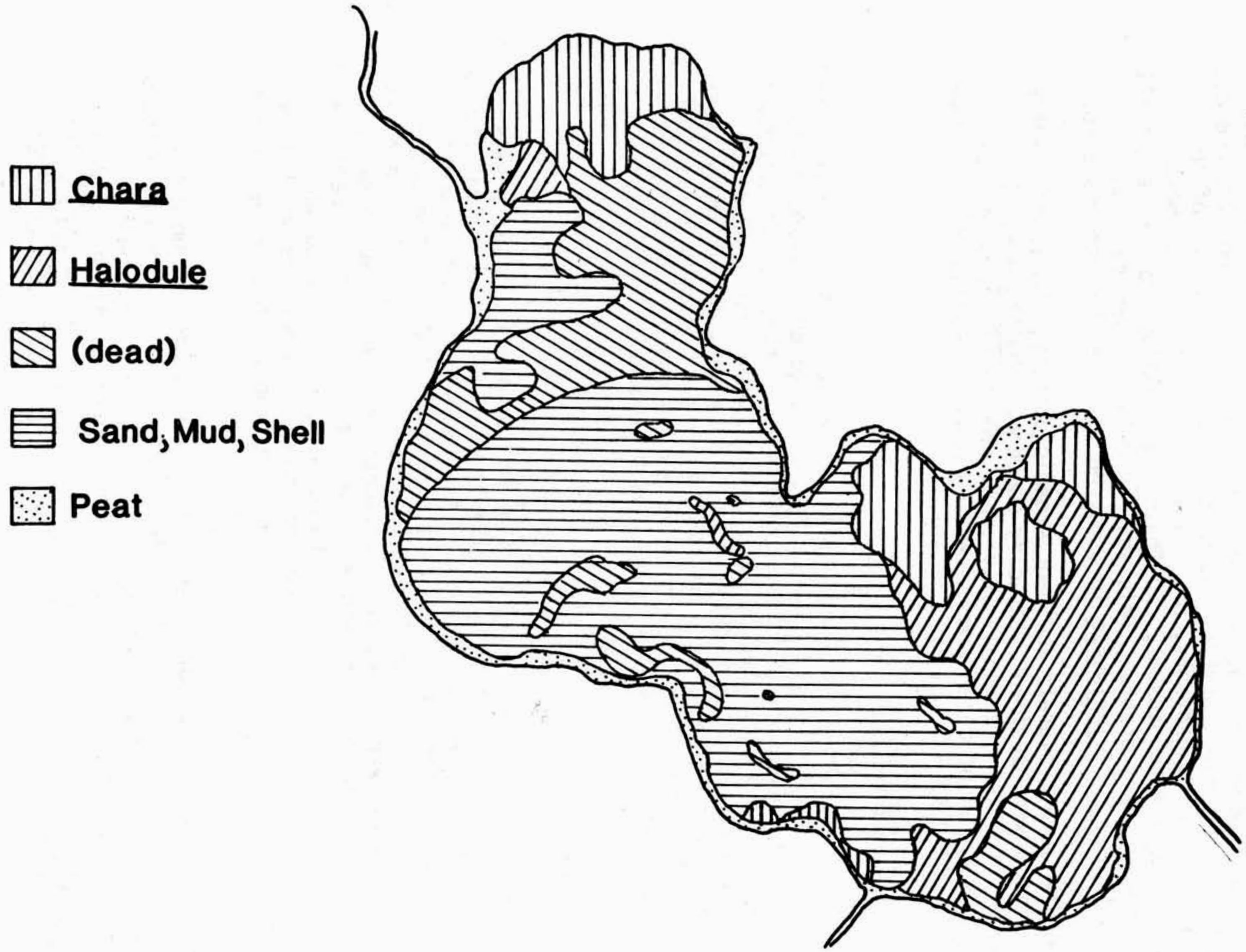


Figure 24. Distribution of bottom types in Coot Bay during March 1984.

and organic matter levels (Table 3). This stratum was the most diverse of the non-channel areas of Florida Bay in terms of seagrass species composition, and exhibited the highest overall densities of Syringodium but not Thalassia. Intermediate densities of Halodule also were present. No seagrasses were observed at sampling locations between East Cape and Curry Key north of Middle Ground.

Stratum II represented the interior of our sampling universe in Florida Bay (Fig. 4). Sediments generally had intermediate organic levels and low overall silt-clay contents. However, stations along the northern boundary of this stratum had high silt-clay contents, presumably from land runoff. Both Thalassia and Halodule were present, and Thalassia standing crops were overall greater here than in other strata. This was the only stratum where an increasing standing crop of Thalassia in a northerly direction was observed.

Stratum I, had the lowest overall sediment organic content, shallowest sediment veneer, and second lowest sediment silt-clay content. Thalassia was the dominant seagrass of this stratum and only small amounts of Halodule were present. The average shoot density and standing crop of seagrasses were lower here than in any other stratum in Florida Bay.

Distribution of Fish Communities

We first present general distributional trends of juvenile fish communities and then compare distributions of fishes among strata. We go on to examine the association of fishery organisms with environmental parameters in an attempt to discriminate their roles in structuring fish communities using habitats in estuarine and marine areas of the Park. These associations do not imply cause and effect but may provide the bases upon which to design experiments to test hypotheses derived from the study. As will be readily observed, the fishes we collected were dominated by juveniles as well as by adults of small forage species.

Relative Abundance and Biomass

There were 93 species and 43 families collected by surface and otter trawls during the nine stratified random surveys between May 1984 and June 1985 (Tables 5 and 6). Of the total collected (43,578), 71% were taken by the two-boat otter trawl. A total of 41 families and 91 species were collected with the otter trawl, while 61 species representing 29 families were collected with the surface trawl. Only four species were exclusively collected in the surface trawls: bonnethead shark, balao, sharksucker and white mullet. Thirty-four species were collected exclusively in the otter trawl. Thus, 56 species were common to the two gear types. The representation of the same species in surface and bottom samples may have been largely the result of our sampling in shallow waters where the two gears overlapped within the water column.

There were only a few of the dominant species that were common to both trawl gear. Eleven species contributed 91.0% of the total number of fish collected by otter trawl: rainwater killifish (Lucania parva) (28.6%); silver jenny (Eucinostomus gula) (27.7); pinfish (Lagodon rhomboides) (15.5); bay anchovy (Anchoa mitchilli) (7.0); goldspotted killifish (Floridichthys carpio) (2.8); white grunt (Haemulon plumieri) (1.9); dusky pipefish (Syngnathus floridae)

Table 5. Listing of fishes collected by bottom trawl and their total abundance in each stratum sampled in Everglades National Park estuarine and marine waters during 1984 and 1985. Scientific and family names are shown. For strata locations see Figures 2-5 and text. AFS standardized names used throughout.

Family/Scientific Name	--	Common Name	STRATUM I	II	III	IV	V	TOTAL
Dasyatidae - stingrays								
Dasyatis americana	--	southern stingray	-	-	-	1	-	1
Elopidae - tarpons								
Elops saurus	--	ladyfish	-	-	-	-	1	1
Albulidae - bonefishes								
Albula vulpes	--	bonefish	-	-	-	3	-	3
Clupeidae - herrings								
Brevoortia smithi	--	yellowfin menhaden	-	-	-	15	-	15
Harengula humeralis	--	redear sardine	-	1	-	-	-	1
Harengula jaguana	--	scaled sardine	3	2	5	9	-	19
Jenkinsia lamprotaenia	--	dwarf herring	8	-	5	20	-	33
Opisthonema oglinum	--	Atlantic thread herring	1	-	-	14	5	20
Sardinella aurita	--	Spanish sardine	-	-	-	91	-	91
Engraulidae - anchovies								
Anchoa hepsetus	--	striped anchovy	-	-	47	1	12	60
Anchoa mitchilli	--	bay anchovy	10	-	23	205	1935	2173
Synodontidae - lizardfishes								
Synodus foetens	--	inshore lizardfish	20	10	15	19	3	67
Ariidae - sea catfishes								
Arius felis	--	hardhead catfish	1	-	38	21	142	202
Bagre marinus	--	gafftopsail catfish	-	-	12	-	31	43
Batrachoididae - toadfishes								
Opsanus beta	--	gulf toadfish	5	100	75	114	4	298
Gobiesocidae - clingfishes								
Gobiesox strumosus	--	skilletfish	-	-	1	1	-	2
Antennariidae - frogfishes								
Histrio histrio	--	sargassumfish	-	1	-	-	-	1
Ogcocephalidae - batfishes								
Ogcocephalus radiatus	--	polka-dot batfish	-	-	4	-	-	4

Table 5. (Contd)

Family/Scientific Name -- Common Name		I	II	III	IV	V	TOTAL
Bythitidae - viviparous brotulas							
Gunterichthys longipenis --	gold brotula	-	-	-	1	-	1
Exocoetidae - flyingfishes							
Chriodorus atherinoides --	hardhead halfbeak	-	14	-	3	-	17
Hemiramphus brasiliensis --	ballyhoo	-	18	-	-	-	18
Hyporhamphus unifasciatus -	halfbeak	-	2	117	-	-	119
Belonidae - needlefishes							
Strongylura notata --	redfin needlefish	4	20	2	7	11	44
Strongylura timucu --	timucu	2	1	8	-	6	17
Cyprinodontidae - killifishes							
Floridichthys carpio --	goldspotted killifish	115	224	72	443	7	861
Lucania parva --	rainwater killifish	44	81	2714	4065	302	8906
Poeciliidae - livebears							
Poecilia latipinna --	sailfin molly	-	3	-	2	-	5
Atherinidae - silversides							
Atherinomorus stipes --	hardhead silverside	-	1	-	318	-	319
Hypoatherina harringtonensis --	reef silverside	-	-	-	1	-	1
Membras martinica --	rough silverside	-	-	2	-	18	20
Menidia peninsulae --	tidewater silverside	-	-	-	-	3	3
Syngnathidae - pipefishes							
Hippocampus erectus --	lined seahorse	1	-	16	5	-	22
Hippocampus zosterae --	dwarf seahorse	92	40	74	103	1	310
Syngnathus dunckeri --	pugnose pipefish	4	12	23	48	-	87
Syngnathus floridae --	dusky pipefish	15	54	296	174	3	542
Syngnathus louisianae --	chain pipefish	1	2	5	1	-	9
Syngnathus scovelli --	gulf pipefish	22	32	150	98	32	334
Serranidae - sea basses							
Diplectrum formosum --	sand perch	-	-	1	-	-	1
Hypoplectrus unicolor (or H. puella) --	barred hamlet	-	-	4	-	-	4
Mycteroperca microlepis --	gag	-	-	1	-	-	1

Table 5. (Contd)

Family/Scientific Name	--	Common Name	I	II	III	IV	V	TOTAL
Carangidae - jacks								
Caranx crysos	--	blue runner	-	-	1	-	-	1
Caranx hippos	--	crevalle jack	-	-	-	2	-	2
Oligoplites saurus	--	leatherjacket	-	-	-	-	1	1
Trachinotus carolinus	--	Florida pompano	-	-	-	1	-	1
Lutjanidae - snappers								
Lutjanus griseus	--	gray snapper	-	-	33	65	2	100
Lutjanus synagris	--	lane snapper	2	-	69	11	-	82
Ocyurus chrysurus	--	yellowtail snapper	3	-	-	4	-	7
Gerreidae - mojarras								
Eucinostomus argenteus	--	spotfin mojarra	58	42	92	180	57	429
Eucinostomus gula	--	silver jenny	1495	878	2329	2746	1192	8640
Haemulidae - grunts								
Haemulon aurolineatum	--	tomtate	-	-	-	3	-	3
Haemulon flavolineatum	--	French grunt	-	-	-	7	-	7
Haemulon parrai	--	sailor's choice	6	1	9	40	-	76
Haemulon plumieri	--	white grunt	-	-	40	168	-	588
Haemulon sciurus	--	bluestriped grunt	5	-	1	73	-	89
Orthopristis chrysoptera	--	pigfish	1	1	28	136	7	393
Sparidae - porgies								
Archosargus probatocephalus	--	sheepshead	5	38	7	1	-	61
Calamus arctifrons	--	grass porgy	1	-	4	24	-	39
Calamus leucosteus	--	whitebone porgy	2	-	-	-	-	2
Lagodon rhomboides	--	pinfish	98	100	330	1276	29	4823
Sciaenidae - drums								
Bairdiella chrysoura	--	silver perch	2	4	38	45	122	481
Cynoscion nebulosus	--	spotted seatrout	1	-	8	10	10	49
Menticirrhus americanus	--	southern kingfish	-	-	-	-	2	2
Ephippidae - spadefishes								
Chaetodipterus faber	--	Atlantic spadefish	-	1	1	4	-	6
Scaridae - parrotfishes								
Cryptotomus roseus	--	bluelip parrotfish	-	-	-	2	-	2
Nicholsina usta	--	emerald parrotfish	-	-	2	4	-	6
Mugilidae - mullets								
Mugil cephalus	--	striped mullet	-	-	2	1	-	3

Table 5. (Contd)

Family/Scientific Name	--	Common Name	I	II	III	IV	V	TOTAL
Sphyraenidae - barracudas								
Sphyraena baracuda	--	great barracuda	10	6	7	10	1	34
Sphyraena guachancho	--	guaguanche	1	-	-	-	-	1
Clinidae - clinids								
Chaenopsis limbaughi	--	yellowface pikeblenny	1	-	-	-	-	1
Paraclinus fasciatus	--	banded blenny	2	-	2	29	-	33
Paraclinas marmoratus	--	marbled blenny	-	-	2	23	-	35
Blenniidae - combtooth blennies								
Chasmodes saburrae	--	Florida blenny	2	-	5	17	2	26
Callionymidae - dragonets								
Callionymus pauciradiatus	--	spotted dragonet	6	10	-	16	-	32
Gobiidae - gobies								
Gobiosoma robustum	--	code goby	4	4	2	53	3	76
Microgobius gulosus	--	clown goby	13	6	-	23	33	75
Microgobius microlepsis	--	banner goby	9	-	-	4	-	13
Triglidae - searobins								
Prionotus scitulus	--	leopard searobin	-	-	1	1	-	2
Prionotus tribulus	--	bighead searobin	-	-	-	1	-	1
Bothidae - lefteye flounders								
Ancylopsetta quadrocellata	--	ocellated flounder	-	1	1	-	-	2
Soleidae - soles								
Achirus lineatus	--	lined sole	-	-	1	3	1	5
Trinectes inscriptus	--	scrawled sole	-	-	-	1	-	1
Trinectes maculatus	--	hogchoker	-	-	-	-	1	1
Cynoglossidae - tonguefishes								
Symphurus plagiusa	--	blackcheek tonguefish	-	-	1	2	-	3
Balistidae - leatherjacks								
Aluterus schoepfi	--	orange filefish	-	-	4	-	-	4
Monacanthus ciliatus	--	fringed filefish	-	-	106	1	-	107
Monacanthus hispidus	--	planehead filefish	-	3	17	-	-	20

Table 5. (Contd)

Family/Scientific Name --	Common Name	I	II	III	IV	V	TOTAL
Ostraciidae - boxfishes							
Lactophrys quadricornis --	scrawled cowfish	6	-	18	12	-	36
Lactophrys trigonus --	trunkfish	-	-	1	-	-	1
Tetraodontidae - puffers							
Sphoeroides nephelus --	southern puffer	3	6	15	8	3	35
Sphoeroides spengleri --	bandtail puffer	1	-	1	5	-	7
Diodontidae - porcupinefishes							
Chilomycterus schoepfi --	striped burrfish	2	4	17	6	-	29
		2082	3390	10876	10817	3983	31148

(1.7); silver perch (Bairdiella chrysoura) (1.5); pigfish (Orthopristis chrysoptera) (1.3); gulf pipefish (Syngnathus scovelli) (1.1); hardhead silverside (Atherinomorus stipes) (1.0); and gulf toadfish (Opsanus beta) (1.0). Bay anchovy dominated the surface trawl catches (26.7) followed by halfbeak (Hyporhamphus unifasciatus) (12.3); reef silverside (Hypoatherina harringtonensis) (9.7); rough silverside (Membras martinica) (9.4); hardhead silverside (7.5%); ; redfin needlefish (Strongylura notata) (7.3); hardhead halfbeak (Chriodorus atherinoides) (5.7); striped anchovy (Anchoa hepsetus) (5.1); silverjenny (2.2); rainwater killifish (1.7); and Spanish sardine (Sardinella aurita) (1.3).

The dominant fish species in our collections were similar to those observed in other studies that have been carried out on fish distribution in south Florida. Tabb and Manning (1961) reported that anchovies, mojarras and pinfish were dominant in trawl collections in northern Florida Bay and Whitewater Bay. Tabb (unpubl. data), recorded a somewhat different species compliment from the area of Eagle Key and Murray Key during 1964-1966, including: fringed pipefish (Micrognathus crinigerus), silver jenny, spotfin mojarra, (Eucinostomus argenteus), pinfish, planehead filefish (Monocanthus hispidus), white grunt, lane snapper (Lutjanus syngaris) and pigfish. Schmidt (1979) found that striped and bay anchovies constituted over 48% of the total trawl catch for western and southwestern Florida Bay, followed by mojarra, killifish, and pinfish. Together, these anchovies composed less than 15% of our total catch using two gears. Weinstein and Heck (1979) observed that silver perch, pinfish, silver jenny, white grunt, pigfish, and lane snapper were among the dominant species in seagrass beds near Cape Romano and Marco Island, similar to what Tabb and Manning (1962) observed for seagrass areas of Florida Bay. Carter et al. (1973) and Colby et al. (1985), working in the Ten Thousand Island area, reported a similar compliment of dominant species as those we found in the Everglades National Park, but both reported a preponderance of species with pelagic affinities even though several gear types were used.

Those species that dominated the overall catch numerically did not necessarily dominate the total wet weight of fish collected. During the stratified random sampling phase of this study, 144 kg wet weight of fish were collected by otter trawls (Table 7) and 49.4 kg were collected in surface trawls (Table 8). Twelve species dominated the biomass of fishes collected by otter trawls: pinfish (29.3%), silver jenny (16.8), hardhead catfish (Arius felis), (10.3), pigfish (4.8), white grunt (4.1), gulf toadfish (3.7), silver perch (3.1), gray snapper (2.8), gafftopsail catfish (Bagre marinus) (2.7), scrawled cowfish (Lactophrys quadricornis) (2.1), inshore lizardfish (Synodus foetens) (1.8) and bluestriped grunt (Haemulon sciurus) (1.5). The gray snapper and the latter five species on this list were not among the numerically dominant species, but together represented greater than 21% of the total biomass collected by otter trawl sampling. Nine species represented 91.2% of the total biomass collected, and only three of these were not among the numerically dominant species. In decreasing order, the species which dominated the biomass collected by surface gear were: halfbeak (32.5%); redfin needlefish (28.2); hardhead halfbeak (9.5); ballyhoo (Hemiramphus brasiliensis) (7.1); timucu (Strongylura timucu) (3.9); bay anchovy (3.3); rough silverside (2.4); pinfish (2.3); and silver jenny (1.9).

Table 6. Listing of species and abundances of fish collected in Everglades National Park during 1984 and 1985 using a surface trawl. Refer to text for strata locations.

Family/Scientific Name	--	Common Name	I	II	III	IV	V	TOTAL
Sphyrnidae - hammerhead sharks								
Sphyrna tiburo	--	bonnethead	-	-	1	-	-	1
Clupeidae - herrings								
Brevoortia smithi	--	yellowfin menhaden	-	-	37	76	20	133
Harengula humeralis	--	redear sardine	-	-	-	3	-	3
Harengula jaguana	--	scaled sardine	22	2	3	102	7	136
Jenkinsia lamprotaenia	--	dwarf herring	1	-	-	-	-	1
Opisthonema oglinum	--	Atlantic thread herring	-	-	119	8	8	135
Sardinella aurita	--	Spanish sardine	-	161	2	1	-	164
Engraulidae - anchovies								
Anchoa hepsetus	--	striped anchovy	-	33	463	29	107	632
Anchoa mitchilli	--	bay anchovy	-	14	167	409	2739	3329
Syndontidae - lizardfishes								
Synodus foetens	--	inshore lizardfish	4	-	1	1	1	7
Ariidae - sea catfishes								
Arius felis	--	hardhead catfish	-	-	-	-	5	5
Bagre marinus	--	gafftopsail catfish	-	-	-	-	1	1
Batrachoididae - toadfishes								
Opsanus beta	--	gulf toadfish	3	9	2	5	1	20
Antennariidae - frogfishes								
Histrio histrio	--	sargassumfish	2	-	-	-	-	2
Exocoetidae - flyingfishes								
Chriodorus atherinoides	--	hardhead halfbeak	322	221	18	150	-	711
Hemiramphus balao	--	balao	-	1	1	-	-	2
Hemiramphus brasiliensis	--	ballyhoo	10	7	45	40	-	102
Hyporhamphus unifasciatus	--	halfbeak	134	32	1083	276	7	1532
Belonidae - needlefishes								
Strongylura notata	--	redfin needlefish	57	455	83	111	199	905
Strongylura timucu	--	timucu	-	6	106	15	38	165

Table 6. (Contd)

Family/Scientific Name	--	Common Name	I	II	III	IV	V	TOTAL
Cyprinodontidae - killifishes								
Floridichthys carpio	--	goldspotted killifish	10	78	13	8	-	109
Lucania parva	--	rainwater killifish	3	115	42	21	33	214
Atherinidae - silversides								
Atherinomorus stipes	--	hardhead silverside	4	447	6	475	-	932
Hypoatherina harringtonensis	--	reef silverside	297	42	27	844	-	1210
Membras martinica	--	rough silverside	82	54	272	63	700	1171
Menidia peninsulae	--	tidewater silverside	-	-	9	-	105	114
Syngnathidae - pipefishes								
Hippocampus erectus	--	lined seahorse	-	2	-	1	-	3
Hippocampus zosterae	--	dwarf seahorse	4	10	3	-	1	8
Syngnathus dunckeri	--	pugnose pipefish	2	2	1	-	-	5
Syngnathus floridae	--	dusky pipefish	3	4	12	5	-	4
Syngnathus louisianae	--	chain pipefish	-	-	1	-	1	2
Syngnathus scovelli	--	gulf pipefish	1	13	14	10	23	1
Serranidae - sea basses								
Hypoplectrus unicolor (or H. puella)	--	barred hamlet	6	-	-	-	-	6
Echeneidae - remoras								
Echeneis naucrates	--	sharksucker	-	-	1	-	-	1
Carangidae - jacks								
Caranx hippos	--	crevalle jack	-	-	1	-	-	1
Oligoplites saurus	--	leatherjacket	2	1	12	7	10	2
Trachinotus carolinus	--	Florida pompano	-	-	1	-	-	1
Lutjanidae - snappers								
Lutjanus griseus	--	gray snapper	-	-	1	-	-	1
Lutjanus synagris	--	lane snapper	2	-	1	-	-	3
Gerreidae - mojarras								
Eucinostomus argenteus	--	spotfin mojarra	-	-	-	-	5	5
Eucinostomus gula	--	silver jenny	27	120	58	25	41	271

Table 6. (Contd)

Family/Scientific Name	--	Common Name	I	II	III	IV	V	TOTAL
Haemulidae - grunts								
Haemulon parrai	--	sailor's choice	-	-	13	-	-	3
Haemulon plumieri	--	white grunt	-	-	4	-	-	4
Haemulon sciurus	--	bluestriped grunt	-	-	3	-	-	3
Orthopristis chrysoptera	--	pigfish	-	-	4	1	-	5
Sparidae - porgies								
Archosargus probatocephal	--	sheepshead	-	-	2	-	-	2
Lagodon rhomboides	--	pinfish	2	29	114	7	-	12
Sciaenidae - drums								
Bairdiella chrysoura	--	silver perch	-	-	6	1	3	0
Cynoscion nebulosus	--	spotted seatrout	-	1	-	-	2	3
Mugilidae - mullets								
Mugil cephalus	--	striped mullet	-	-	1	1	1	3
Mugil curema	--	white mullet	1	-	9	1	-	1
Sphyraenidae - barracudas								
Sphyraena barracuda	--	great barracuda	-	-	-	1	-	1
Callionymidae - dragonets								
Callionymus pauciradiatus	--	spotted dragonet	4	2	-	-	-	6
Gobiidae - gobies								
Gobiosoma robustum	--	code goby	-	3	1	2	1	7
Microgobius gulosus	--	clown goby	6	2	-	3	0	0
Soleidae - soles								
Achirus lineatus	--	lined sole	-	-	1	1	1	3
Balistidae - leatherjacks								
Monacanthus ciliatus	--	fringed filefish	1	-	-	-	-	1
Ostraciidae - boxfishes								
Lactophrys quadricornis	--	scrawled cowfish	1	-	-	-	-	1
Tetraodontidae - puffers								
Sphoeroides nephelus	--	southern puffer	1	1	11	1	-	4
Diodontidae - porcupinefishes								
Chilomycterus schoepfi	--	striped burrfish	-	-	1	-	-	1
			1014	1867	2776	2703	4070	12430

Distribution of Fish Among Strata

The distribution of total numbers and weight of fish varied among strata for species collected by the two gear (Tables 5-8). Western Florida Bay and the channels (Strata III and IV) consistently displayed a similar and larger fish community (otter trawl) in terms of numerical abundance, biomass and species composition relative to other areas in Florida Bay, Whitewater Bay and Coot Bay. Approximately 70% of the total number and wet weight of fish from the otter trawl collections was from these two strata, with a slightly greater overall biomass of fish being taken from the channels (Stratum IV). Of the other three strata, eastern Florida Bay (Stratum I) exhibited the numerically smallest demersal fish community while the interior stratum (II) displayed the smallest demersal fish community in terms of total weight (Tables 5 and 7). Thus, the overall fish community collected by otter trawl was numerically larger and exhibited a higher overall biomass in those strata (Strata III and IV) that generally exhibited the largest and most diverse seagrass assemblages (see Fig. 18).

The composition of the fish community varied among strata for species collected by both gear types (Tables 5-8) but there were numerous species in common. The near-gulf and channel strata (Strata III and IV) had the largest number of species collected by either gear type, while Whitewater and Coot Bay (Stratum V) had the lowest. Thus, the Margalef diversity index (S-1/ln N, where S = number of species and N = number of individuals) was greatest for Strata III and IV (6.240 and 7.105, respectively, for bottom trawls and 5.675 and 4.176 for surface trawls, respectively) and least for the Whitewater Bay and Coot Bay stratum (3.981 for otter trawls and 3.128 for surface trawls).

Venn diagrams were developed to depict the co-occurrence of fish species among strata for the survey as a whole. A species-by-strata matrix was constructed based on data presented in Tables 5 and 6. Only those species for which there were more than 10 individuals in any single stratum were included. Each stratum or strata-combination is represented by a ring in the Venn diagram and the rings intersect so that the number of species found in all strata is indicated within the intersection of all three rings; the number of species found in two of the three strata is indicated within the corresponding intersection of those two respective rings; and those species unique to a particular stratum are indicated within the appropriate ring outside of intersections with the other two. Two comparisons each were made for the otter trawl and surface samples (Figs. 25 and 26): 1) a comparison of the low salinity stratum composed of Coot Bay and Whitewater Bay (V), channels in Florida Bay (IV), and the open water strata of Florida Bay (I, II and III combined); and 2) a comparison of Strata I, II and III in Florida Bay.

A comparison of open water, low and high salinity, strata with the high salinity channel stratum demonstrated that there were numerous species common to all areas and that the open water area of Florida Bay (Strata I, II and III combined) had a larger complement of co-occurring species than did the other areas sampled (Figs. 25 and 26). Ten species were truely ubiquitous in the fish community sampled by otter trawl: bay anchovy, rainwater killifish, redfin needlefish, spotfin mojarra, silver jenny, pinfish, spotted seatrout (*Cynoscion nebulosus*), clown goby (*Microgobius gulosus*), hardhead catfish and silver perch. Nine species collected by surface trawls were common to all of these areas: yellowfin (*Brevoortia smithi*), menhaden, striped anchovy, bay anchovy, redfin needlefish, timucu, rainwater killifish, rough silverside, gulf

Table 7. Listing of fishes collected by bottom trawl and their total biomass (grams wet weight) in each stratum sampled in Everglades National Park estuarine and marine waters during 1984 and 1985. Scientific and family names are shown. For strata locations see Figures 2-5 and text. AFS standardized names used.

		STRATUM					
Family/Scientific Name	-- Common Name	I	II	III	IV	V	TOTAL
Dasyatidae - stingrays							
Dasyatis americana	-- southern stingray	-	-	-	2430.0	-	2430.0
Elopidae - tarpons							
Elops saurus	-- ladyfish	-	-	-	-	15.2	15.2
Albulidae - bonefishes							
Albula vulpes	-- bonefish	-	-	-	19.8	-	19.8
Clupeidae - herrings							
Brevoortia smithi	-- yellowfin menhaden	-	-	-	73.3	-	73.3
Harengula humeralis	-- redear sardine	-	0.6	-	-	-	0.6
Harengula jaguana	-- scaled sardine	0.6	52.3	75.9	25.0	-	153.8
Jenkinsia lamprotaenia	-- dwarf herring	1.1	-	0.7	5.8	-	7.6
Opisthonema oglinum	-- Atlantic thread herring	64.6	-	-	25.9	18.4	108.9
Sardinella aurita	-- Spanish sardine	-	-	-	36.9	-	36.9
Engraulidae - anchovies							
Anchoa hepsetus	-- striped anchovy	-	-	11.9	0.2	12.8	24.9
Anchoa mitchilli	-- bay anchovy	1.8	-	13.3	145.7	1624.0	1784.8
Synodontidae - lizardfishes							
Synodus foetens	-- inshore lizardfish	1418.4	637.0	286.2	71.7	118.2	2531.3
Ariidae - sea catfishes							
Arius felis	-- hardhead catfish	86.9	-	2704.4	3695.2	8314.8	4801.3
Bagre marinus	-- gafftopsail catfish	-	-	1237.7	-	2702.4	3940.1
Batrachoididae - toadfishes							
Opsanus beta	-- gulf toadfish	41.0	653.7	2702.6	2006.3	2.0	5405.6
Gobiesocidae - clingfishes							
Gobiesox strumosus	-- skilletfish	-	-	0.9	2.6	-	3.5
Antennariidae - frogfishes							
Histrio histrio	-- sargassumfish	-	1.4	-	-	-	1.4

Table 7 (Contd).

Family/Scientific Name --	Common Name	STRATUM I	II	III	IV	V	TOTAL
Ogcocephalidae - batfishes							
Ogcocephalus radiatus --	polka-dot batfish	-	-	333.4	-	-	333.4
Bythitidae - viviparous brotulas							
Gunterichthys longipenis --	gold brotula	-	-	-	0.6	-	0.6
Exocoetidae - flyingfishes							
Chriodorus atherinoides --	hardhead halfbeak	-	71.9	-	51.6	-	123.5
Hemiramphus brasiliensis --	ballyhoo	-	139.3	-	-	-	139.3
Hyporhamphus unifasciatus --	halfbeak	-	15.3	827.6	-	-	842.9
Belonidae - needlefishes							
Strongylura notata --	redfin needlefish	0.7	651.7	1.2	2.4	2.6	682.0
Strongylura timucu --	timucu	0.8	0.2	3.8	-	42.7	
Cyprinodontidae - killifishes							
Floridichthys carpio --	goldspotted killifish	50.7	137.7	82.1	248.4	9.5	
Lucania parva --	rainwater killifish	7.9	401.8	637.1	792.6	49.3	
Poeciliidae - livebears							
Poecilia latipinna --	sailfin molly	-	0.9	-	2.4	-	3.3
Atherinidae - silversides							
Atherinomorus stipes --	hardhead silverside	-	0.2	-	186.4	-	186.6
Hypoatherina harringtonensis -	reef silverside	-	-	-	0.5	-	0.5
Membras martinica --	rough silverside	-	-	1.0	-	13.3	14.3
Menidia peninsulae --	tidewater silverside	-	-	-	-	0.4	0.4
Syngnathidae - pipefishes							
Hippocampus erectus --	lined seahorse	0.4	-	52.7	2.1	-	55.2
Syngnathus dunckeri --	pugnose pipefish	0.8	1.3	5.2	12.4	-	19.7
Syngnathus floridae --	dusky pipefish	40.5	146.9	488.3	343.0	0.9	1020.5
Syngnathus louisianae --	chain pipefish	3.8	7.9	7.7	1.6	-	21.0
Syngnathus scovelli --	gulf pipefish	18.5	28.5	84.9	57.3	10.2	199.4

Table 7 (Contd).

Family/Scientific Name -- Common Name	STRATUM I	II	III	IV	V	TOTAL
Serranidae - sea basses						
Diplectrum formosum -- sand perch	-	-	77.9	-	-	77.9
Hypoplectrus unicolor (or H. puella) -- barred hamlet	-	-	43.3	-	-	43.3
Mycteroperca microlepis- gag	-	-	1.9	-	-	1.9
Carangidae - jacks						
Caranx crysos -- blue runner	-	-	5.8	-	-	5.8
Caranx hippos -- crevalle jack	-	-	-	1.5	-	1.5
Oligoplites saurus -- leatherjacket	-	-	-	-	0.2	0.2
Trachinotus carolinus -- Florida pompan	-	-	-	172.2	-	172.2
Lutjanidae - snappers						
Lutjanus griseus -- gray snapper	-	-	934.6	2966.0	200.4	4101.0
Lutjanus synagris -- lane snapper	30.0	-	418.4	171.8	-	620.2
Ocyurus chrysurus -- yellowtail snapper	40.7	-	-	70.4	-	111.1
Gerreidae - mojarras						
Eucinostomus argenteus-- spotfin mojarra	255.2	53.8	94.9	350.6	250.3	1004.8
Eucinostomus gula -- silver jenny	652.9	2760.0	3087.0	3757.7	4981.0	24238.6
Haemulidae - grunts						
Haemulon aurolineatum -- tomtate	-	-	-	28.8	-	28.8
Haemulon flavolineatum -- French grunt	-	-	-	261.4	-	261.4
Haemulon parrai -- sailor's choice	2.0	0.8	15.3	433.3	-	261.4
Haemulon plumieri -- white grunt	-	-	3500.5	2379.7	-	5880.2
Haemulon sciurus -- bluestriped grunt	24.1	-	37.8	2284.0	-	2345.9
Orthopristis chrysoptera -- pigfish	139.8	72.2	2642.6	3833.9	266.5	6955.0
Sparidae - porgies						
Archosargus probatocephalus -- sheepshead	-	35.3	292.7	1277.2	107.2	1712.4
Calamus arctifrons -- grass porgy	65.0	-	692.4	975.9	-	1733.3
Calamus leucosteus -- whitebone porgy	37.7	-	-	-	-	37.7
Lagodon rhomboides -- pinfish	2260.4	2710.8	18677.3	17299.7	1205.5	42153.7

Table 7 (Contd).

Family/Scientific Name -- Common Name		STRATUM I	II	III	IV	V	TOTAL
Sciaenidae - drums							
Bairdiella chrysoura	-- silver perch	97.6	20.5	2724.3	230.2	1658.7	4731.3
Cynoscion nebulosus	-- spotted seatrout	76.4	-	253.1	756.3	29.5	1115.3
Menticirrhus americanus	-- southern kingfish	-	-	-	-	396.8	396.8
Ephippidae - spadefishes							
Chaetodipterus faber	-- Atlantic spadefish	-	196.1	79.2	331.2	-	606.5
Scaridae - parrotfishes							
Cryptotomus roseus	-- bluelip parrotfish	-	-	-	5.2	-	5.2
Nicholsina usta	-- emerald parrotfish	-	-	24.5	160.7	-	185.2
Mugilidae - mullets							
Mugil cephalus	-- striped mullet	-	-	53.9	394.4	-	448.3
Sphyraenidae - barracudas							
Sphyraena barracuda	-- great barracuda	13.8	107.3	68.3	310.1	26.0	510.1
Sphyraena guachancho	-- guaguanche	1.0	-	-	-	-	1.0
Clinidae - clinids							
Chaenopsis limbaughi	-- yellowface pikeblenny	1.1	-	-	-	-	1.1
Paraclinus fasciatus	-- banded blenny	1.3	-	0.9	27.7	-	29.9
Paraclinus marmoratus	-- marbled blenny	-	-	16.1	24.0	-	40.1
Blenniidae - combtooth blennies							
Chasmodes saburrae	-- Florida blenny	5.8	-	6.2	32.4	2.0	46.4
Callionymidae - dragonets							
Callionymus pauciradiatus	-- spotted dragonet	2.9	2.8	-	7.2	-	12.9
Gobiidae - gobies							
Gobiosoma robustum	-- code goby	1.4	2.9	4.6	18.2	0.7	27.8
Microgobius gulosus	-- clown goby	3.0	1.9	-	6.0	17.2	28.1
Microgobius microlepsis	-- banner goby	2.5	-	-	1.2	-	3.7

Table 7 (Contd).

Family/Scientific Name -- Common Name		STRATUM I	II	III	IV	V	
Triglidae - searobins							
Prionotus scitulus	-- leopard searobin	-	-	3.9	3.2	-	
Prionotus tribulus	-- bighead searobin	-	-	-	0.1	-	
Bothidae - lefteye flounders							
Ancylopsetta quadrocellata	-- ocellated flounder	-	23.9	42.6	-	-	
Soleidae - soles							
Achirus lineatus	-- lined sole	-	-	0.6	30.6	3.9	
Trinectes inscriptus	-- scrawled scole	-	-	-	17.4	-	
Trinectes maculatus	-- hogchoker	-	-	-	-	4.1	
Cynoglossidae - tonguefishes							
Symphurus plagiusa	-- blackcheek tonguefish	-	-	3.9	6.3	-	
Balistidae - leatherjacks							
Aluterus schoepfi	-- orange filefish	-	-	174.5	-	-	1
Monacanthus ciliatus	-- fringed filefish	-	-	544.6	8.8	-	5
Monacanthus hispidus	-- planehead filefish	-	2.1	93.4	-	-	
Ostraciidae - boxfishes							
Lactophrys quadricornis	-- scrawled cowfish	545.7	-	1279.9	1160.4	-	25
Lactophrys trigonus	-- trunkfish	-	-	98.3	-	-	
Tetraodontidae - puffers							
Sphoeroides nephelus	-- southern puffer	19.3	271.9	197.7	133.6	217.4	8
Sphoeroides spengleri	-- bandtail	5.1	-	4.6	175.5	-	1
Diodontidae - porcupinefishes							
Chilomycterus schoepfi	-- striped burrfish	46.9	168.8	691.3	460.6	-	13
		15076.7	9383.3	46453.1	50815.0	22307.2	1440

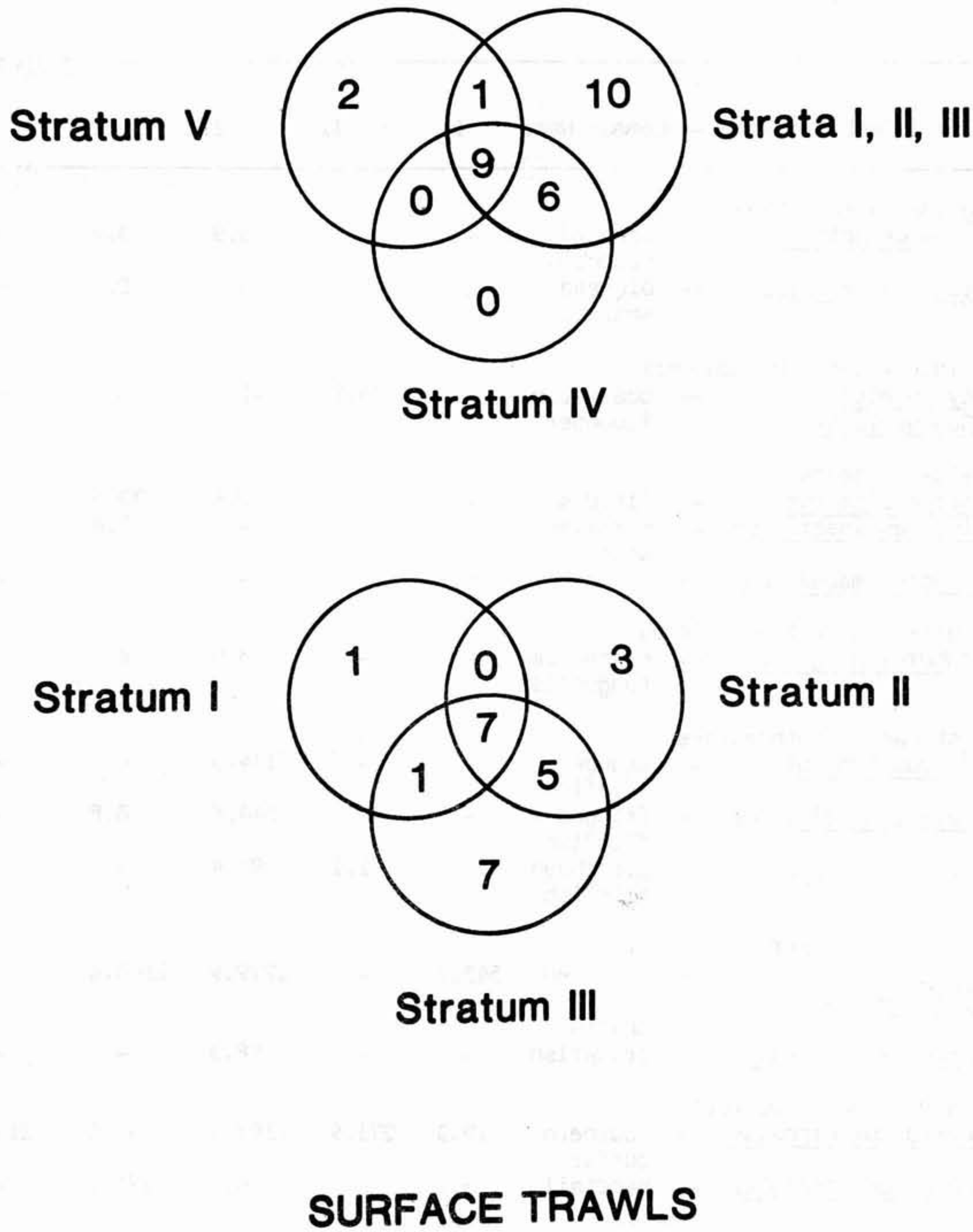


Figure 25. Diagrammatic representation of the overall similarities and differences in numbers of fish species collected from within Coot Bay-Whitewater Bay (Stratum V), open-water areas of Florida Bay (Strata, I, II, III) and channel areas of Florida Bay (Stratum IV) (upper), and among the three open-water strata in Florida Bay (lower) for surface trawl samples.

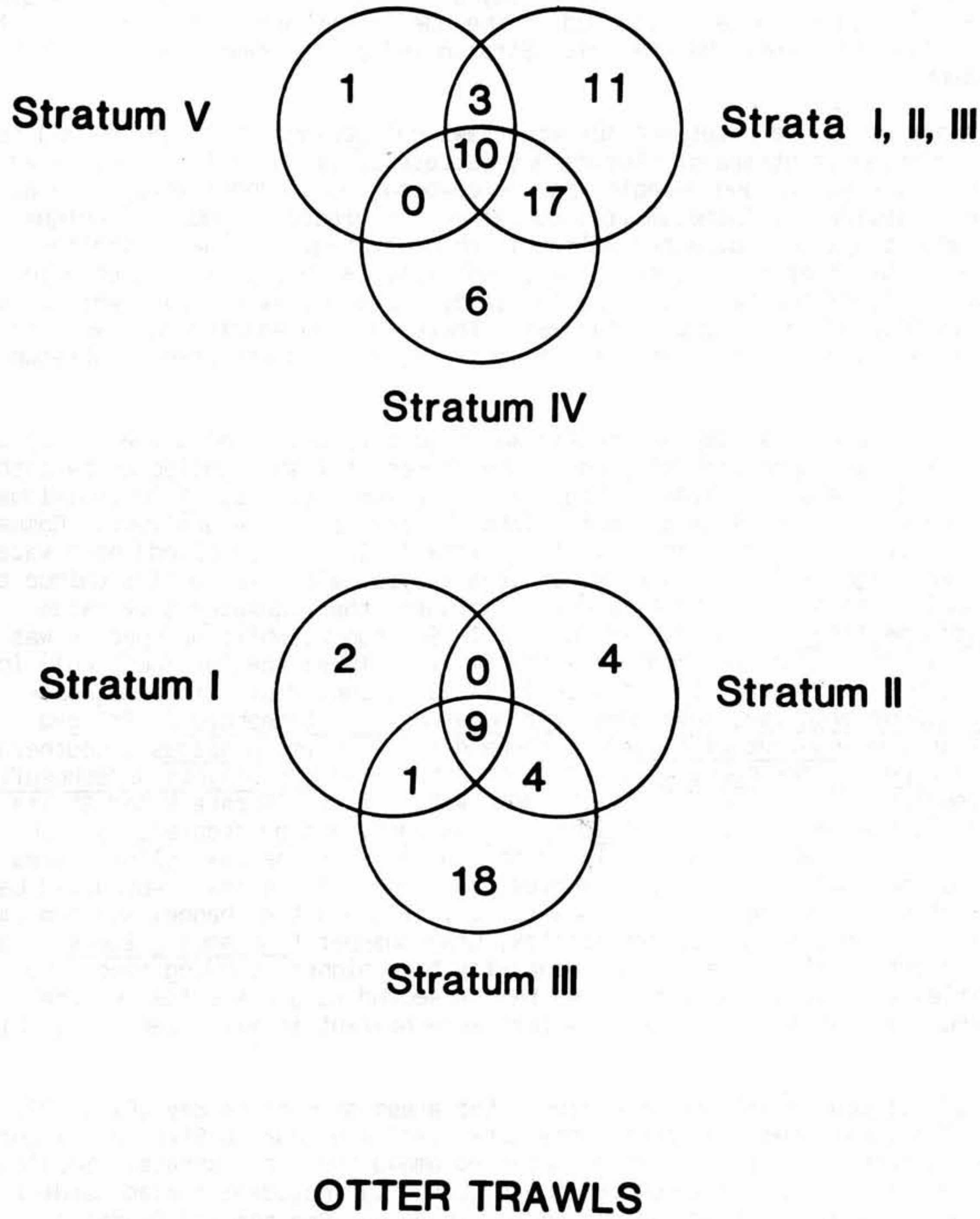


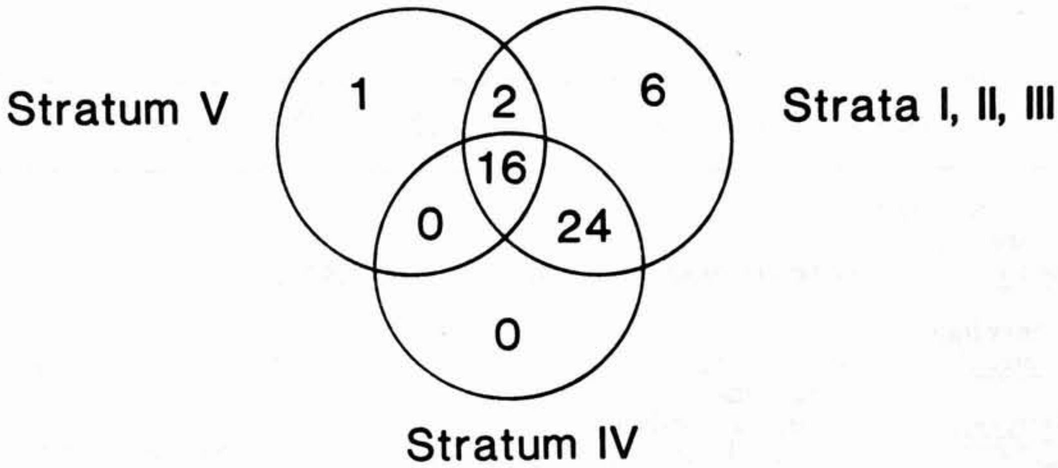
Figure 26. Diagrammatic representation of the overall similarities and differences in numbers of fish species collected by otter trawl within Coot Bay-Whitewater Bay (Stratum V), open-water areas of Florida Bay (Strata I, II, III) and channel areas of Florida Bay (Stratum IV) (upper), and among the three open-water strata in Florida Bay (lower).

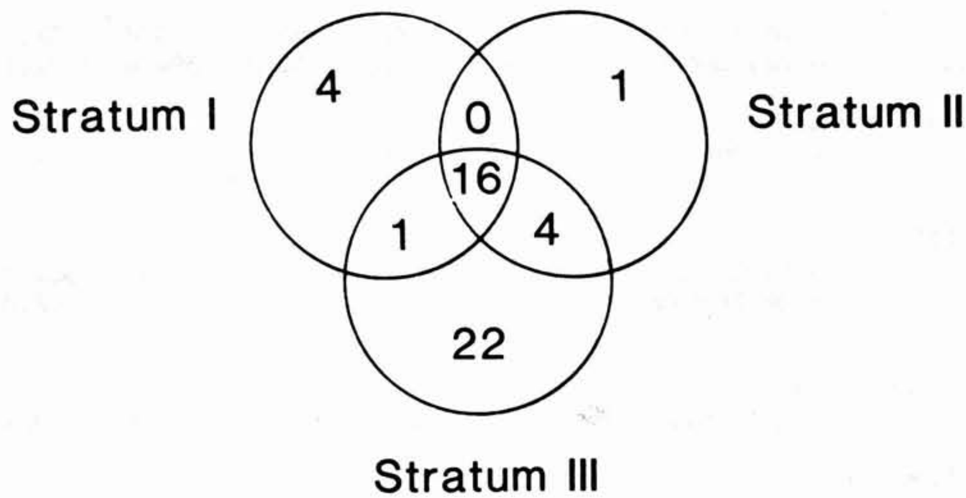
pipefish, and silver jenny. Only four of these ubiquitous species were common to both gear types. Three demersal species were common to the two open water strata (V and III, II, I combined), while 17 demersal species were common to the channels and open water areas of Florida Bay. No demersal (otter trawl) or pelagic (surface trawl) species co-occurred only between the channel stratum and the low salinity Coot Bay-Whitewater Bay stratum. By far, there were a greater number of unique species collected in the open water areas of Florida Bay than were unique to either the channels (Stratum IV) or Whitewater Bay and Coot Bay (Stratum V).

Our analysis of the otter and surface trawl collections (Fig. 25 and 26) for the three open water strata of Florida Bay (Strata I, II and III) demonstrated that, while many demersal and pelagic species co-occurred in these three strata, western Florida Bay (Stratum III) contained the greatest number of unique species, or species collected solely in that stratum. Of the 38 species collected by otter trawl used in this analysis, 18 were collected only in Stratum III; of the 24 species collected by surface trawls, seven were present only in Stratum III (Figs. 25 and 26). There were no species that were found both Strata I and II but not III, and only one species occurred in stratum I and III but not II.

Because there was overlap of species among gear types, a third species by strata matrix was developed combining total abundances of fishes collected by both gear to examine stratum occurrance (Fig. 27). The same criteria (≥ 10 individuals) was used for inclusion of a species into the co-occurrence analyses. Comparison of low (Stratum V) and high salinity (Strata I, II, III combined) open water areas and high salinity channels (Stratum IV) revealed few species unique to any one habitat class. Of the 49 species included, the tidewater silverside (Menidia peninsulae) was collected only in Stratum V, while no species was collected only from the channels (Stratum IV). Those species found only in open water areas of Florida Bay (Stratum I, II, III) included: lined seahorse (Hippocampus erectus), sheepshead (Archosargus probatocephalus), fringed filefish (Monacanthus ciliatus), planehead filefish (M. hispidus), southern puffer (Sphoeroides nephelus), and striped burrfish (Chilomycterus schoepfi). Two species were common only to the open water strata (Strata V and Strata I, II, III), the leatherjacket (Oligoplites saurus), and gafftopsail catfish, while there were no species common only to the channels or the low salinity area of Coot Bay and Whitewater Bay. The greatest number of species co-occurred between the high salinity open water strata (I, II, III) and the channel stratum (48%), and included one of the target species, gray snapper (Lutjanus griseus). As was pointed out earlier, these areas generally have higher standing crops and densities of seagrasses than elsewhere. A second target species, spotted seatrout, was among the 16 species that were present in all three areas (Fig. 27).

Analysis of pooled data for the open water areas of Florida Bay (Fig. 27, bottom) demonstrated that there were more species unique to Stratum III than to either Stratum I or II or that co-occurred among the three strata. Species prevalent to the eastern-most stratum (Stratum I) included: scaled sardine, Spanish sardine, great barracuda, and clown goby. One species (hardhead silversides) was prevalent only in the central stratum of Florida Bay. Four species co-occurred between Stratum II and Stratum III: striped anchovy, gulf toadfish, pugnose pipefish (Syngnathus dunckeri), and sheepshead. A large proportion of the species that showed a preference to high salinity open water





COMBINED TRAWL DATA

Figure 27. Diagrammatic representation of the overall similarities and differences in numbers of fish species collected by both surface and otter trawls within Coot Bay-Whitewater Bay (Stratum V), open-water areas of Florida Bay (Strata I, II, III) and channel areas of Florida Bay (Stratum IV) (upper), and among the three open-water strata in Florida Bay (lower).

Table 8. Listing of species and total biomass (grams wet weight) of fish collected in Everglades National Park during 1984 and 1985 using a surface trawl. Refer to text for strata locations.

Family/Scientific Name	-- Common Name	I	II	III	IV	V	TOTAL
Sphyrnidae - hammerhead sharks							
Sphyrna tiburo	-- bonnethead	-	-	192.1	-	-	192.1
Clupeidae - herrings							
Brevoortia smithi	-- yellowfin menhaden	-	-	7.7	9.0	35.9	52.6
Harengula humeralis	-- redear sardine	-	-	-	7.1	-	7.1
Harengula jaguana	-- scaled sardine	58.0	3.4	3.0	382.9	89.3	536.6
Jenkinsia lamprotaenia	-- dwarf herring	0.2	-	-	-	-	0.2
Opisthonema oglinum	-- Atlantic thread herring	-	-	76.2	0.9	5.4	82.5
Sardinella aurita	-- Spanish sardine	-	37.9	0.6	1.1	-	39.6
Engraulidae - anchovies							
Anchoa hepsetus	-- striped anchovy	-	7.8	154.6	5.9	59.0	227.3
Anchoa mitchilli	-- bay anchovy	-	6.2	48.0	394.4	1192.1	1640.7
Syndontidae - lizardfishes							
Synodus foetens	-- inshore lizardfish	106.3	-	1.1	0.1	26.6	134.1
Ariidae - sea catfishes							
Arius felis	-- hardhead catfish	-	-	-	-	305.3	305.3
Bagre marinus	-- gafftopsail catfish	-	-	-	-	48.8	48.8
Batrachoididae - toadfishes							
Opsanus beta	-- gulf toadfish	6.3	30.5	93.0	14.4	0.3	144.5
Antennariidae - frogfishes							
Histrio histrio	-- sargassum fish	5.2	-	-	-	-	5.2
Exocoetidae - flyingfishes							
Chriodorus atherinoides	-- hardhead halfbeak	1351.5	2693.7	209.5	470.6	-	4725.3
Hemiramphus balao	-- balao	-	1.2	108.8	-	-	110.0
Hemiramphus brasiliensis	-- ballyhoo	364.9	263.1	1253.0	1648.8	-	3529.8
Hyporhamphus unifasciatus	-- halfbeak	2071.4	508.1	9253.0	3998.2	228.5	16059.2
Belonidae - needlefishes							
Strongylura notata	-- redfin needlefish	936.4	6138.1	863.3	2131.5	3866.3	13935.6
Strongylura timucu	-- timucu	-	46.7	1124.8	57.3	708.7	1937.5

Table 8. (Contd)

Family/Scientific Name -- Common Name		I	II	III	IV	V	TOTAL
Cyprinodontidae - killifishes							
Floridichthys carpio	-- goldspotted killifish	3.4	44.2	17.1	6.8	-	71.5
Lucania parva	-- rainwater killifish	1.4	29.1	11.3	5.3	7.5	54.6
Atherinidae - silversides							
Atherinomorus stipes	-- hardhead silverside	2.0	319.7	5.2	272.3	-	599.2
Hypoatherina harringtonensis	-- reef silverside	137.9	3.3	18.4	244.7	-	404.3
Membras martinica	-- rough silverside	184.6	155.3	236.5	53.1	574.1	1203.6
Menidia peninsulae	-- tidewater silverside	-	-	1.2	-	37.3	
Syngnathidae - pipefishes							
Hippocampus erectus	-- lined seahorse	-	16.6	-	0.1	-	16.7
Hippocampus zosterae	-- dwarf seahorse	0.6	1.0	0.3	-	0.1	2.0
Syngnathus dunckeri	-- pugnose pipefish	0.3	0.5	0.4	-	-	1.2
Syngnathus floridae	-- dusky pipefish	11.6	11.4	15.0	5.0	-	43.0
Syngnathus louisianae	-- chain pipefish	-	-	1.9	-	0.6	2.5
Syngnathus scovelli	-- gulf pipefish	0.8	9.5	6.8	7.8	7.0	31.9
Serranidae - sea basses							
Hypoplectrus unicolor (or H. puella)	-- barred hamlet	1.6	-	-	-	-	1.6
Echeneidae - remoras							
Echeneis naucrates	-- sharksucker	-	-	1.5	-	-	1.5
Carangidae - jacks							
Caranx hippos	-- crevalle jack	-	-	0.3	-	-	0.3
Oligoplites saurus	-- leatherjacket	13.4	0.2	11.5	-	-	151.1
Trachinotus carolinus	-- Florida pompano	-	-	0.6	-	-	0.6
Lutjanidae - snappers							
Lutjanus griseus	-- gray snapper	-	-	25.8	-	-	25.8
Lutjanus synagris	-- lane snapper	78.0	-	11.9	-	-	89.9
Gerreidae - mojarras							
Eucinostomus argenteus	-- spotfin mojarra	-	-	-	-	5.5	5.5
Eucinostomus gula	-- silver jenny	160.5	4 66.7	119.0	64.4	193.3	1003.9

Table 8. (Contd)

Family/Scientific Name --	Common Name	I	II	III	IV	V	TOTAL
Haemulidae - grunts							
Haemulon parrai --	sailor's choice	-	-	9.4	-	-	9.4
Haemulon plumieri --	white grunt	-	-	23.7	-	-	23.7
Haemulon sciurus --	bluestriped grunt	-	-	32.9	-	-	32.9
Orthopristis chrysoptera--	pigfish	-	-	12.6	0.1	-	12.7
Sparidae - porgies							
Archogargus probatocephalus --	sheepshead	-	-	5.3	-	-	5.3
Lagodon rhomboides --	pinfish	4.0	608.3	489.5	68.8	-	1170.6
Sciaenidae - drums							
Bairdiella chrysoura --	silver perch	-	-	19.3	1.9	28.6	49.8
Cynoscion nebulosus --	spotted seatrout	-	4.6	-	-	0.7	5.3
Mugilidae - mullets							
Mugil cephalus --	striped mullet	-	-	0.2	-	540.9	541.1
Mugil curema --	white mullet	0.2	-	0.6	0.1	-	0.9
Sphyraenidae - barracudas							
Sphyraena barracuda --	great barracuda	-	-	-	52.3	-	52.3
Callionymidae - dragonets							
Callionymus pauciradiatus--	spotted dragonet	2.3	0.5	-	-	-	2.8
Gobiidae - gobies							
Gobiosoma robustum --	code goby	-	1.7	0.5	0.6	0.3	3.1
Microgobius gulosus --	clown goby	1.4	0.7	-	2.7	3.5	8.3
Soleidae - soles							
Achirus lineatus --	lined sole	-	-	2.0	0.6	7.4	10.0
Balistidae - leatherjacks							
Monacanthus ciliatus --	fringed filefish	0.3	-	-	-	-	0.3
Ostraciidae - boxfishes							
Lactophrys quadricornis--	scrawled cowfish	29.6	-	-	-	-	29.6
Tetraodontidae - puffers							
Sphoeroides nephelus --	southern puffer	0.1	0.1	16.1	0.3	-	16.6
Diodontidae - porcupinefishes							
Chilomycterus schoepfi--	striped burrfish	-	-	1.3	-	-	1.3
		5534.2	11410.1	14486.8	10014.5	7992.4	49438.0

areas of Florida Bay (Fig. 27, top) were also among the 22 species that showed a decided preference for the near-gulf open water stratum (Stratum III) (Fig. 27, bottom). Of these 22 species, 9 species were common to both channels (Stratum IV) and the near-gulf stratum (Stratum III): gray snapper, lane snapper, sailor's choice (Haemulon parrai), white grunt, bluestriped grunt, pigfish, grass porgy (Calamus arctifrons), code goby, and scrawled cowfish.

Distribution of Fish Within and Between Strata

The distribution of numbers of individuals and biomass of fishes per unit area and numbers of species per station varied within strata as well as between strata. Numerical abundance of the demersal community (otter trawl) averaged 17.3 individuals$\cdot$100 m^{-2} and ranged from a low 0.08 individuals$\cdot$100 m^{-2} (station 17-7 in January 1985) to 215.3 individuals$\cdot$100 m^{-2} (channel 6 in June 1984). The distribution of numbers of fish collected by otter trawls is shown in Figures 28, 29, and 30. Overall, Stratum I had the lowest density of fish while channel stations had the highest density. In increasing order the strata are ranked: Stratum I ($\bar{x}$ = 4.4 indiv$\cdot$100 m^{-2}; range = 0.1-24.0), Stratum V ($\bar{x}$ = 9.1$\cdot$100 m^{-2}; range = 0.2-161.8), Stratum II ($\bar{x}$ = 13.2$\cdot$100 m^{-2}; range = 0.1-102.2), Stratum III ($\bar{x}$ = 26.5$\cdot$100 m^{-2}; range = 0.4-182.1), and Stratum IV ($\bar{x}$ = 33.3$\cdot$100 m^{-2}; range = 0.8-215.3). For the open water strata of Florida Bay (Strata I-III) there was a trend for the density of fish to increase in a northerly direction in all but Stratum I, with maximum fish numbers at stations generally between First National Bank and Snake Bight (Fig. 28).

With the exception of one large catch of bay anchovy near the entrance to the Buttonwood Canal in Coot Bay in November 1984, the catches of fish were generally low and uniform (i.e., 1-15 indiv$\cdot$100 m^{-2}) in Stratum V (Fig. 30). The overall fish catch and species composition, however, differed between Coot Bay and Whitewater Bay (Tables 9 and 10). A greater number and biomass of fishes were collected in Coot Bay than in Whitewater Bay. The differences were due largely to greater catches of bay anchovy in Coot Bay. The demersal component of the fish community also was more diverse in Coot Bay than in Whitewater Bay, with a total of 30 species collected in Coot Bay and 22 species in Whitewater Bay.

The distribution of numbers of species within and between strata (Figs. 31, 32, and 33) followed a trend similar to that observed for total standing stock numbers. There was an average of seven species collected at each station throughout the study area, and the five strata were ranked as follows: Stratum I (4.7), Stratum V (4.8), Stratum II (5.7), Stratum III (10.1) and Stratum IV (11.7). Of the three non-channel strata in Florida Bay, only stations in Stratum III showed a trend for the number of species collected to increase in a northerly direction. This trend of increasing species numbers in a northerly direction coincided with an increase in seagrass shoot density and seagrass species diversity. Channels also had relatively high densities of mixed seagrass species and, with the exception of three (channels 3, 26 and 38), channels also harbored relatively large and diverse fish communities.

The average biomass of fishes (Figs. 34, 35, and 36) varied within strata, and the distribution was similar to that of both number of species and individual abundances. Wet weight biomass of fish collected by otter trawl ranged from 2 mg$\cdot$100 m^{-2} at station 17-7 (Stratum II) to 621 g$\cdot$100 m^{-2} at station 5-6 (Stratum III), and averaged 73 g$\cdot$100 m^{-2} for the entire study area. There was a definite

Table 9. Total abundance of fish taken in bottom trawls from stratum V broken into its component Whitewater Bay and Coot Bay areas.

Species Code	Whitewater Bay	Coot Bay
Ladyfish	-	1
Atlantic thread herring	-	5
Striped anchovy	9	3
Bay anchovy	104	1831
Inshore lizardfish	3	-
Hardhead catfish	30	112
Gafftopsail catfish	6	25
Gulf toadfish	3	1
Redfin needlefish	2	9
Timucu	3	3
Goldspotted killifish	7	-
Rainwater killifish	71	231
Rough silverside	16	2
Tidewater silverside	-	3
Dwarf seahorse	-	1
Dusky pipefish	-	3
Gulf pipefish	9	23
Leatherjacket	1	-
Gray snapper	-	2
Spotfin mojarra	32	25
Silver jenny	663	529
Pigfish	5	2
Sheepshead	-	1
Pinfish	21	8
Silver perch	109	13
Spotted seatrout	8	2
Southern kingfish	2	-
Great barracuda	-	1
Florida blenny	-	2
Code goby	1	2
Clown goby	16	17
Lined sole	-	1
Yellowface pikeblenny	-	1
Southern puffer	-	3
TOTAL	1121	2862

Table 10. Surface trawl data for total catches of each species in Stratum V separated into data for Whitewater Bay and Coot Bay.

Species	Whitewater Bay	Coot Bay
Yellowfin menhaden	-	20
Scaled sardine	7	-
Atlantic thread herring	8	-
Striped anchovy	38	69
Bay anchovy	713	2026
Inshore lizardfish	1	-
Hardhead catfish	3	2
Gafftopsail catfish	1	-
Gulf toadfish	-	1
Halfbeak	7	-
Redfin needlefish	62	137
Timucu	10	28
Rainwater killifish	6	27
Rough silverside	310	390
Tidewater silverside	-	105
Drawf seahorse	-	1
Chain pipefish	-	1
Gulf pipefish	6	17
Leatherjacket	4	6
Spotfin mojarra	5	-
Silver jenny	15	26
Silver perch	1	2
Spotted seatrout	1	1
Striped mullet	-	1
Code goby	1	-
Clown goby	2	8
Lined sole	1	-
Total	1202	2868

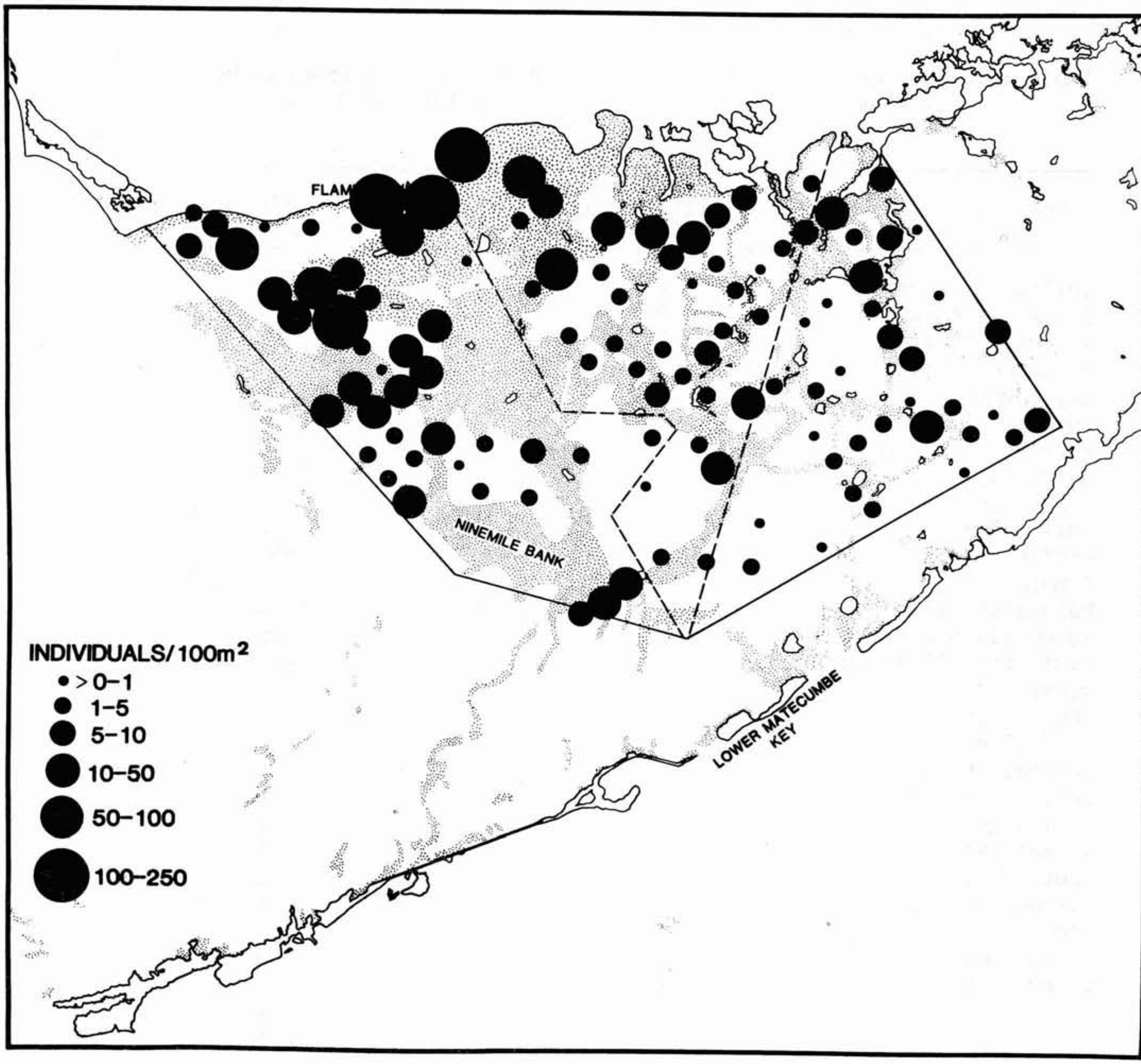


Figure 28. Distribution of average number of individuals collected by otter trawl in Florida Bay during 1984-1985.

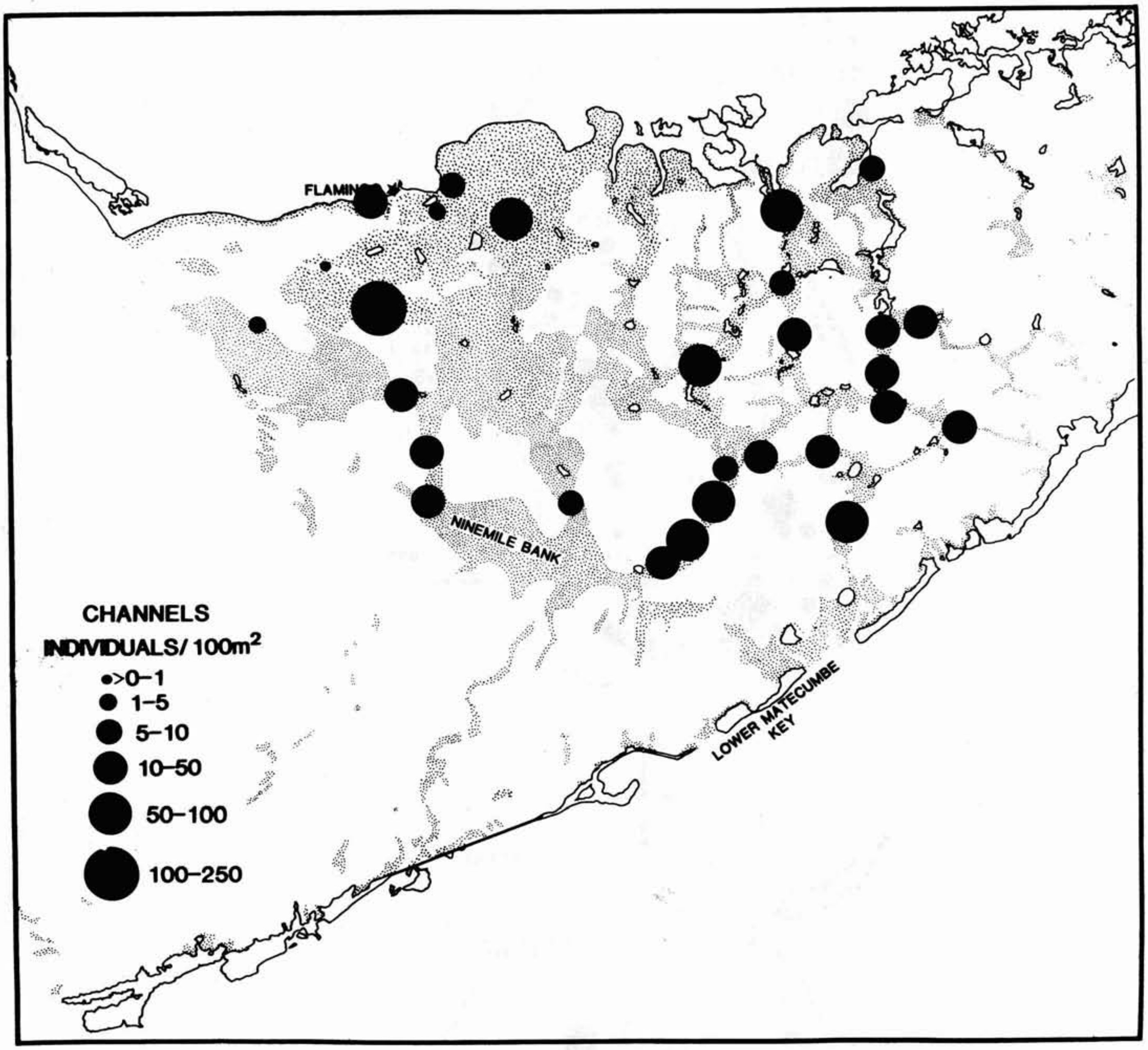


Figure 29. Distribution of average number of individuals collected by otter trawl from channels in Florida Bay during 1984-1985.

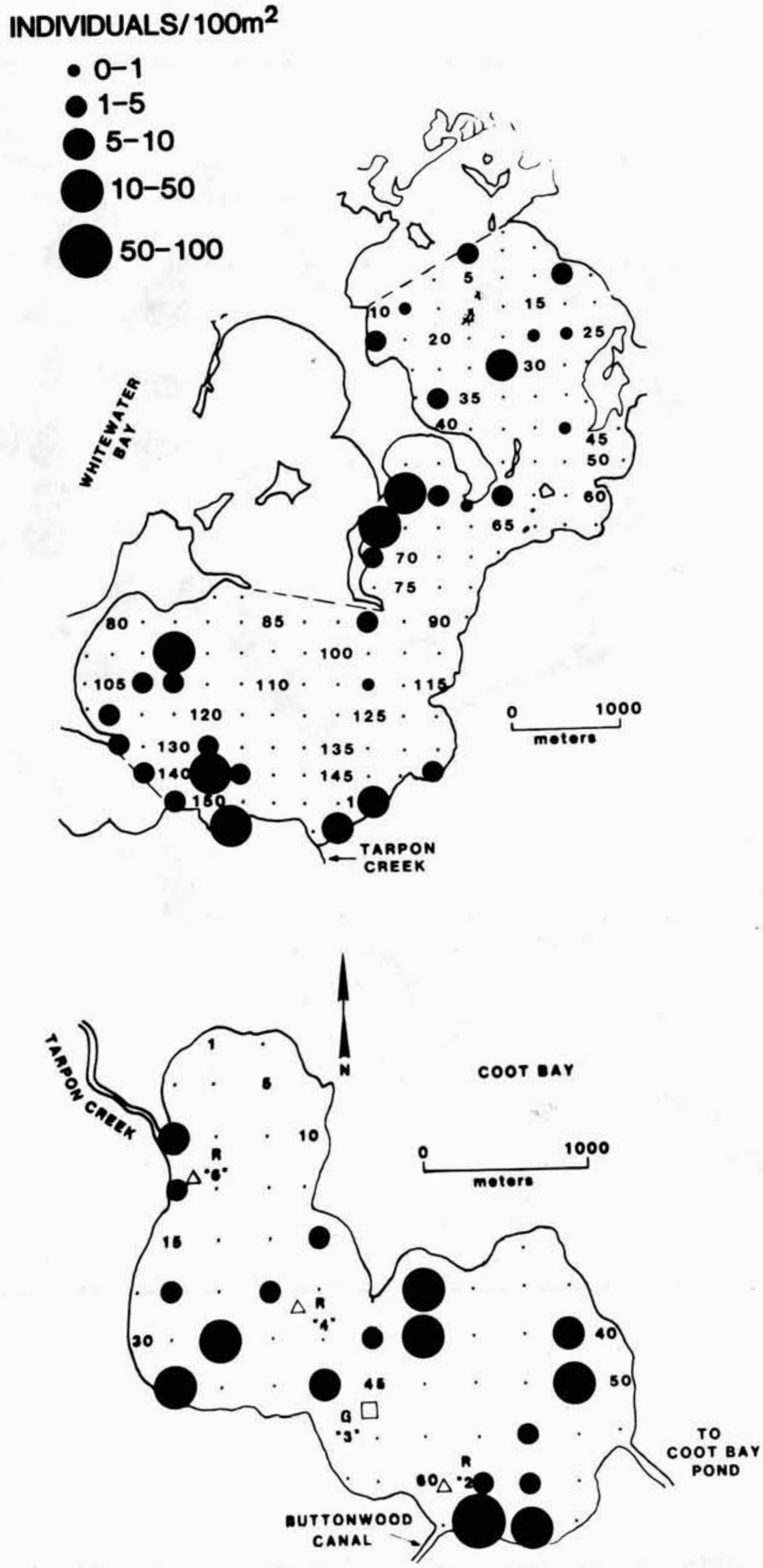


Figure 30. Distribution of average number of individuals collected by otter trawls at stations in eastern Whitewater Bay (upper) and Coot Bay during 1984-1985.

trend for higher biomasses of fish to be at stations in the northern portion of Stratum III, between First National Bank, Johnson Key Basin and Flamingo (Fig. 34); these areas also generally displayed the most diverse and dense seagrass communities. The standing crop biomass of demersal fishes tended to be greater in Coot Bay than Whitewater Bay (Fig. 36), and in both areas station values generally were greatest near shore.

Our data on numerical abundance of fishes and their wet weight biomasses fall within the range of values reported in the literature, but are on the low end of the spectrum. Because of the recognized biases associated with various collecting gear (see discussions by Kjelson and Johnson 1978; Weinstein and Brooks 1983; Thayer et al., 1987) few comparisons of numbers and biomasses are possible. Our estimate of fishes from bottom trawls averaged about $0.2 \cdot m^{-2}$ with a range of $8x10^{-4}$ to 2.2 individuals$\cdot m^{-2}$. Adams (1976), using drop nets, observed a standing stock average for two eelgrass beds in North Carolina of about 1.8 individuals$\cdot m^{-2}$ with a range of ~ $0.06\text{-}6.0 \cdot m^{-2}$. Using otter trawls in the Chesapeake Bay, Weinstein and Brooks (1983) observed juvenile fish abundances regularly of less than a single individual per m^2. Sogard (1982) observed densities of 0.2-2.0 fish$\cdot m^{-2}$ using a push net in Biscayne Bay seagrass beds, but, using a throw trap, Sogard et al. (In press) reported mean densities of 11 fish$\cdot m^{-2}$ on several carbonate mud banks in Florida Bay. These authors also have computed values of $0.3\text{-}1.5 \cdot m^{-2}$ in Apalachee Bay and $<0.6 \cdot m^{-2}$ in Indian River based on available literature. The average wet weight standing crop of fish we collected by otter trawl was 0.73 $g \cdot m^{-2}$ with a range of $2x10^{-4}$ to 6.2 $g \cdot m^{-2}$. Standing crop biomass of fish reported from other seagrass beds include: 6.0 g wet weight$\cdot m^{-2}$ in Laguna Madre (Hellier 1962); 0.4-2.5 g wet weight$\cdot m^{-2}$ in a Thalassia bed in Texas (Hoese and Jones 1963); 0.2-2.0 g wet weight$\cdot m^{-2}$ in an eelgrass bed in Rhode Island (Nixon and Oviatt 1972); and 7.5 g wet weight$\cdot m^{-2}$ in two eelgrass beds near Beaufort, N.C. (Adams 1976). Thus, the average numerical abundance and standing crop biomass values we observed are similar to but at the low end of the range of several published reports on fishes in seagrass meadows. Individual stations in the study area provided values that equaled or exceeded (e.g., Figs. 28 and 34), many published abundance and biomass values. For the most part, the stations falling into this category were located in Stratum III and Stratum IV, and have generally dense stands of mixed seagrass.

Similarity Among Stations

With respect to the juvenile fish community, the degree of similarity among stations occupied during the study was examined using numerical classification (cluster analysis). Initially, the number of species included in the analysis was reduced from 93 to 44 by requiring that each species be present at least 10% of the stations during any one of the surveys. Species-specific numerical abundance data then were transformed by applying the $\log_e(\bar{x} + 1)$ function. Following construction of a station by station (249x249) Bray-Curtis dissimlarity matrix, a group-average clustering algorithm (Bloom et al. 1977) was used to aggregate stations. Although numerous associations emerged, 2 geographically distinct station clusters were obvious at a level of similarity of 0.45 (Figs. 37,38).

Cluster 1 was associated with vegetated areas primarily in Stratum III and selected channels in Stratum IV (Fig. 37). Approximately 39% of the stations sampled in Stratum III and Stratum IV were clustered in this group (Table 11).

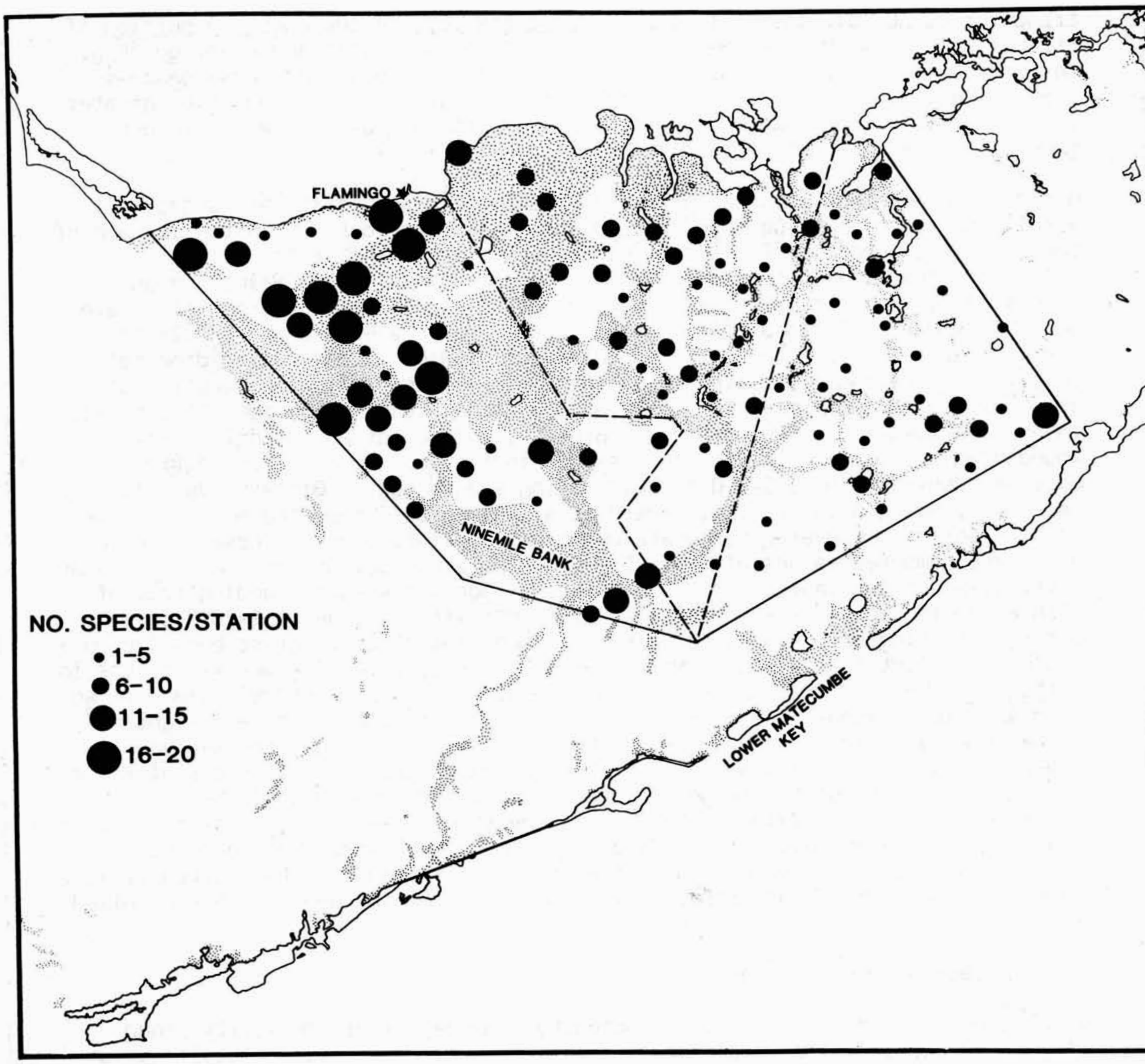


Figure 31. Distribution of average species numbers collected by otter trawl in Florida Bay during 1984-1985.

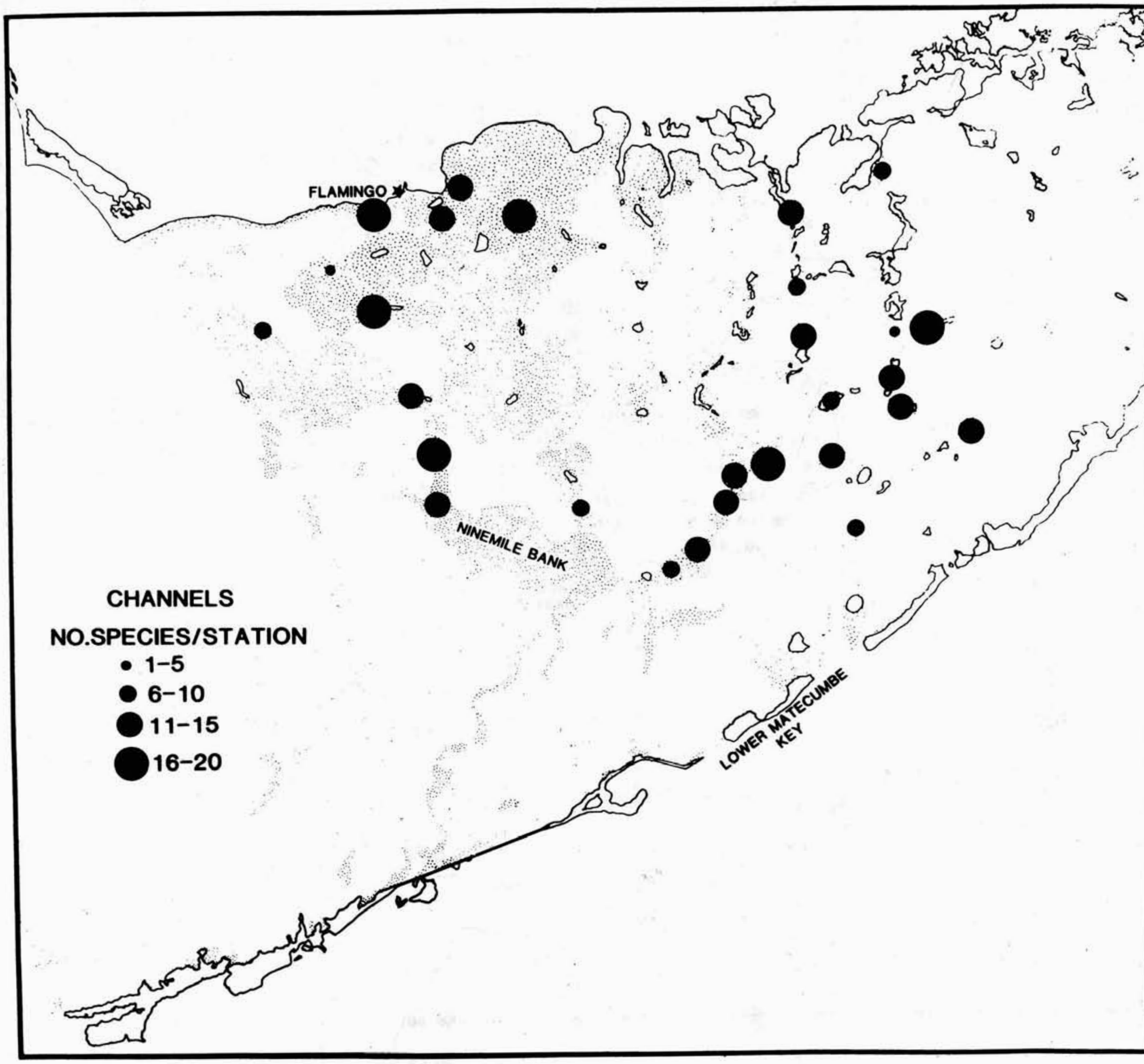


Figure 32. Distribution of average species numbers collected by otter trawl from channels in Florida Bay during 1984-1985.

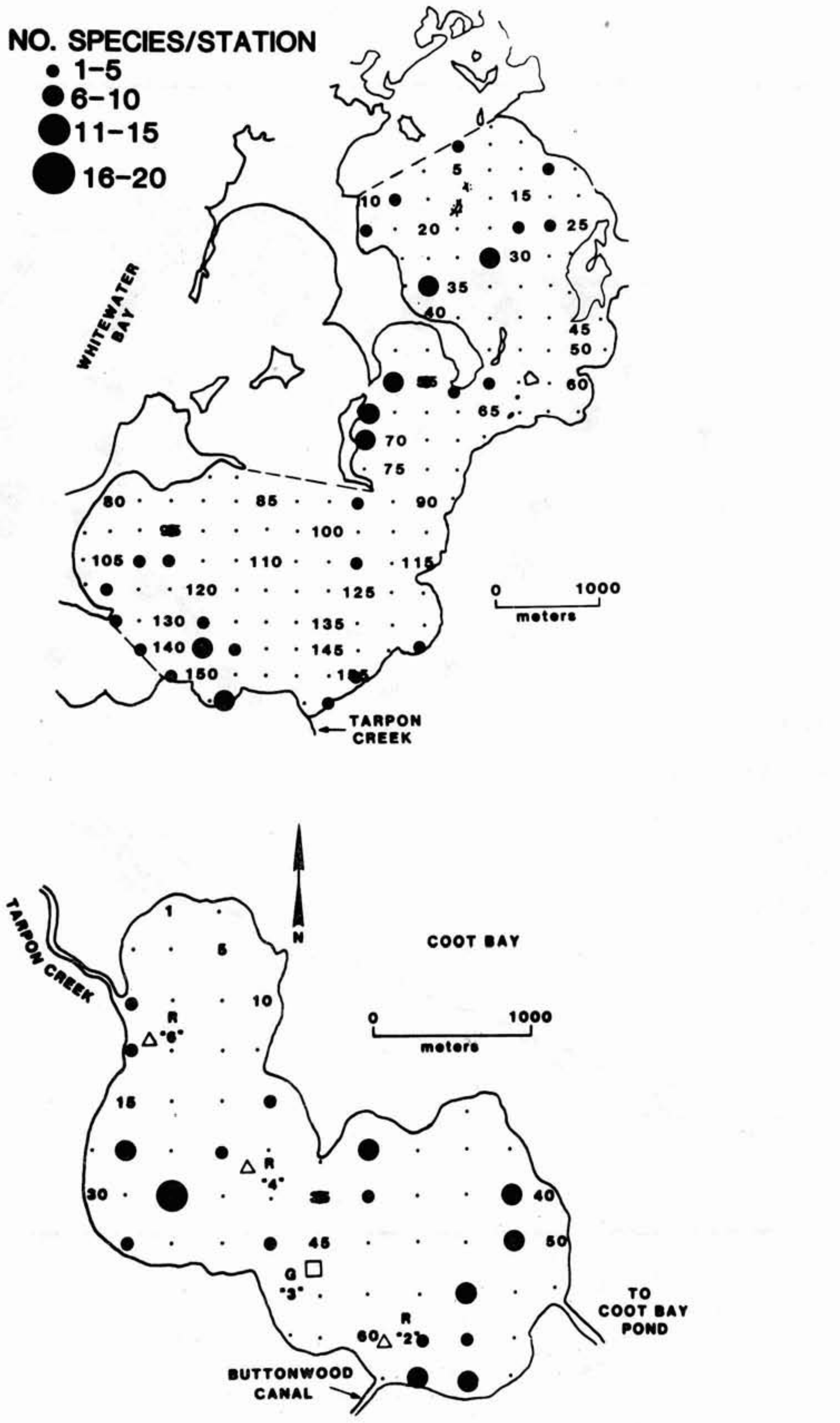


Figure 33. Distribution of average number of species collected by otter trawl at eastern Whitewater Bay (upper) and Coot Bay sampling stations during 1984-1985.

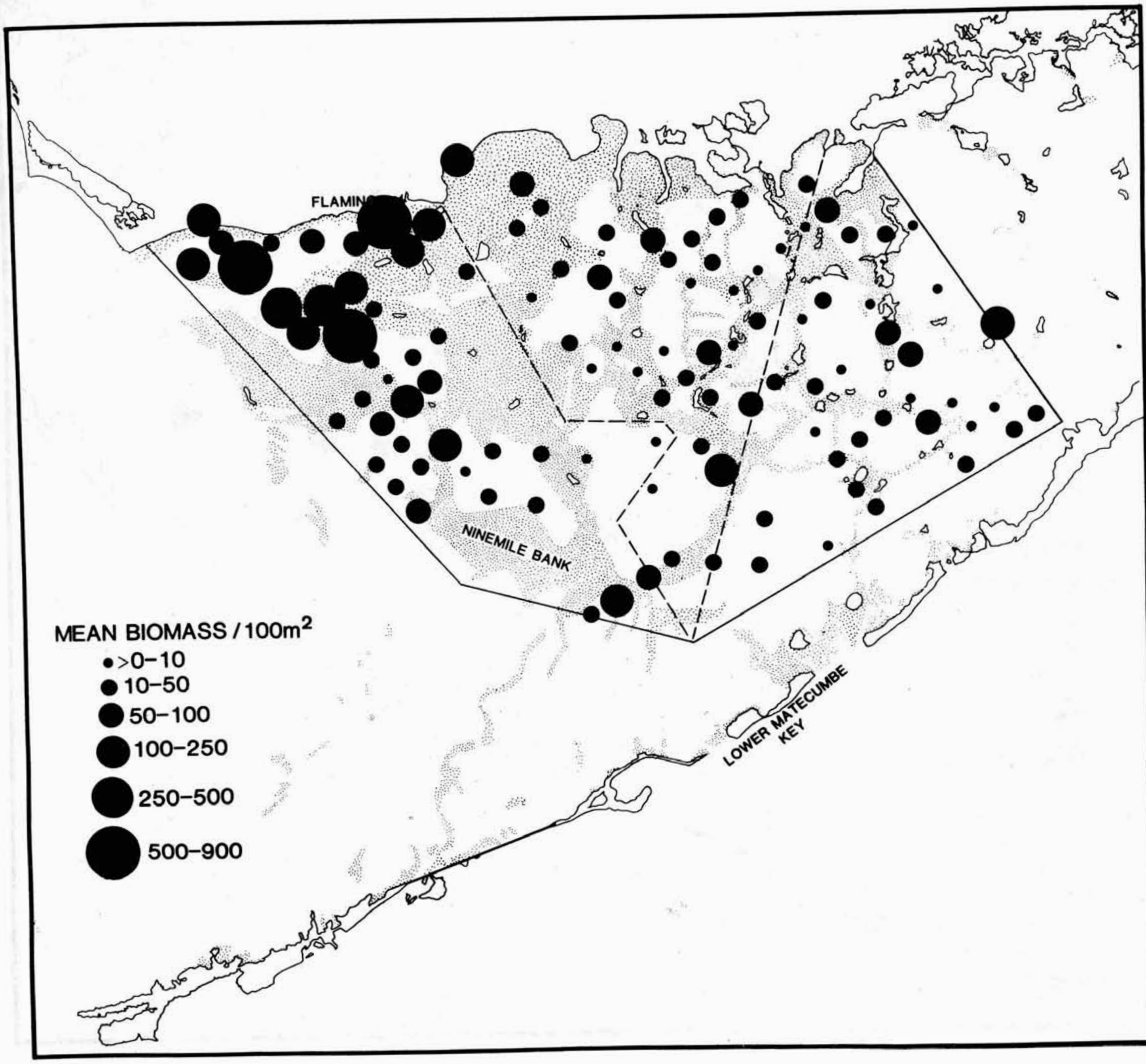


Figure 34. Mean wet weight biomass of fish collected by otter trawl in Florida Bay during 1984-1985.

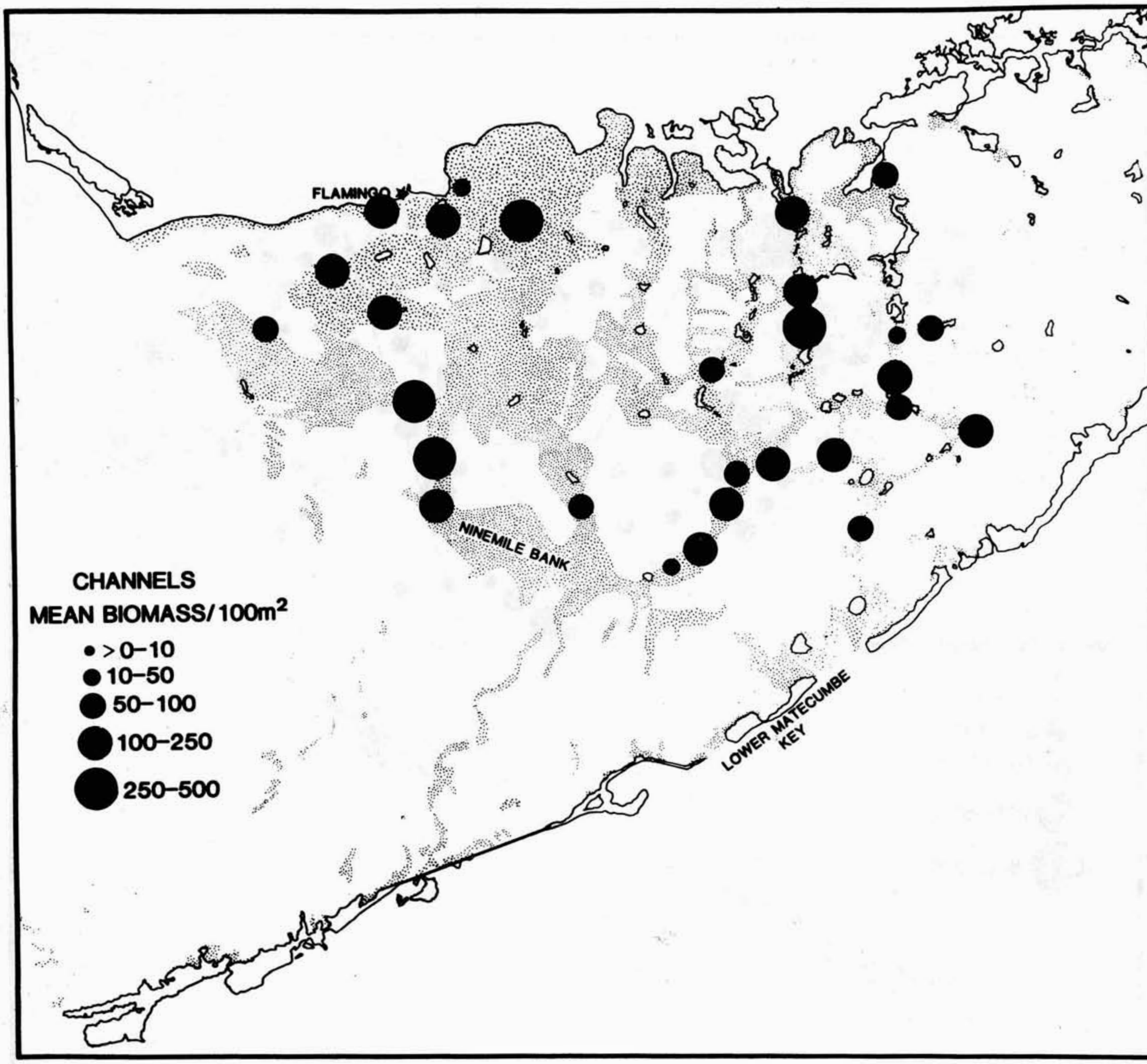


Figure 35. Mean wet weight biomass of fish collected by otter trawl in Florida Bay channels during 1984-1985.

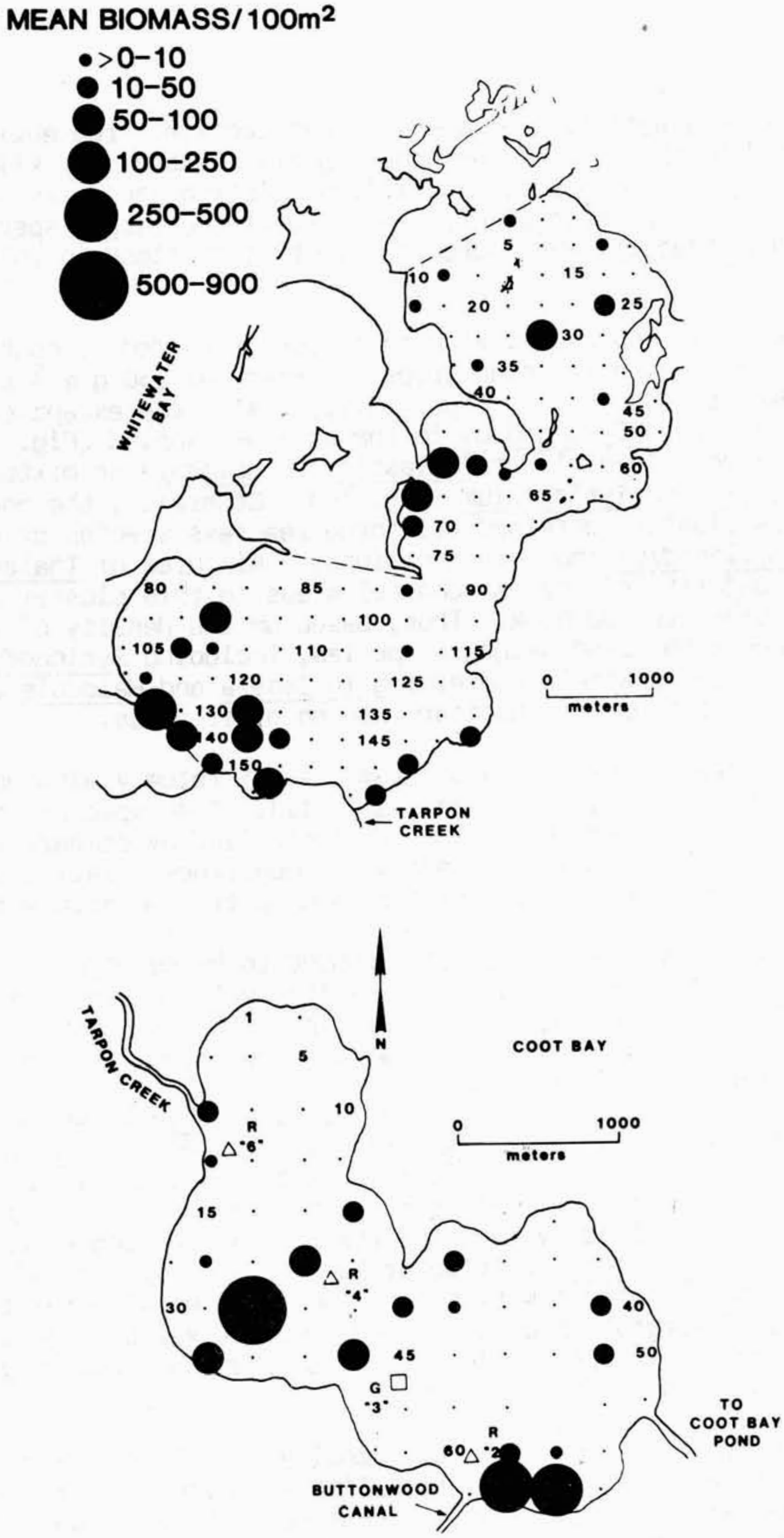


Figure 36. Mean wet weight biomass of fish collected by otter trawl in eastern Whitewater Bay (upper) and Coot Bay (lower) during 1984-1985.

This cluster was characterized by species that occurred frequently and in large numbers compared to the rest of the sampling area. Rainwater killifish, pinfish, silver jenny, goldspotted killifish, pigfish and dusky pipefish were most abundant in this cluster (Table 12). Two of the target species, spotted seatrout and gray snapper, were more prevalent at stations in this cluster than elsewhere.

The plant communities associated with this cluster tended to contain a mixture of seagrass species, with standing crops in excess of 250 $g \cdot m^{-2}$ and shoot densities in excess of $2000 \cdot m^{-2}$ (Figs. 18-21). With the exception of Man of War Channel, which had pure Syringodium in the area we sampled (Fig. 19), the channel stations contained either Thalassia and Halodule or mixtures of Thalassia, Halodule and Syringodium (Fig. 19). Generally, the non-channel stations in this cluster contained all three seagrass species or mixtures of Thalassia and Syringodium and only occasionally mixtures of Thalassia and Halodule. The majority of the non-channel areas in this cluster also were adjacent to a carbonate mud bank. Thus, based on the density of fish, it would appear that areas with mixed seagrass species, including Syringodium, and areas adjacent to banks and channels containing Thalassia and Halodule potentially offer greater juvenile nursery habitat than do other areas.

Cluster 2 was located primarily in Stratum I and Stratum V with only a few stations in Stratum II (Fig. 38a,b and Table 11). Fish species that were present in this cluster (Table 12) were characterized by comparatively low abundances and relatively low frequencies of occurrence relative to Cluster 1. Silver jenny, rainwater killifish, pinfish and spotfin mojarra were present.

The seagrasses associated with Cluster 2 tended to be monotypic. The seagrass community at these stations was almost pure Thalassia for the non-channel areas of Strata I and II with standing crops less than 250 $g \cdot m^{-2}$ and shoot densities generally of $\leq 2000 \cdot m^{-2}$; in Stratum I seagrass shoot densities generally were $\leq 1000 \cdot m^{-2}$. Two channel stations also were associated with this low fish density cluster; channel 13 south of Joe Kemp Key was pure Halodule while channel 27 at Bob Allen Key was primarily Thalassia with a small amount of Halodule. The majority of Cluster 2 stations were located in basins and only a few were adjacent to carbonate banks. In Stratum V, the stations within this cluster generally were characterized by intermediate to low standing crops of pure Ruppia (Coot Bay) or Halodule (Whitewater Bay) or a total lack of vegetation. Thus, it appears that stations within our sampling area with relatively sparce monotypic stands of seagrass provide a lower nursery value to juvenile fish in general and to the target species in particular than do mixed seagrass habitats near carbonate banks and in channel areas.

The diversity of plant species and their density as well as the location of habitats may be influential in regulating fish abundance and the complement of species utilizing habitats in the bay systems we sampled. This complexity may be a function of total plant biomass or surface area (Heck and Orth 1980, Stoner 1980); whether the meadow is generally in a high current or low current area (Thayer et al. 1984, Fonseca and Fisher 1986); or seagrass species composition (Stoner 1982, 1983, Virnstein and Howard In press). Virnstein and Howard (In press) have shown that food resource density (epifauna and gastropods) were greater on Halodule while crustacean resource density was greatest on Thalassia on a per m^2 basis. However, when data were evaluated in terms of plant surface area, crustaceans were most abundant on Syringodium. Stoner (1982) noted that

Table 11. Stations grouped into two prominent clusters derived from Bray-Curtis dissimilarity index analyses (see Text). See Figure 37 and 38 for location of stations.

Cluster 1		Cluster 2		
Stratum III	Stratum IV	Stratum I	Stratum II	Stratum V
5-5	6	14-17	12-8	1007
6-2	7	14-18	12-10	1008
6-3	8	15-17	12-12	1020
6-4	9	16-18	13-9	1039
6-6	14	17-12	13-13	1044
6-7	21	17-16	13-17	2001
7-3	22	18-13	14-15	2009
9-1	23	18-16	15-9	2018
9-2	31	19-16	15-13	2054
9-4	34	20-12	16-10	2055
10-2	40	20-13	20-7	2095
10-3	44	20-14		2107
10-4		20-19		2131
12-3		21-8		2139
13-1		21-12		2142
19-4		21-16		2148
		22-12		2149
		22-16		2155
		22-17		2157
				2159

Table 12. Abundance (no. per 100 m^2) and number of occurrences for fishes grouped in the Strata III-IV and Strata I-II-V clusters. Only those species that occurred in at least 10 cases in one of the clusters are included.

Species	Strata III-IV Abundance	Strata III-IV Occurrence (n=39)	Strata I-II-V Abundance	Strata I-II-V Occurrence (n=55)
Sheepshead	0.15	19	-	
Silver perch	0.63	19	0.05	2
Spotted seatrout	0.10	13	0.02	4
Spotfin mojarra	0.47	8	0.13	15
Silver jenny	13.51	39	3.14	55
Goldspotted killifish	2.10	23	0.06	11
Code goby	0.20	18	0.01	3
White grunt	0.84	27	-	
Dwarf seahorse	0.55	26	0.04	7
Pinfish	15.36	39	0.13	25
Rainwater killifish	25.10	39	0.37	23
Gray snapper	0.20	24	-	
Gulf toadfish	0.36	30	0.02	6
Pigfish	1.15	19	0.01	2
Southern puffer	0.05	10	0.00	1
Pugnose pipefish	0.13	14	0.01	3
Dusky pipefish	1.15	37	0.02	6
Gulf pipefish	0.72	25	0.05	13
Inshore lizardfish	0.07	11	0.04	11

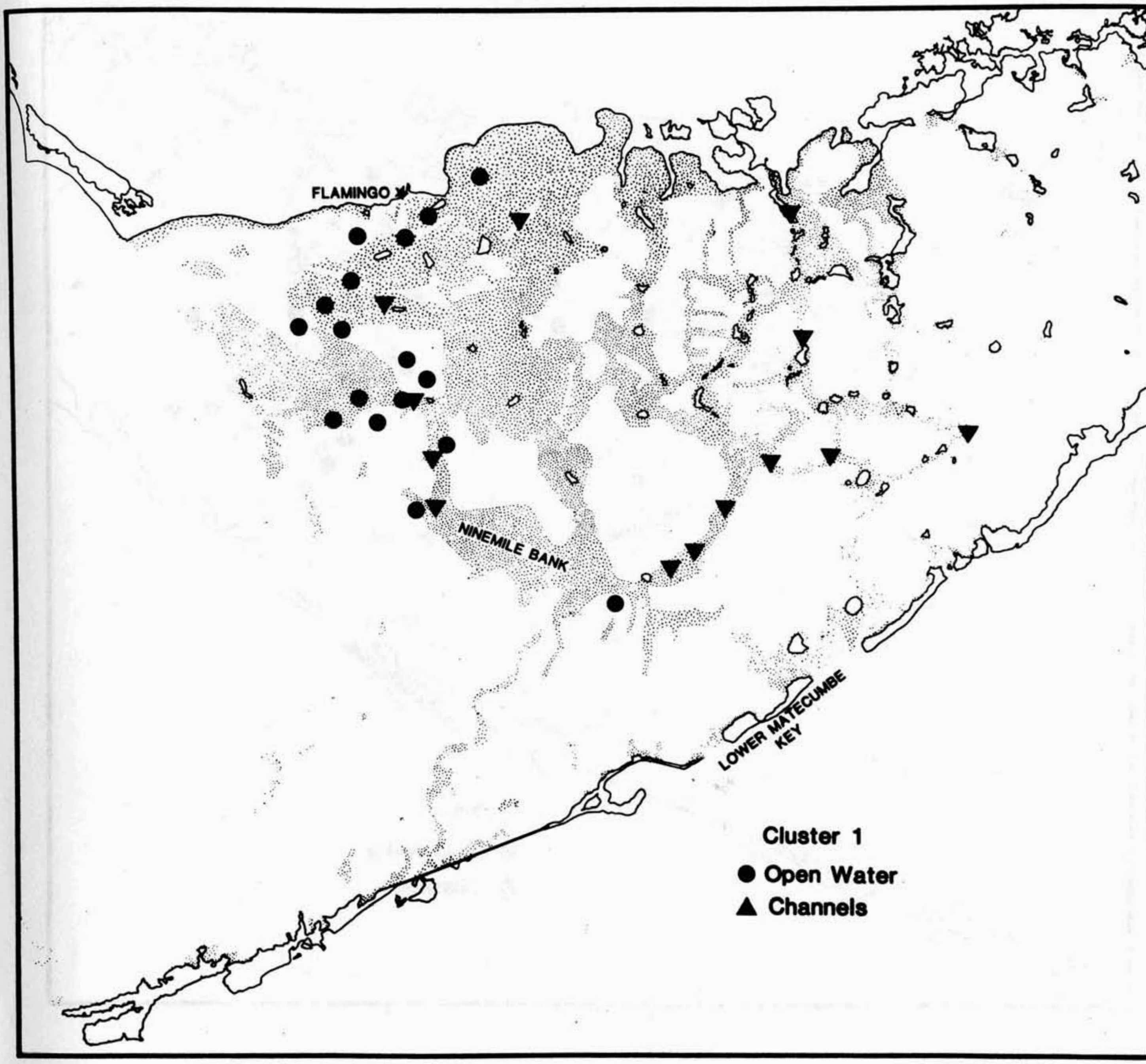


Figure 37. Distribution of stations associated with Cluster 1 developed from Bray-Curtis dissimilarity index analysis (see text for discussion).

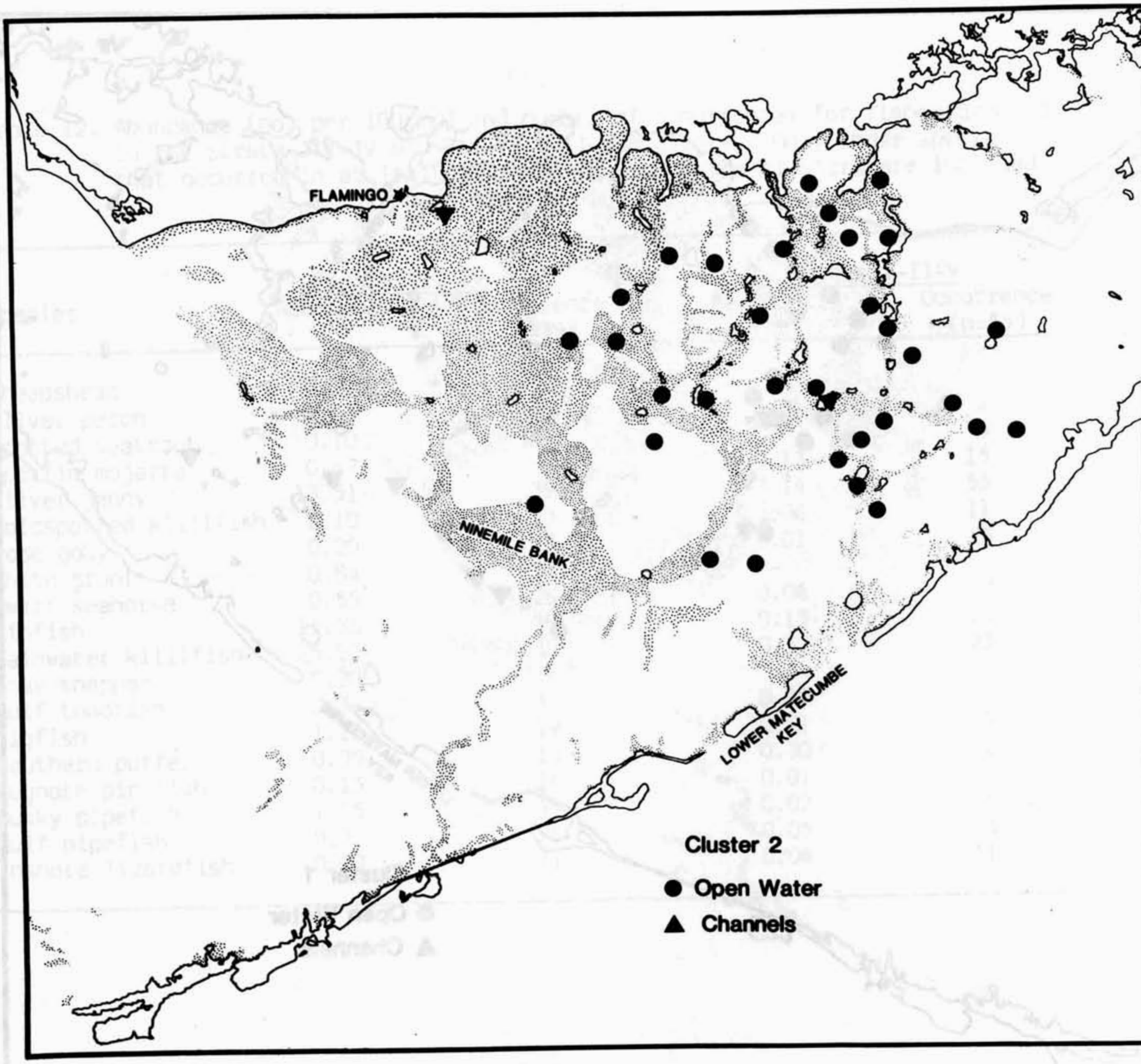


Figure 38a. Distribution of stations in Florida Bay associated with Cluster 2 developed from Bray-Curtis dissimilarity index analysis (see text for discussion).

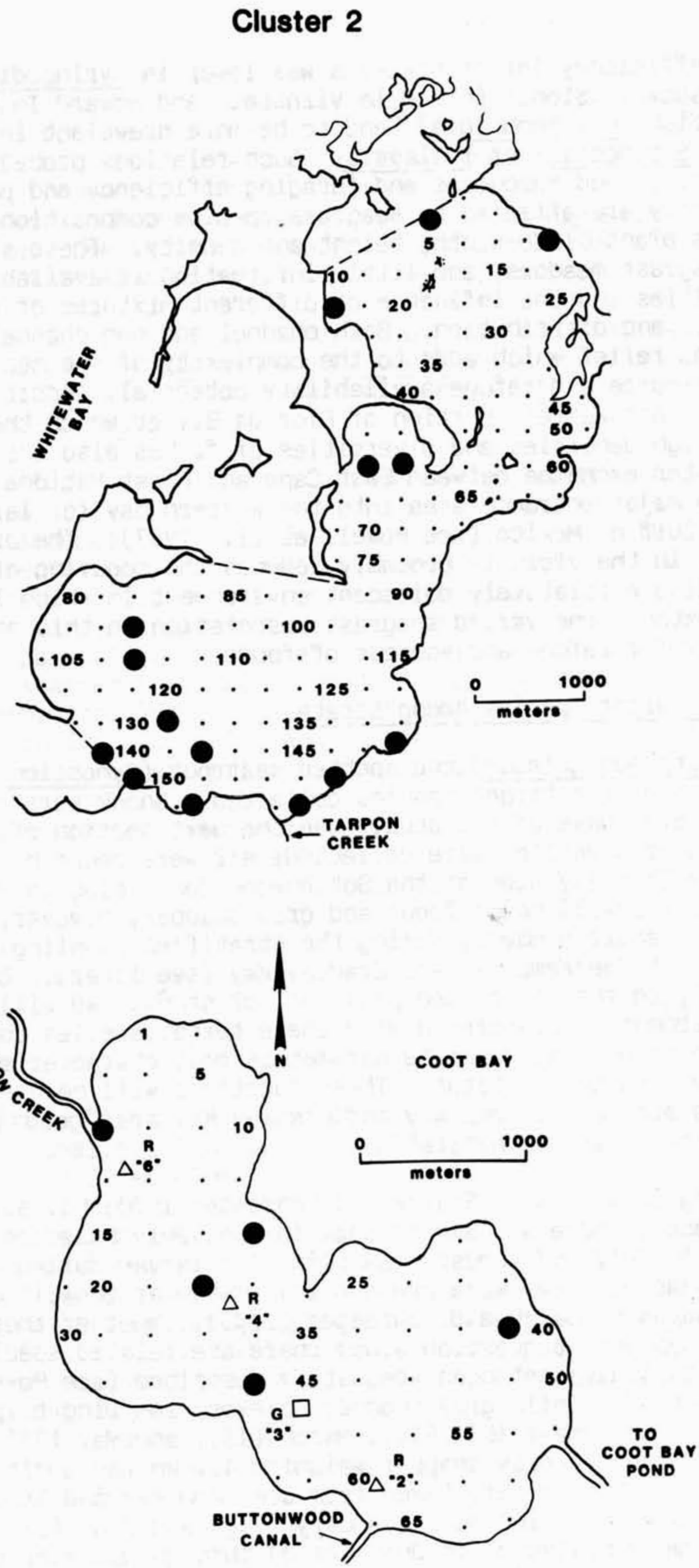


Figure 38b. Distribution of stations in Stratum V associated with Cluster 2 (see text for discussion).

fish foraging efficiency for crustaceans was lower in Syringodium meadows than in Halodule meadows. Stoner (cited in Virnstein and Howard In press) also has noted that pinfish (L. rhomboides) tend to be more prevalant in Halodule beds than in either Syringodium or Thalassia. Such relations probably also exist for other fish. Thus, food resources and foraging efficiency and possibly fish species apparently are affected by seagrass species composition and probably by such factors as plant blade width, height and density. These studies pertain to almost pure seagrass meadows, and little information is available on mixed species communities and the influence of different mixtures of seagrasses on faunal abundance and distribution. Both channel and non-channel areas adjacent to banks present relief which adds to the complexity of the habitat and may be important in resource and refuge availability potential. Additionally, the stations in the northwestern portion of Florida Bay at which there were comparatively high densities and diversities of fishes also are in the vicinity of the major water exchange between East Cape and First National Bank. This appears to be a major entrance area into the western bay for larval fishes spawned in the Gulf of Mexico (see Powell et al. 1987). The presence of extensive banks in the vicinity probably reduces the scouring effects of tidal currents providing a relatively quiescent environment in which larvae can settle out of the plankton. The varied seagrass association in this area would provide a wide diversity for refuge and sources of food.

Distribution of Target Species Among Strata

Gray snapper (Lutjanus griseus) and spotted seatrout (Cynoscion nebulosus) were the most abundant of the target species collected. Snook were collected only during the mangrove phase of our study (see the next section of this report). Only three red drum juveniles were collected; all were taken by seine at the boat ramp on the Coot Bay side of the Buttonwood Canal plug in March 1985 (< 80 mm) and May 1985 (110-130 mm). Trout and gray snapper, however, were collected regularly, but in small numbers, during the stratified sampling phase of our study as well as at Joe Kemp Key and Bradley Key (see later). Data presented here pertain only to the stratified phase of our study. We will use environmental parameters associated with these target species to develop discriminant functions that describe parameters most characteristic of preferred juvenile trout and snapper habitat. These functions will be used to evaluate whether the area around Joe Kemp Key and Bradley Key are "good juvenile gray snapper and spotted seatrout habitat".

Previous sampling in the Park (Starck and Schroeder 1970) has suggested that gray snapper probably have a spawning peak in June-July based on the presence of small juveniles in July and August. Sampling for larvae during 1984-1985 indicated that snapper larve were present in mid-summer (Powell et al. 1987), which tends to support Starck and Schroeder (1970). Whether these larvae are gray snapper is subject to question since there are related species potentially in the vicinity that have not been adequately described (see Powell et al. 1987). We collected juvenile gray snapper on every sampling trip, with the largest numbers in September 1984 (18), March (15), and May 1985 (23); in total we collected 101 juvenile gray snapper weighing 4.1 kg (an additional 52 individuals weighing 2.6 kg were taken from Joe Kemp Key and Bradley Key). Smallest specimens were collected in January (7 g) and June (18-30 g) while larger specimens were collected in July (41 g) through November (88 g). These data also suggest that spawning may occur in late spring and extend into the fall.

Juvenile gray snapper were collected almost exclusively in two of the four strata in Florida Bay. Only two gray snapper were collected in the low salinity stratum (V) and both were in Coot Bay. Channel habitats appeared to be used most frequently by this species; only 35% of these target fish were taken from non-channel environments. Although collected in western Florida Bay, gray snapper were most abundant in channels in southeastern Florida Bay, principally between Twin Key Bank and the Russell Key and Cross Bank area (Fig. 39). The habitats where this species was most frequently collected tended to have total seagrass densities of 1000-4000 shoots$\cdot m^{-2}$ (68% of the 41 occasions and 83% of the gray snapper). Channel stations in southeastern Florida Bay generally contained mixtures of _Thalassia_ and _Halodule_ while non-channel stations in western Florida Bay tended to contain mixtures of _Thalassia_ and _Syringodium_ or _Syringodium_ and _Halodule_.

It is possible that channels in southeastern Florida Bay represented the only suitable habitat (other than mangrove prop root habitats; see part II) for juvenile gray snapper in this area of our study. The southeastern part of the bay is dominated by generally shallow sediments that are low in organic matter and on which has developed relatively sparce monotypic _Thalassia_ communities. The relief and varied seagrass habitat present in channels in southeastern Florida Bay apparently is preferred (along with the mangrove habitat) by juvenile gray snapper that are spawned offshore on reefs such as Alligator Reef (Starck and Schroeder 1970). The relief and varied seagrass habitat of these channels may provide protection and abundant food resources for juvenile gray snapper when they are not utilizing the mangrove prop root habitat.

Juvenile spotted seatrout were collected in all sampling strata, but never in large numbers. A total of 52 seatrout weighing 1.1 kg wet weight were collected; only two were collected in Strata I and II. This species was present primarily in Stratum III (Table 5), and specifically in the northwest portion of this area (Fig. 39). This is the same general area that the larval phase of the Beaufort Laboratory study found to be a major area of larval seatrout abundance (Powell et al. 1987). (An additional 72 seatrout weighing 0.6 kg wet weight were collected in 15 2-min bottom trawls at Joe Kemp Key and Bradley Key during the year; see later).

We found juvenile seatrout present in every month sampled but May 1984 and January 1985. Smallest juveniles (0.4-1.4 g$\cdot$individual^{-1}) were observed in Whitewater Bay in June. The smallest juveniles in Florida Bay were present between June (0.8 g$\cdot$individual^{-1}) and July (7.9 g$\cdot$individual^{-1}), and these were taken in seagrass meadows. These data suggest that trout probably spawn primarily in early summer and settle out of the plankton into seagrass meadows. Individuals collected in channel habitats always were larger than those collected in basin seagrass meadows; this observation may suggest that net avoidance differs in these habitat types or that small individuals tend to prefer seagrass meadows to channels. Powell et al. (1987) observed the greatest frequency of spotted seatrout larvae in passes leading into western Florida Bay. Based on these data and our juvenile collections, we hypothesize that larvae settle out of the plankton into mixed seagrass beds in the vicinity of their point of entrance into the Park.

Juvenile spotted seatrout, although prevalent primarily in the western part of Florida Bay adjacent to the Gulf of Mexico, apparently utilize a wide variety of seagrass community types. Juvenile trout were most frequently collected and

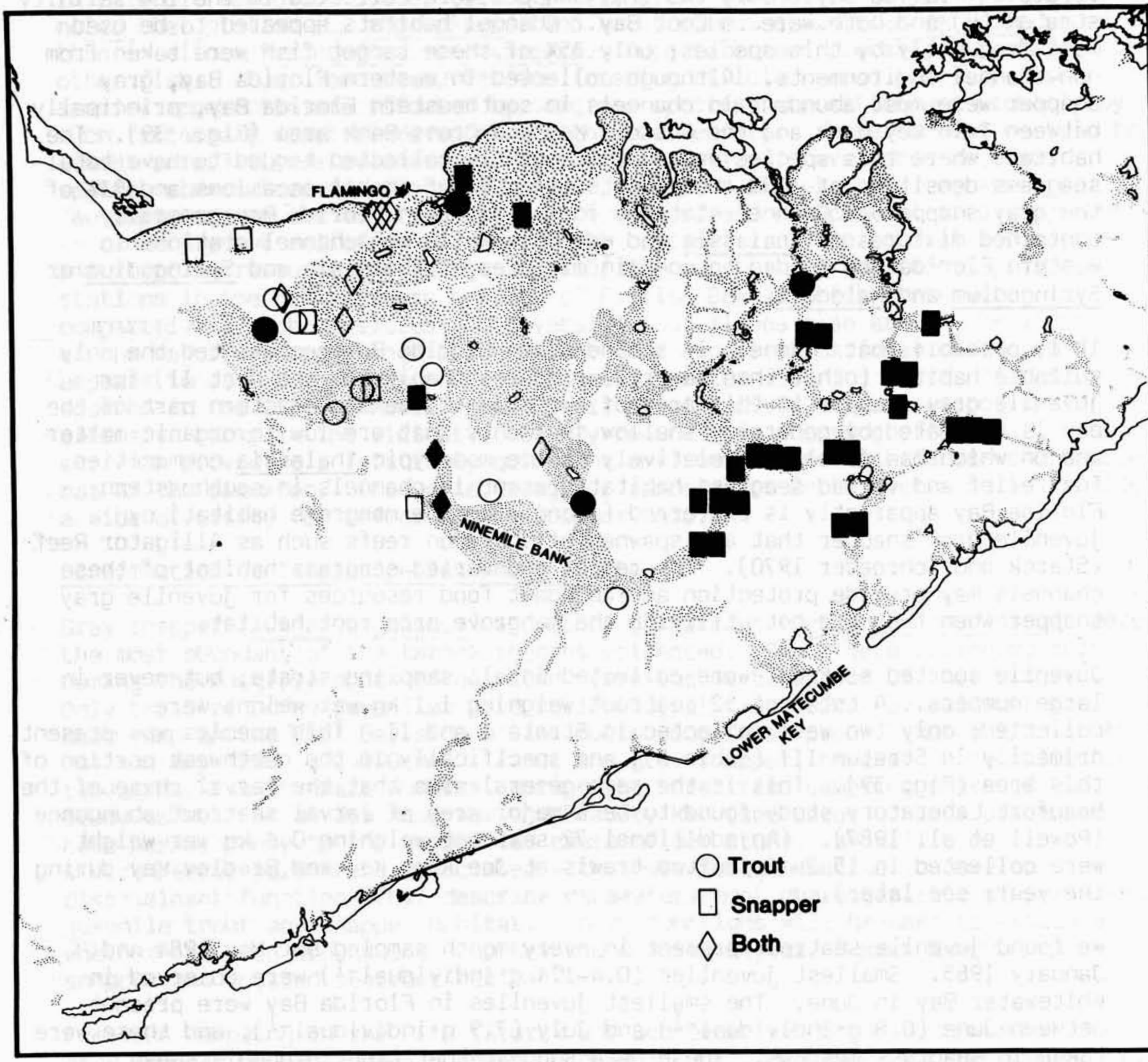


Figure 39. Distribution of collections of gray snapper and spotted seatrout in Florida Bay. Darkened areas represent channel stations.

present in higher numbers (~ 60% of those collected) in seagrass meadows with 1000-4000 shoots$\cdot$m^{-2}. More individuals (19) were collected from mixed Thalassia, Syringodium and Halodule meadows having lush growths of Syringodium than were collected from any single monotypic seagrass habitat type.

Discriminant function analysis was carried out in an attempt to identify those environmental characteristics most important in determining gray snapper and spotted seatrout habitat in Florida Bay. For each analysis, all Florida Bay stations (202) were divided empirically into two groups: those at which target species were captured and those at which target species were not captured. A multivariate analysis of variance (MANOVA) then was conducted using environmental parameters (temperature, salinity, percent organic matter in the sediments, sediment thickness, depth of the water column, and logarithms of Thalassia abundance and biomass, Halodule abundance and biomass, and Syringodium abundance and biomass) to verify that the two station groups had, in fact, divergent environmental characteristics. These analyses included data from all surveys. Therefore, any seasonal patterns in environmental characteristics would constitute added sources of variation. Upon finding a significant MANOVA, discriminant functions were derived in a stepwise fashion (BMDP 1983) to identify those parameters most important in differentiating the station groups. Finally, the efficacy of using the measured environmental parameters to disclose the presence or absence of target species at a particular station was evaluated with a relatively unbiased "jackknife" classification technique (Snapinn and Knoke 1984).

In the first analysis, stations at which seatrout were caught had significantly higher organic matter content, thickness of sediment, and numbers and biomass of Syringodium (ANOVA, $p<0.05$) (Table 13). The overall MANOVA test was significant, and a discriminant function was derived. Temperature, organic matter, sediment thickness, and Syringodium density were included in the function, with high densities of Syringodium and high percentages of organic matter being particularly diagnostic of spotted seatrout habitat (Table 13B). (Relative importance of discriminating variables was judged by the magnitude of the absolute value of discriminant function coefficients and the strength of correlation between each variable and the derived function). Subsequent evaluation of the linear discriminate functions (2) revealed a relatively accurate separation of spotted seatrout habitat based on these variables. Of 23 stations where we actually collected seatrout, 61% were correctly identified as "seatrout habitat" on the basis of these combined environmental conditions; of 179 non-seatrout stations, 82% were so classified. With the classification analysis employed (BMDP 1983) a total of 47 stations were classified as "seatrout habitat" (regardless of whether we collected seatrout there or not). The majority of these potential or actual seatrout habitat occurred in western Florida Bay (Stratum III) and in channels (Stratum IV) generally located in the western and southern portions of Florida Bay (Fig. 40). Larval entrance into the Park, at least into Florida Bay, appears to be at passes between Ninemile Bank and East Cape (Powell et al. 1987). No stations along the extreme northwestern shoreline of Stratum III were classified as "seatrout habitat". This was an area that we found basically void of benthic vegetation.

The second analysis, using the same approach employed for seatrout, defined station groups by the presence or absence of gray snapper. Significant environmental differences again were found, and gray "snapper habitat" was characterized by higher densities of shoots and biomass of Halodule and

Table 13. Means, significance levels for univariate ANOVA, and overall significance of MANOVA for variables used to distinguish stations with from stations without spotted seatrout. Significance levels are for $\log_{10}(x+1)$ transformations of abundance and biomass of seagrass species; B. variables comprising the discriminant function, standardized discriminant coefficients, correlation coefficients relating variables to the discriminant function, and mean discriminant scores for seatrout and non-seatrout stations. * refers to being considered significant.

A.

Variable	Target (n = 23)	No. Snapper (n = 179)	Significance
Temperature (°C)	27.4	26.7	0.42
Salinity (ppt)	35.6	36.1	0.59
Organic matter (%)	17.8	12.2	0.00*
Sediment thickness (m)	1.2	0.9	0.00*
Water depth (m)	1.5	1.5	0.54
Thalassia (shoots/m^2)	622	668	0.66
(gdwt/m^2)	208.3	144.2	0.33
Halodule (shoots/m^2)	304	368	0.13
(gdwt/m^2)	10.2	8.1	0.10
Syringodium (shoots/m^2)	877	199	0.00*
(gdwt/m^2)	58.6	15.6	0.00*
MANOVA	Wilk's Lamda =	0.82	
	Equivalent F =	10.63	0.00*

B.

Discriminant Function	Standardized Coefficient	Correlation Coefficient
Temperature	0.21	0.12
Organicymatter	0.45	0.65
Sediment thickness	0.23	0.50
Syringodium abundance	0.71	0.80

Mean score: seatrout stations = +1.29
non-seatrout stations = 0.17

Syringodium (ANOVA, $p<0.05$). Following significant MANOVA, a discriminant function utilizing salinity, sediment thickness, numbers and biomass of Thalassia, and biomasses of Halodule and Syringodium was developed (Table 14). Halodule and Syringodium biomasses were the most informative variables (Table 14B). Stations were correctly assigned to groups in 68% of cases (40) where gray snapper were collected and 79% of cases (162) without gray snapper. Of 61 stations classified as "snapper habitat" (whether or not snapper were caught there), 29 (48%) occurred in western Florida Bay (Stratum 3) and 27 (44%) occurred in channels (Stratum IV) (Fig. 41). Channels appeared to be good habitat for gray snapper virtually everywhere in the Bay, particularly where seagrass communities included substantial stands of Halodule and/or Syringodium.

Gray snapper habitat appeared to be focused primarily in grass beds and channels located between Ninemile Bank and East Cape and in channels in the near vicinity of the Florida Keys. As was the case for spotted seatrout, these data suggest to us that early stage juvenile gray snapper generally settle out of the plankton after entrance into Florida Bay, and only move into interior areas of the Bay after an unknown period of growth. As noted earlier, smaller snapper appeared more frequently in grass meadows while larger juveniles were more characteristic of channels.

For the final analysis, we pooled stations at which either gray snapper or spotted seatrout occurred and compared them to stations where neither target species was caught. The station groups differed significantly (MANOVA, $p<0.05$), stations with target species having more organic matter in the sediments, greater sediment thickness, and greater abundances and biomasses of Halodule and Syringodium (ANOVA, $p<0.05$). Discriminant analysis identified temperature, salinity, water depth, abundance and biomass of Thalassia, and biomasses of Halodule and Syringodium as important discriminating variables (Table 15A). Halodule and Syringodium biomasses were most influential (Table 15B). Classification analysis successfully grouped 72% of 54 snapper-seatrout stations and 83% of 148 non-target stations. This analysis of pooled snapper-seatrout habitat yielded results similar to those of the two single-species analyses. That is, best habitats for juvenile target fish appear to lie in open waters of western and northwestern Florida Bay (most of Stratum III) and in channels (Stratum IV), especially those to the west and south (Fig. 42).

Seasonality of Environmental Parameters and Fishes at Joe Kemp Key and Bradley Key

Two stations were regularly sampled independent of the stratified random design to provide insight into the seasonality of fishes and seagrasses. Joe Kemp Key #1 (JKK), located east of the Flamingo Channel near day marker "12", was sampled nine times from May 1984 - June 1985. Bradley Key Station (BK), located about 200 meters SW of Bradley Key, was sampled six times from September 1984 - June 1985. The sampling procedure was exactly the same at these two stations as it was for all other stations; surface trawl data have not been included in the analyses.

The areas sampled near Joe Kemp Key (station 1) and Bradley Key (Fig. 8) are shallow, carbonate mud areas adjacent to islands and had a thick sediment layer with relatively high silt-clay (73%) and organic matter (15-16 %) contents in the surface sediments. The sediments for these two general sites are characteristic of those in much of the northwest portion of Florida Bay (Figs.

Table 14. Means, significance levels for univariate ANOVA, and overall significance of MANOVA for variables used to distinguish stations with from stations without gray snapper. Significance levels are for $\log_{10}(x+1)$ transformations of abundance and biomass of seagrass species; B. variables comprising the discriminant function, standardized discriminant coefficients, correlation coefficients relating variables to the discriminant function, and mean discriminant scores for snapper and non-snapper stations. * refers being considered significant.

A. Variable	Snapper (n = 40)	No. Snapper (n = 162)	Significance
Temperature (°C)	27.1	26.7	0.57
Salinity (ppt)	35.5	36.0	0.40
Organic matter (%)	14.1	12.8	0.13
Sediment thickness (m)	0.9	0.9	0.98
Water depth (m)	1.6	1.5	0.07
Thalassia (shoots/m^2)	722	648	0.67
(gdwt/m^2)	195.2	140.7	0.25
Halodule (shoots/m^2)	914	223	0.00*
(gdwt/m^2)	19.5	5.5	0.00*
Syringodium (shoots/m^2)	713	168	0.00*
(gdwt/m^2)	56.0	11.7	0.00*
MANOVA	Wilk's Lamda =	0.77	
	Equivalent F =	9.82	0.00*

B. Discriminant Function	Standardized Coefficient	Correlation Coefficient
Salinity	-0.24	-0.11
Sediment thickness	-0.40	0.00
Thalassia abundance	-1.22	-0.05
Thalassia biomass	1.36	0.15
Halodule biomass	0.52	0.62
Syringodium biomass	0.58	0.66

Mean score: snapper stations = + 1.10
non-snapper stations = -0.217

Table 15. Means, significance levels for univariate ANOVA, and overall significance of MANOVA for variables used to distinguish station with from stations to without target species (spotted seatrout and/or gray snapper). Significance levels are for $\log_{10}(x+1)$ transformations of abundance and biomass of seagrass species; B. variables comprising the discriminant function, standardized discriminant coefficients, and correlation coefficients relating variables to the discriminant function. * refers to variables considered significant.

A.

Variable	Target (n = 54)	No. Snapper (n = 148)	Significance
Temperature (°C)	27.2	26.6	0.36
Salinity (ppt)	35.6	36.2	0.36
Organic matter (%)	14.4	12.2	0.03*
Sediment thickness (m)	1.0	0.9	0.04*
Water depth (m)	1.6	1.5	0.29
Thalassia (shoots/m^2)	736	636	0.52
(gdwt/m^2)	209.2	130.4	0.17
Halodule (shoots/m^2)	751	218	0.00*
(gdwt/m^2)	16.6	5.3	0.00*
Syringodium (shoots/m^2)	727	112	0.00*
(gdwt/m^2)	54.0	8.3	0.00*
MANOVA	Wilk's Lamda =	0.70	
	Equivalent F =	11.61	0.00*

B.

Discriminant Function	Standardized Coefficient	Correlation Coefficient
Temperature	0.15	0.10
Salinity	-0.22	-0.10
Depth	0.21	0.12
Thalassia abundance	-1.31	-0.07
Thalassia biomass	1.41	0.15
Halodule biomass	0.43	0.55
Syringodium biomass	0.57	0.69

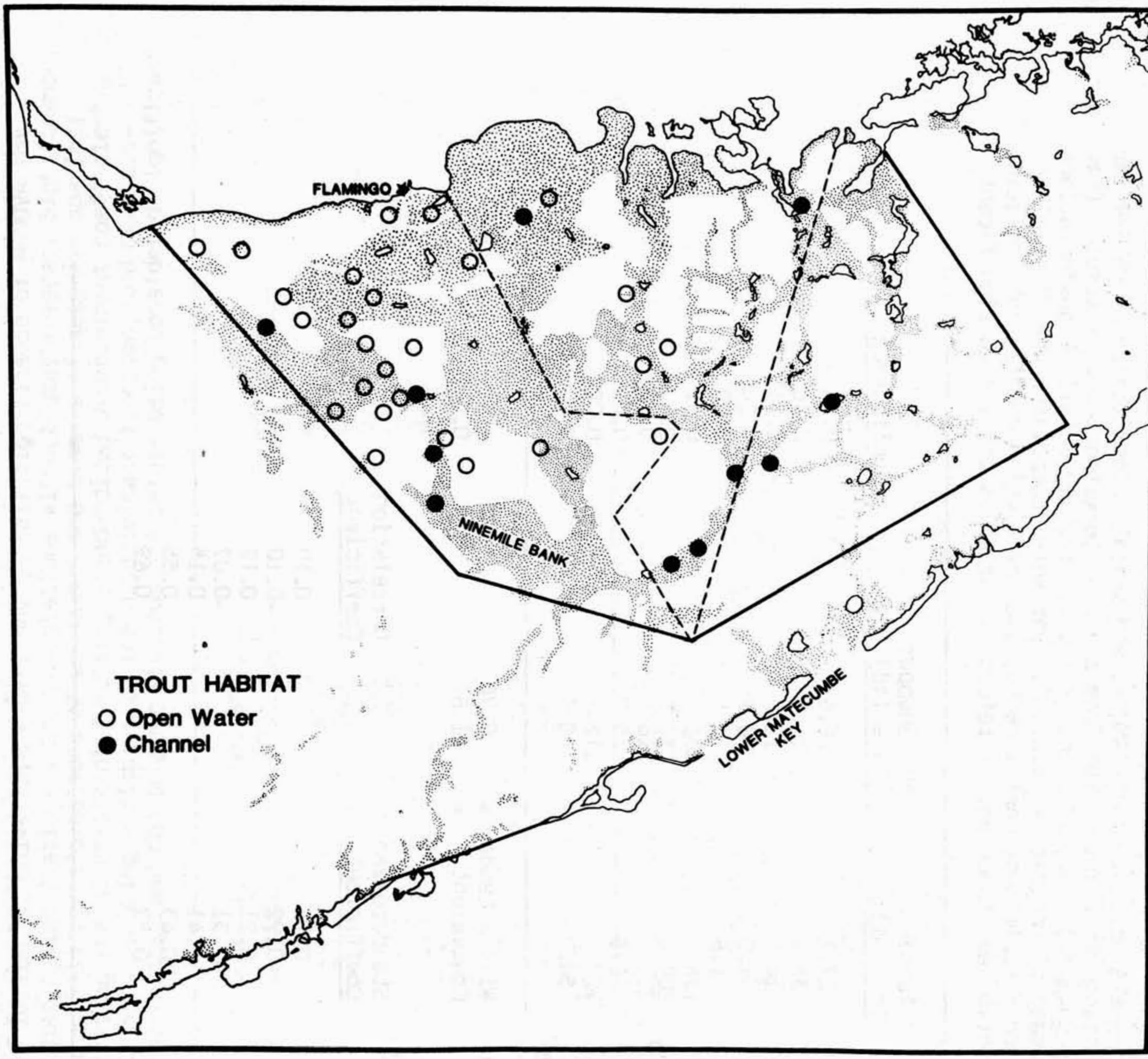


Figure 40. Results of discriminant analysis depicting seatrout habitat.

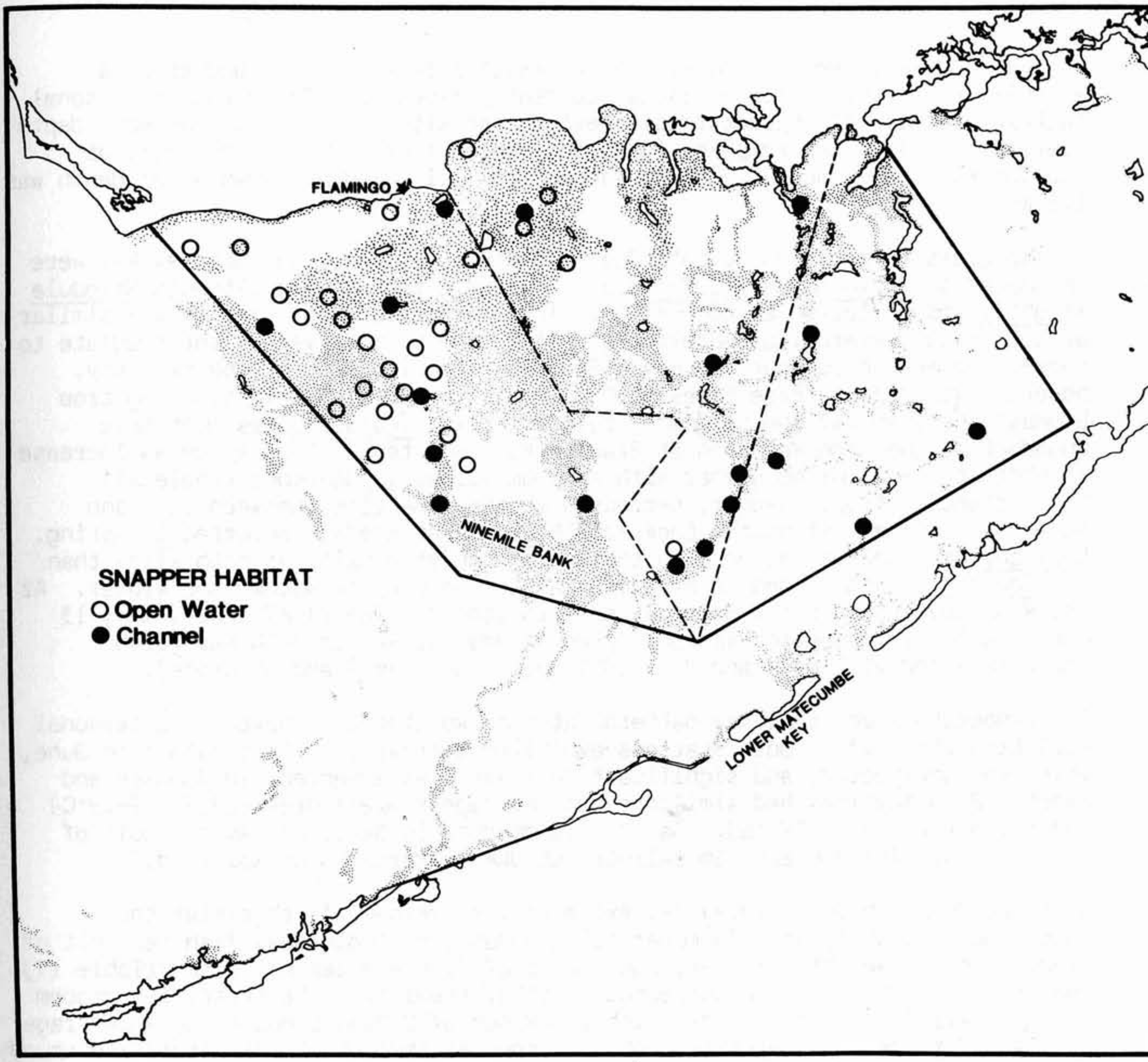


Figure 41. Results of discriminant analysis depicting gray snapper habitat.

11, 14, and 16). We did not sample the exact area each time, and this is exemplified by the highly variable sediment parameters. There was no seasonal pattern in sediment characteristics evident at either location. Sediment depth averaged 1.3 m at Joe Kemp Key (JKK) and ranged from 1.0 - 1.6 m, while at Bradley Key it averaged 1.4 m and ranged from 1.1 - 1.9 m. Mean water depth was 1.1 m.

The seagrass communities at both Joe Kemp Key (station 1) and Bradley Key were dominated by Syringodium filiforme and Thalassia testudinum, although Halodule wrightii was collected at both sites. Total seagrass shoot density was similar at both sites, averaging approximately 1400 shoots$\cdot$ m^{-2}, values intermediate to those observed throughout the Bay. Seagrass standing crop at Joe Kemp Key, however, was almost three times that collected at Bradley Key; standing crop biomass averaged 247 and 81 $g \cdot m^{-2}$, respectively. Thalassia was much more abundant at Joe Kemp Key than at Bradley Key, and tended to display an increase in shoot numbers during summer with maximum values in November (Table 16). Plant standing crop, however, decreased at the same time, between July and November. Highest standing stocks of Thalassia at Bradley occurred in spring. Syringodium contributed more to the average shoot density at both sites than did Thalassia, and tended to have its maximum density in autumn and winter. At Joe Kemp Key we collected Halodule only in January 1985 (1067 shoots$\cdot m^{-2}$; 13 $g \cdot m^{-2}$) while this species was collected at Bradley Key in both May (1100 shoots$\cdot m^{-2}$ and 22 $g \cdot m^{-2}$) and June 1985 (3100 shoots$\cdot m^{-2}$ and 67 $g \cdot m^{-2}$).

The temperature and salinity patterns at the two stations showed some seasonal variation (Fig. 43). Both stations exhibited decreases in temperature in June, which was unexpected, and significant decreases, as expected, in January and March. Both stations had similar annual average temperatures (26.7°, 26.9°C) and salinities (33, 35°/oo). Salinities dropped in September as a result of heavy rains. The decrease in salinity at JKK in March is unexplained.

Both Joe Kemp Key and Bradley Key exceeded the average of other stations throughout the study area in numerical abundance of individual fish per unit of area, fish wet weight per area, and number of fish species collected (Table 17). The average number of fish collected by otter trawl from the stratified random sampling was 17.3 fish$\cdot$100 m^{-2}, with a maximum of 215.3, compared to an average of 124.6 for JKK. The average number of species throughout the stratified study was seven, compared to 19 for JKK. The average wet weight biomass was 73 g from the other strata, compared to an average of 579 g$\cdot$100 m^{-2}. The maximum biomass of 1170 g$\cdot$100 m^{-2} in May 1985 from JKK far exceeded the maximum of 621 g$\cdot$100 m^{-2} we collected at any station (station 5-6) during the stratified survey. These data suggest that bank habitats may be among the most diverse habitats in terms of fish, at least relative to the basin and channel habitats we sampled. Powell et al. (1986), sampling on the banks, also observed fish abundances exceeding those we generally observed in the basin-channel areas of the Bay.

Joe Kemp Key had about twice the number of fish for each 100 m^2 (124.6 vs. 64.6) and about 60% more biomass for each 100 m^2 (579.0 vs. 362.7) than at Bradley Key. JKK also averaged about two more species in each sample than did Bradley Key (19 vs. 17). These species numbers are higher than those for most of the stratified sampling phase of our study.

Seasonal trends in both fish numbers and biomass were evident at both Joe Kemp Key and Bradley Key (Table 17 and Fig. 44). Overall, total fish numbers and

11, 14, and 16). We did not sample the exact area each time, and this is exemplified by the highly variable sediment parameters. There was no seasonal pattern in sediment characteristics evident at either location. Sediment depth averaged 1.3 m at Joe Kemp Key (JKK) and ranged from 1.0 - 1.6 m, while at Bradley Key it averaged 1.4 m and ranged from 1.1 - 1.9 m. Mean water depth was 1.1 m.

The seagrass communities at both Joe Kemp Key (station 1) and Bradley Key were dominated by *Syringodium filiforme* and *Thalassia testudinum*, although *Halodule wrightii* was collected at both sites. Total seagrass shoot density was similar at both sites, averaging approximately 1400 shoots$\cdot$ m^{-2}, values intermediate to those observed throughout the Bay. Seagrass standing crop at Joe Kemp Key, however, was almost three times that collected at Bradley Key; standing crop biomass averaged 247 and 81 $g \cdot m^{-2}$, respectively. *Thalassia* was much more abundant at Joe Kemp Key than at Bradley Key, and tended to display an increase in shoot numbers during summer with maximum values in November (Table 16). Plant standing crop, however, decreased at the same time, between July and November. Highest standing stocks of *Thalassia* at Bradley occurred in spring. *Syringodium* contributed more to the average shoot density at both sites than did *Thalassia*, and tended to have its maximum density in autumn and winter. At Joe Kemp Key we collected *Halodule* only in January 1985 (1067 shoots$\cdot m^{-2}$; 13 $g \cdot m^{-2}$) while this species was collected at Bradley Key in both May (1100 shoots$\cdot m^{-2}$ and 22 $g \cdot m^{-2}$) and June 1985 (3100 shoots$\cdot m^{-2}$ and 67 $g \cdot m^{-2}$).

The temperature and salinity patterns at the two stations showed some seasonal variation (Fig. 43). Both stations exhibited decreases in temperature in June, which was unexpected, and significant decreases, as expected, in January and March. Both stations had similar annual average temperatures (26.7°, 26.9°C) and salinities (33, 35°/oo). Salinities dropped in September as a result of heavy rains. The decrease in salinity at JKK in March is unexplained.

Both Joe Kemp Key and Bradley Key exceeded the average of other stations throughout the study area in numerical abundance of individual fish per unit of area, fish wet weight per area, and number of fish species collected (Table 17). The average number of fish collected by otter trawl from the stratified random sampling was 17.3 fish$\cdot$100 m^{-2}, with a maximum of 215.3, compared to an average of 124.6 for JKK. The average number of species throughout the stratified study was seven, compared to 19 for JKK. The average wet weight biomass was 73 g from the other strata, compared to an average of 579 g$\cdot$100 m^{-2}. The maximum biomass of 1170 g$\cdot$100 m^{-2} in May 1985 from JKK far exceeded the maximum of 621 g$\cdot$100 m^{-2} we collected at any station (station 5-6) during the stratified survey. These data suggest that bank habitats may be among the most diverse habitats in terms of fish, at least relative to the basin and channel habitats we sampled. Powell et al. (1986), sampling on the banks, also observed fish abundances exceeding those we generally observed in the basin-channel areas of the Bay.

Joe Kemp Key had about twice the number of fish for each 100 m^2 (124.6 vs. 64.6) and about 60% more biomass for each 100 m^2 (579.0 vs. 362.7) than at Bradley Key. JKK also averaged about two more species in each sample than did Bradley Key (19 vs. 17). These species numbers are higher than those for most of the stratified sampling phase of our study.

Seasonal trends in both fish numbers and biomass were evident at both Joe Kemp Key and Bradley Key (Table 17 and Fig. 44). Overall, total fish numbers and

Table 17. Catch data from the two permanent stations - Joe Kemp Key #1 (JKK) and Bradley Key (BK) in 1984, 1985. Margalef index of diversity is (S-1)/ln N, where S = number of species and N = number of fish.

		No. Fish	Wet wt. (g)	Fish/ 100 m^2	g/100 m^2	No. species	Diversity Index
JKK	May	639	4426.6	106.5	737.8	23	3.41
	Jun	562	4611.2	89.2	731.9	19	2.84
	Jul	520	2535.8	108.3	528.3	20	3.04
	Sep	724	4123.6	107.3	610.9	17	2.43
	Nov	814	2559.5	90.4	284.4	17	2.38
	Jan	564	637.1	94.0	106.2	22	3.31
	Mar	679	1487.7	90.5	198.4	17	2.45
	May	1199	6668.4	210.4	1169.9	19	2.54
	Jun	1753	6578.8	224.7	843.4	17	2.14
	TOTAL	7454	33628.7	1121.3	5211.2	-	
	AVERAGE	828.2	3736.5	124.6	579.0	19.0	2.68
	Sep	616	5640.3	80.5	737.3	18	2.65
	Nov	134	1544.8	24.8	286.1	15	2.86
	Jan	109	1024.1	14.5	136.5	11	2.13
	Mar	588	2746.5	71.3	332.9	20	2.98
	May	703	1558.1	72.1	159.8	20	2.90
	Jun	973	4160.3	124.7	533.4	20	2.76
	TOTAL	3123	16674.1	387.9	217.6	-	
	AVERAGE	520.5	2779.0	64.6	362.7	17.3	2.61

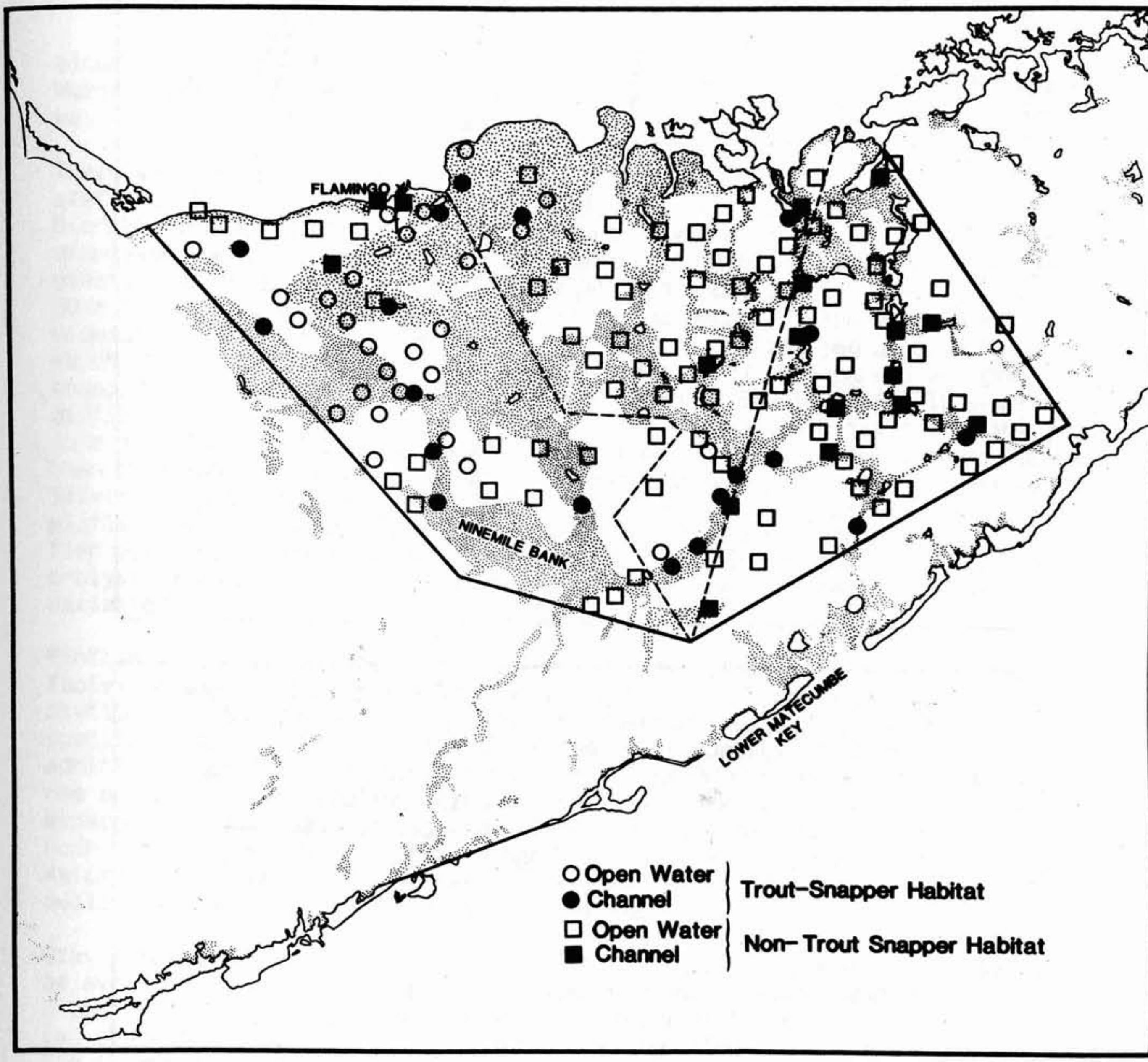


Figure 42. Results of discriminant analysis of preferred trout-snapper habitat and non-trout-snapper habitat.

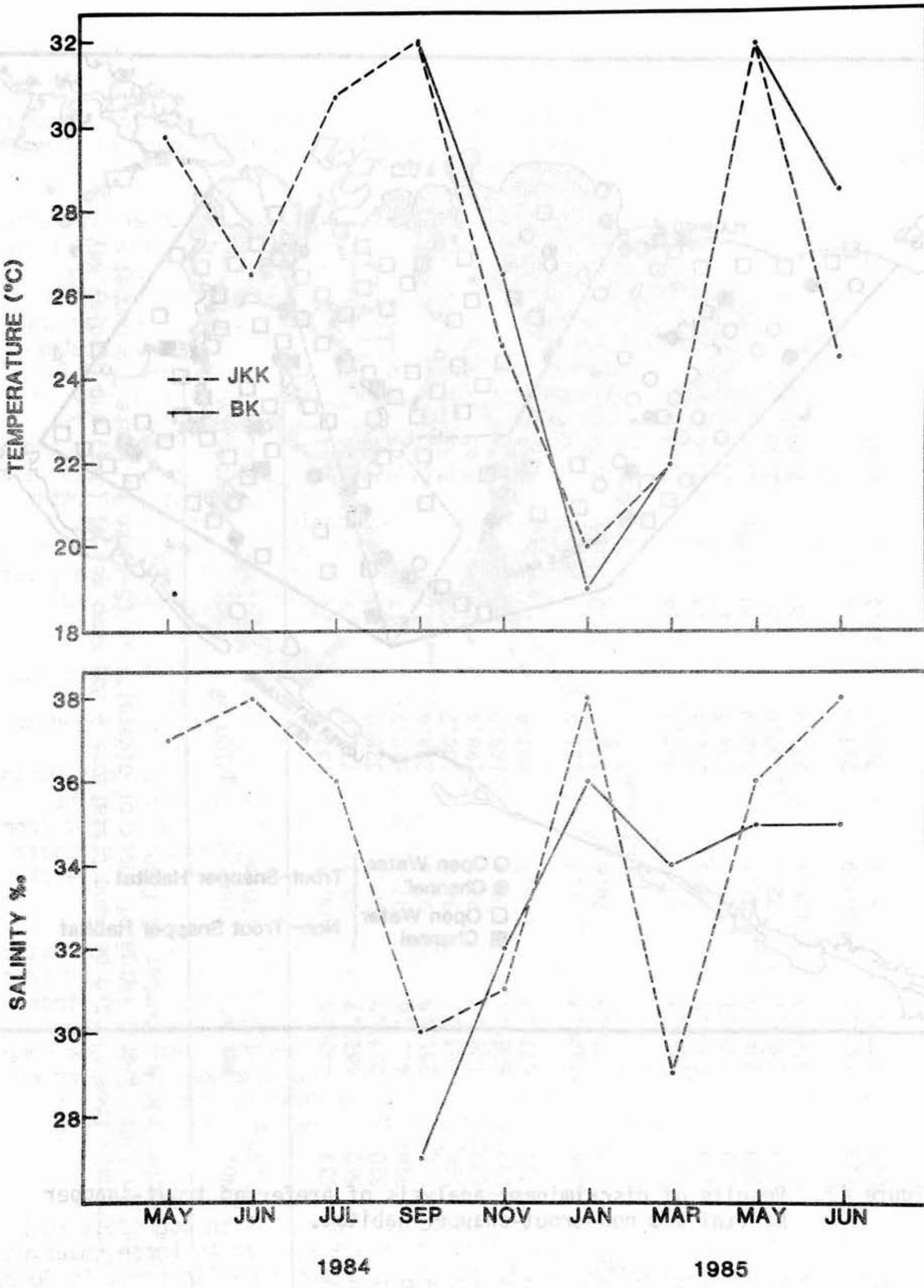


Figure 43. Temperatures and salinities at Joe Kemp Key (JKK) and Bradley Key (BK) during study period.

biomass were highest from May through September and lowest in November through March. Except for the January collection at Bradley Key, the number of species was fairly consistent and showed no seasonal trend.

There was a seasonal trend in biomass of the most abundant species at these two stations (Tables 17-20, Figs. 45 and 46). Most species displayed a decline in biomass from November through March. Spotted seatrout and silver jenny displayed the least seasonal change, whereas pinfish and pigfish showed the greatest seasonal differences, decreasing from about 300 $g \cdot 100\ m^{-2}$ in May and June to less than 10 $g \cdot 100\ m^{-2}$ in November and January. There was a greater biomass of silver jenny, sheepshead, and spotted seatrout at Bradley Key in March than at JKK whereas in September, silver jenny, sheepshead and gray snapper displayed a greater biomass at JKK than at Bradley Key. It was difficult to discern an annual pattern to the changes in biomass when May and June of 1984 and 1985 are compared. For example, gray snapper biomass was less than 25 $g \cdot 100\ m^{-2}$ in May-June 1984, but exceeded 125 $g \cdot 100\ m^{-2}$ one year later. Silver jenny and pinfish were more abundant in the spring of 1985, whereas pigfish were less abundant in 1985 than 1984. These temporal variability in fish data shown here were characteristic of data for the stratified survey; our analyses incorporate these patterns which have been accepted as a source of variation.

Pinfish were the most abundant species (in terms of biomass) at both stations. Tables 18 and 19 list the eight most abundant species collected at the two stations. Both gray snapper and spotted seatrout were among the most abundant species. Tables 20 and 21 list these top eight species, plus about 20 additional species which provided at least 1 $g \cdot 100\ m^{-2}$ wet weight biomass during one or more of the sampling trips. When these data are summed, there is no apparent overall seasonal pattern. Some species were absent in the winter from both stations, which indicates perhaps that they migrate to deeper or offshore waters. These are pigfish, gray snapper, gulf toadfish, striped mullet, white mullet, southern flounder, and gulf pipefish.

Gray snapper ranged in biomass from 0 (January) to 134.2 $g \cdot 100\ m^{-2}$ (June) with an average biomass of 25.4 $g \cdot 100\ m^{-2}$ year around. Spotted seatrout ranged from 0 (March) to 18.2 (May) and provided an average of 5.4 $g \cdot 100\ m^{-2}$. Thus, these two grass bed stations appear to provide almost five-fold more snapper than trout biomass. More trout biomass was observed at Bradley Key than at Joe Kemp Key, while more gray snapper biomass was observed at Joe Kemp Key than Bradley Key. These station biomasses as well as numerical abundances for both gray snapper and seatrout are larger than were taken from most of the stations sampled during our stratified phase of this study.

Joe Kemp Key and Bradley Key may be inhabited by different sizes of target species. Smallest individual seatrout were collected in May through July (0.3 g-2.9 g) at both JKK and Bradley Key. These data are similar to those observed in our stratified survey, where we collected early stage juvenile trout in June. Overall, JKK appeared to maintain a seatrout population that was either smaller or more recently settled out of the plankton than did Bradley Key. The average size individual at JKK weighed 3.9 g wet weight whereas at Bradley Key it was 18.4 g wet weight. Snapper, on the other hand, individually were smaller at Bradley Key (15.5 $g \cdot individual^{-1}$) that at Joe Kemp Key (76.4 g·individual). Smallest individual snapper generally occurred in autumn at Bradley Key (0.5 g) and in winter at JKK (2.9 g); in general, this agrees with our findings in the

Table 18. Biomass (g wet wt/100 m^2) of species with greatest frequency of occurrence at Joe Kemp Key #1 station.

	May	Jun	Jul	Sep	Nov	Jan	Mar	May	Jun	Total
Pinfish	182.2	282.2	178.5	136.0	111.8	-	25.0	627.9	458.8	2002.4
Pigfish	284.1	219.7	83.9	76.9	-	0.5	5.4	104.3	59.9	834.7
Silver perch	77.1	42.4	40.3	213.4	63.5	4.4	59.9	3.8	79.5	584.3
Silver jenny	-	18.2	59.9	125.7	65.3	35.0	17.6	84.0	43.6	449.3
Gray snapper	22.5	11.0	29.3	15.1	0.3	-	0.4	125.7	134.2	338.5
Sheepshead	13.3	5.0	22.9	20.8	6.2	6.4	-	10.9	0.1	85.6
Inshore lizard-fish	12.1	9.4	1.4	0.7	-	3.0	7.6	23.6	1.1	58.9
Spotted sea-trout	1.6	3.3	0.3	15.0	0.6	6.6	-	0.1	1.0	28.5

Table 19. Biomass (g wet wt/100 m^2) of species with greatest frequency of occurrence at Bradley Key Station.

	Sep	Nov	Jan	Mar	May	Jun	Total
Pinfish	125.3	69.1	18.3	11.5	32.5	305.9	562.6
Silver perch	374.8	119.0	16.3	4.4	0.2	11.2	525.9
Silver jenny	74.6	28.6	26.4	135.4	50.3	59.7	375.0
Pigfish	93.3	50.4	-	0.3	20.2	106.1	270.3
Spotted seatrout	16.4	2.3	4.3	10.7	18.2	0.9	52.8
Gray snapper	0.1	0.8	-	10.2	10.1	21.6	42.8
Sheepshead	9.6	-	-	11.3	9.3	6.3	36.5
Inshore lizardfish	1.5	2.3	1.0	2.4	6.2	2.2	15.6

Table 20. Frequency of occurrence on Joe Kemp Key of fish species exceeding 1 g. (wet wt)/100 m^2.

	May	Jun	July	Sept	Nov	Jan	Mar	May	Jan	Total
Silver perch	x	x	x	x	x	x	x	x	x	9
Silver jenny		x	x	x	x	x	x	x	x	8
Pinfish	x	x	x	x	x		x	x	x	8
Sheepshead	x	x	x	x	x	x		x		7
Pigfish	x	x	x	x			x	x	x	7
Inshore lizardfish	x	x	x			x	x	x	x	7
Spotted seatrout	x	x		x		x			x	5
Gray snapper	x	x	x					x	x	5
Southern puffer	x	x				x		x		4
Gulf pipefish	x	x						x	x	4
Hardhead catfish		x	x		x					3
Spotfin mojarra	x	x	x							3
Fringed filefish				x	x	x				3
Gulf toadfish	x						x	x		3
Dusky pipefish					x	x			x	3
Bay anchovy						x	x			2
Striped burrfish						x	x			2
White grunt				x		x				2
Rainwater killifish				x					x	2
Gulf flounder	x						x			2
Gafftopsail catfish								x		1
Grass porgy									x	1
Planehead filefish						x				1
Gag									x	1
Southern flounder			x							1
Leopard searobin	x									1
Red drum		x								1
Blackcheek tongue-fish	x									1
TOTAL	14	13	10	9	7	12	9	11	12	

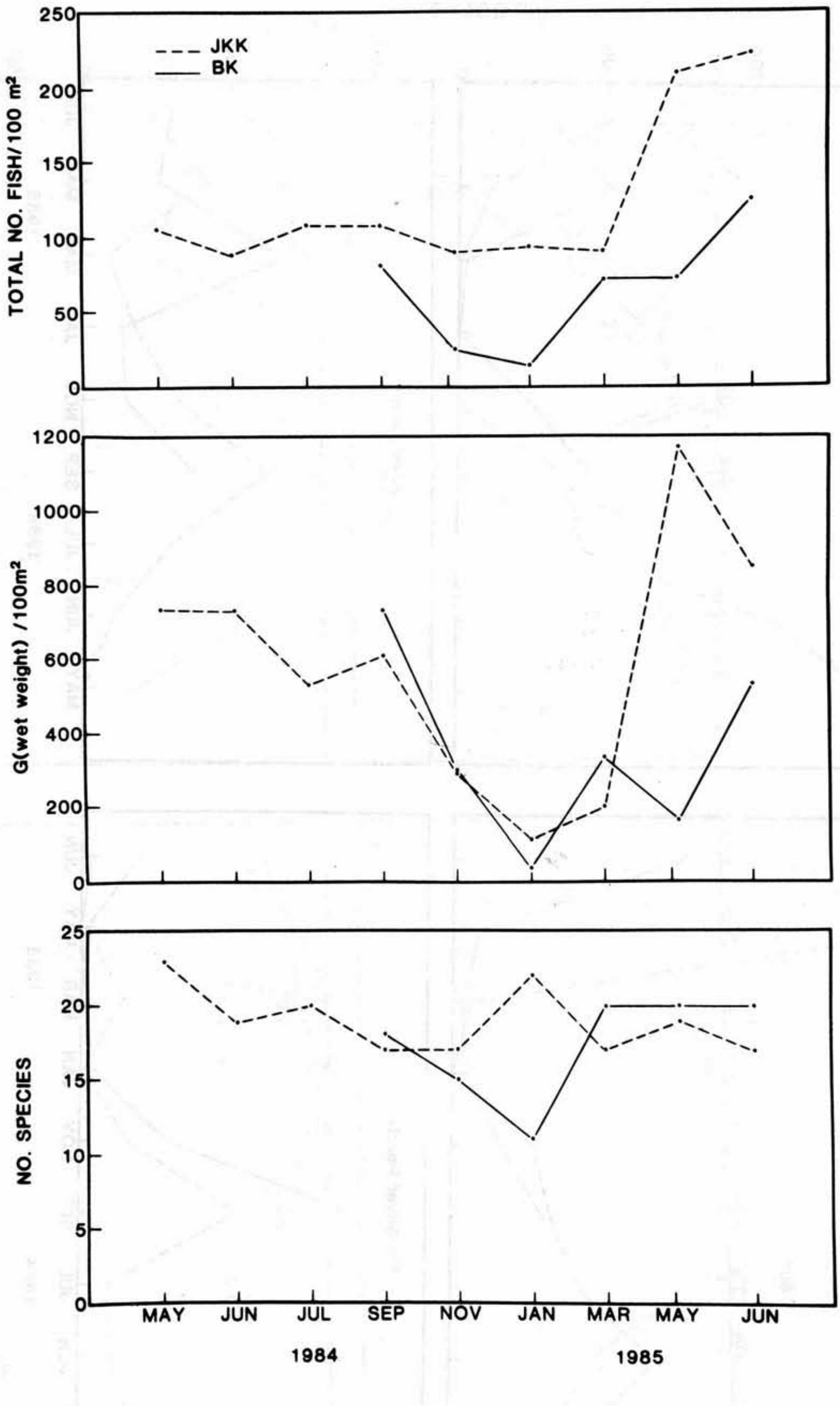


Figure 44. Total number of fish, biomass, and numbers of species at Joe Kemp Key (JKK) and Bradley Key (BK).

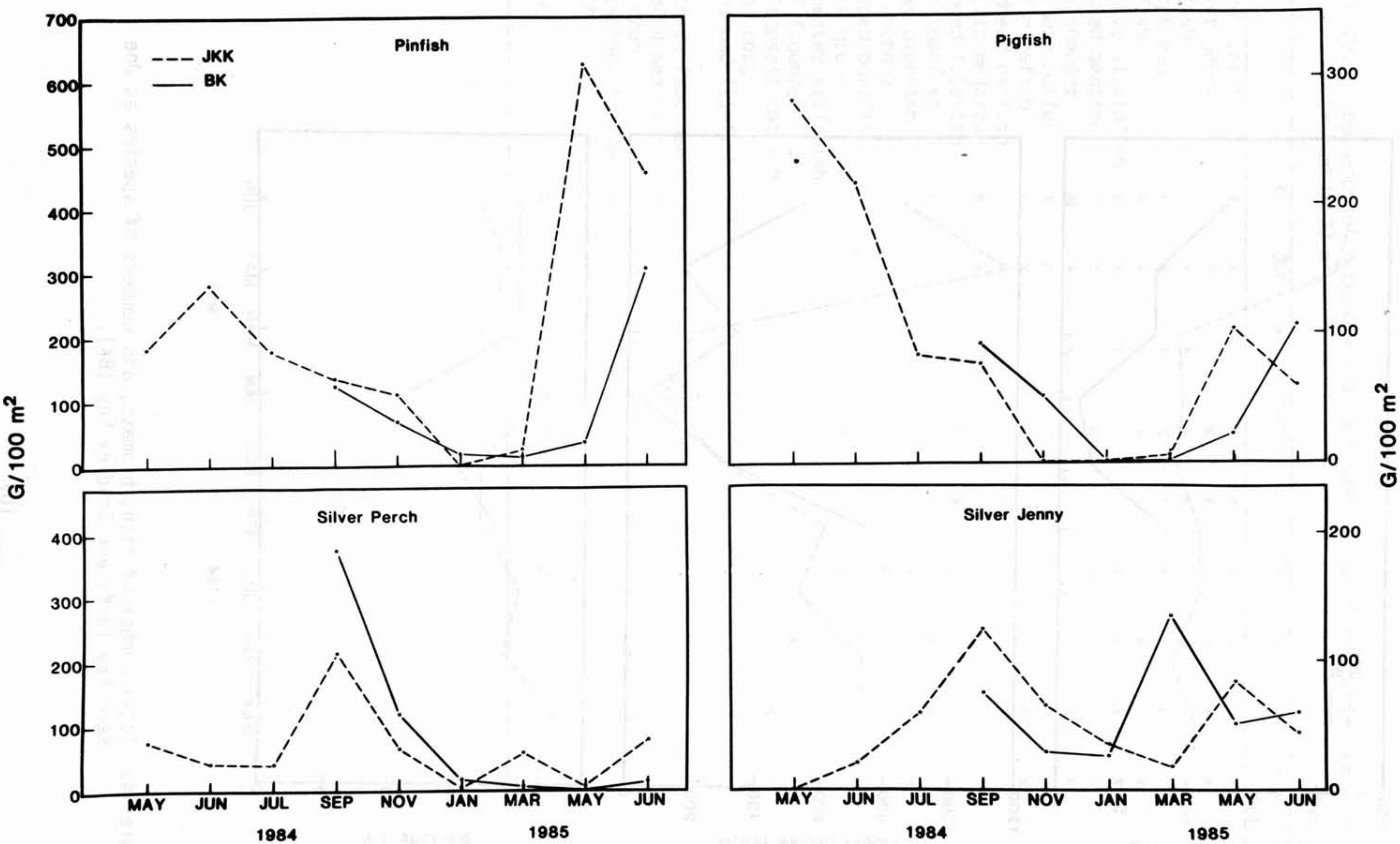


Figure 45. Biomass of pinfish, pigfish, silver perch and silver jenny at Joe Kemp Key (JKK) and Bradley Key (BK).

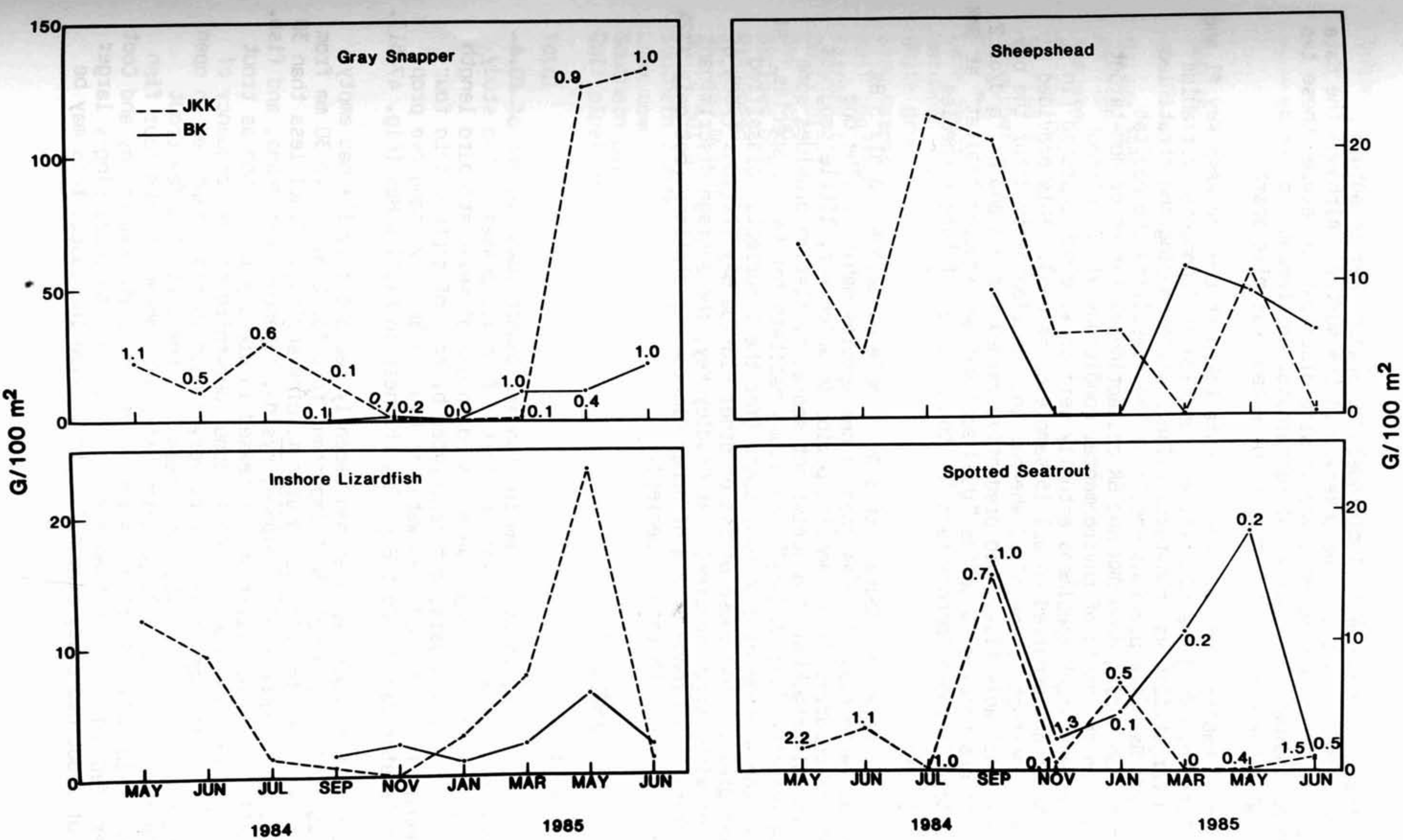


Figure 46. Biomass of gray snapper, sheepshead, inshore lizardfish and spotted seatrout at Joe Kemp Key (JKK) and Bradley Key (BK).

stratified survey, although small individuals at Bradley Key in autumn (September) occurred earlier than we observed in the survey. Although the data are limited, the differences we observed in size distribution between these two sites may be an indication of different patterns of settlement and use by seatrout and gray snapper at sites only about a nautical mile apart.

Classification of habitat was performed on data taken at the Joe Kemp Key #1 and Bradley Key sites by using the discriminant function environmental variables developed from target-fish vs. non-target-fish stations during the stratified survey of Florida Bay (see previous section). We classified the habitat conditions recorded during each JKK and BK collection as target or non-target species habitat on the basis of environmental conditions alone, without considering whether target specimens actually were or were not captured (in fact, target specimens occurred on all 15 sample occasions). This provided a useful, though imperfect, gauge of 1) whether the function derived for the bay as a whole was applicable (i.e., had predictive value) for JKK and BK, and/or 2) whether the factors helping to define "good seatrout and snapper habitat" at JKK and BK are generally those factors favoring the presence of target species throughout the Bay.

Using the criteria developed above 7 of 8 JKK sample occasions and all 5 BK sampling periods were classified as good target species habitat. The one exception at JKK occurred for a sampling period in which very little seagrass was found. The distribution of discriminant scores by station provides some index of the relative "suitability" of various habitats for target species. At Joe Kemp Key, the average discriminant score (for the 7 correctly classified stations) was greater than those of 94% of other Florida Bay stations (>68% of those stations with target species). At Bradley Key, the average discriminant score was greater than those of 81% of other Florida Bay stations (but only >32% of those for stations with target species).

Feeding Habits of Target Fish

Spotted Sea Trout

Stomachs from 173 trout, 15 to 315 mm in standard length (mean length of 60.4 mm), were examined. These trout were collected from all phases of the study (open water and mangrove). Trout were placed in one of seven standard length size classes for data analysis, and segregated by area of capture into four habitat groups: (1) grass bed/open water in Florida Bay; (2) mangrove prop root; (3) Whitewater Bay and Coot Bay; (4) channels in Florida Bay (Fig. 47-51).

Overall, most of the trout captured had recently fed and only 17% had empty stomachs (Fig. 47). The single most important food for trout above 30 mm from all habitats were penaeids (Penaeus duorarum, pink shrimp). Trout less than 30 mm ate almost equal numbers of amphipods, mysids, copepods, carideans, and fish. Fish, primarily rainwater killifish, increased in dietary importance as trout reached 50 mm, where they contributed to about one-third of the frequency of prey occurrence. Although penaeids were very common in trout captured in open water/seagrass habitats (Fig. 48), and present in the diet of a few trout collected in channels (Fig. 51), penaeid shrimp were absent in the four fish from mangroves(Fig. 49). Spotted seatrout captured in Whitewater Bay and Coot Bay, however, fed more on fish than shrimp (Fig. 50). An increasingly larger proportion of trout had empty stomachs as their size increased; this may be

Table 21. Frequency of occurrence on Bradley Key of fish species exceeding 1 g (wet wt)/100 m^2.

	MONTH						
Species	Sept	Nov	Jan	Mar	May	Jun	Total
Silver jenny	x	x	x	x	x	x	6
Pinfish	x	x	x	x	x	x	6
Inshore lizardfish	x	x	x	x	x	x	6
Silver perch	x	x	x	x		x	5
Spotted seatrout	x	x	x	x	x		5
Sheepshead	x			x	x	x	4
Pigfish	x	x			x	x	4
Lane snapper	x		x	x		x	4
Hardhead catfish	x		x	x			3
White grunt	x	x				x	3
Gray snapper				x	x	x	3
Gulf toadfish				x	x	x	3
Fringed filefish		x	x				2
Dusty pipefish			x			x	2
Bay anchovy	x						1
Striped burrfish						x	1
Planehead filefish	x						1
Striped mullet				x			1
White mullet				x			1
Southern flounder	x						1
Look down		x					1
Southern puffer					x		1
Gulf pipefish				x			1
Total	13	9	9	13	9	12	

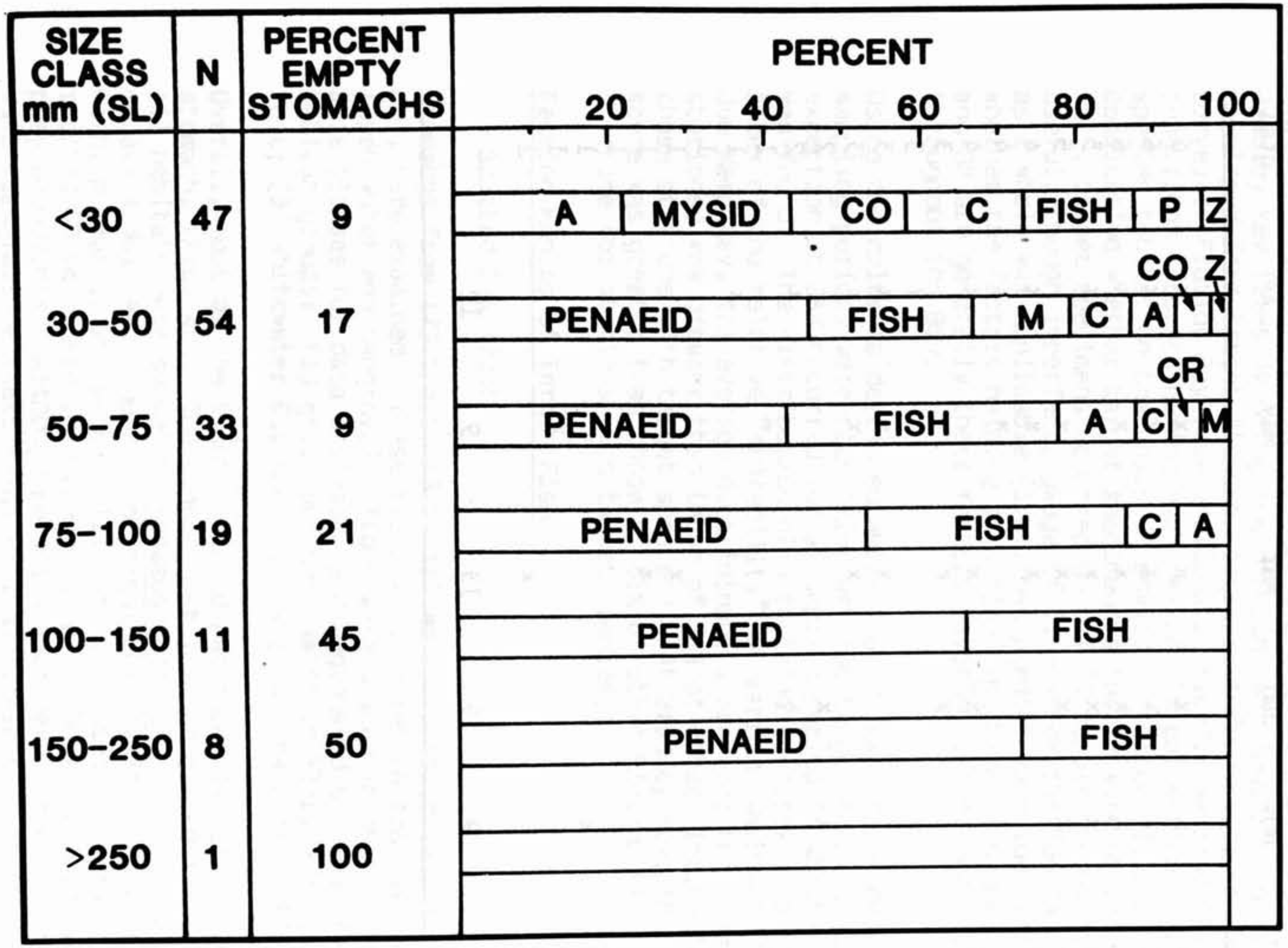


Figure 47. Percent occurrence of food items found in the stomachs of 173 spotted seatrout collected from all habitats in Everglades National Park. N = number of stomachs examined. Code: A = amphipod; C = caridean shrimp; CO = copepod; CR = crab; M = mysid; P = penaeid shrimp; Z = zoea/megalopa.

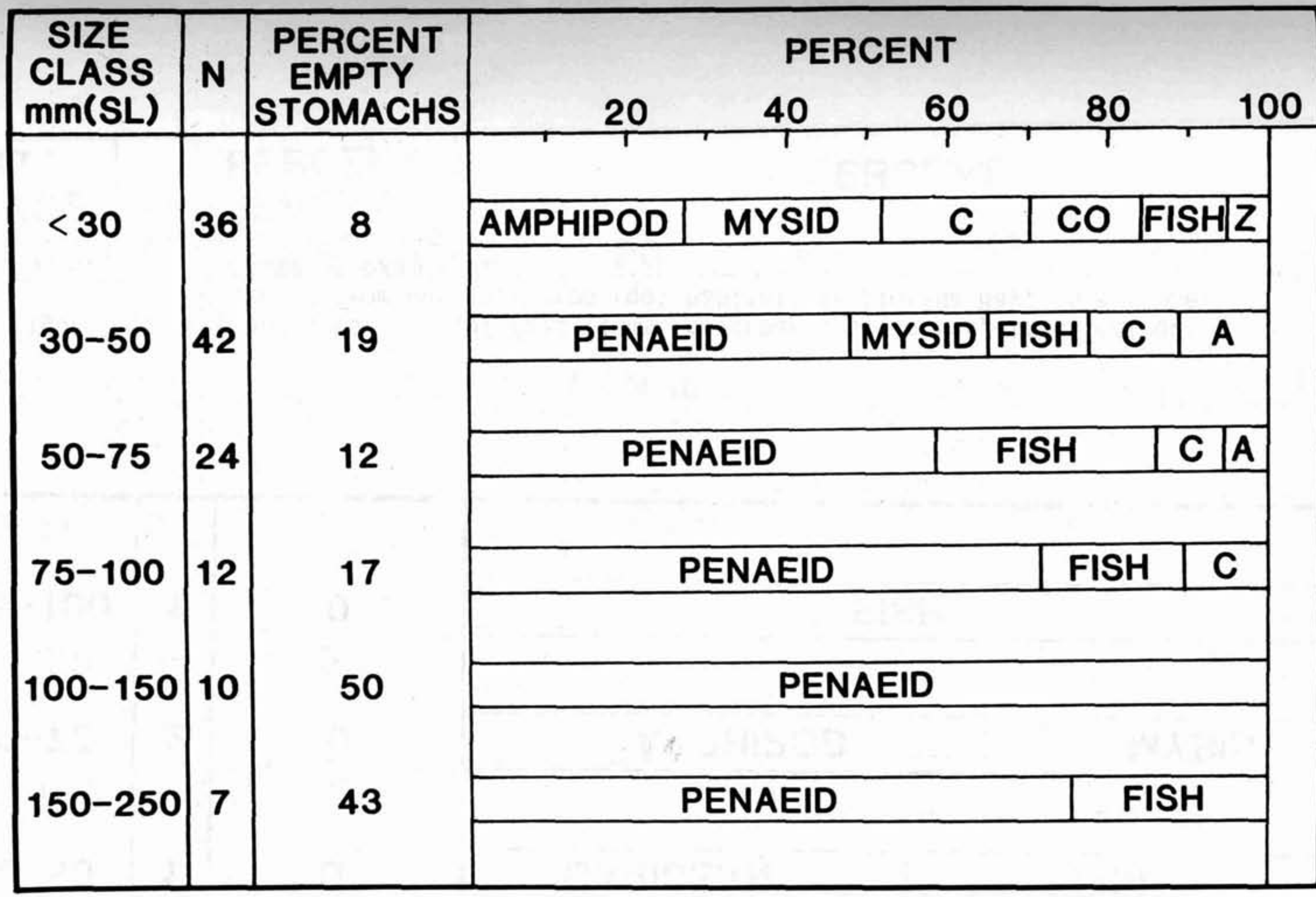


Figure 48. Percent occurrence of food items found in the stomach of 131 spotted seatrout collected from seagrass and open water habitats of Florida Bay. N = number of stomachs examined. Code: A = amphipod; C = caridean shrimp; Z = zoea/megalopa.

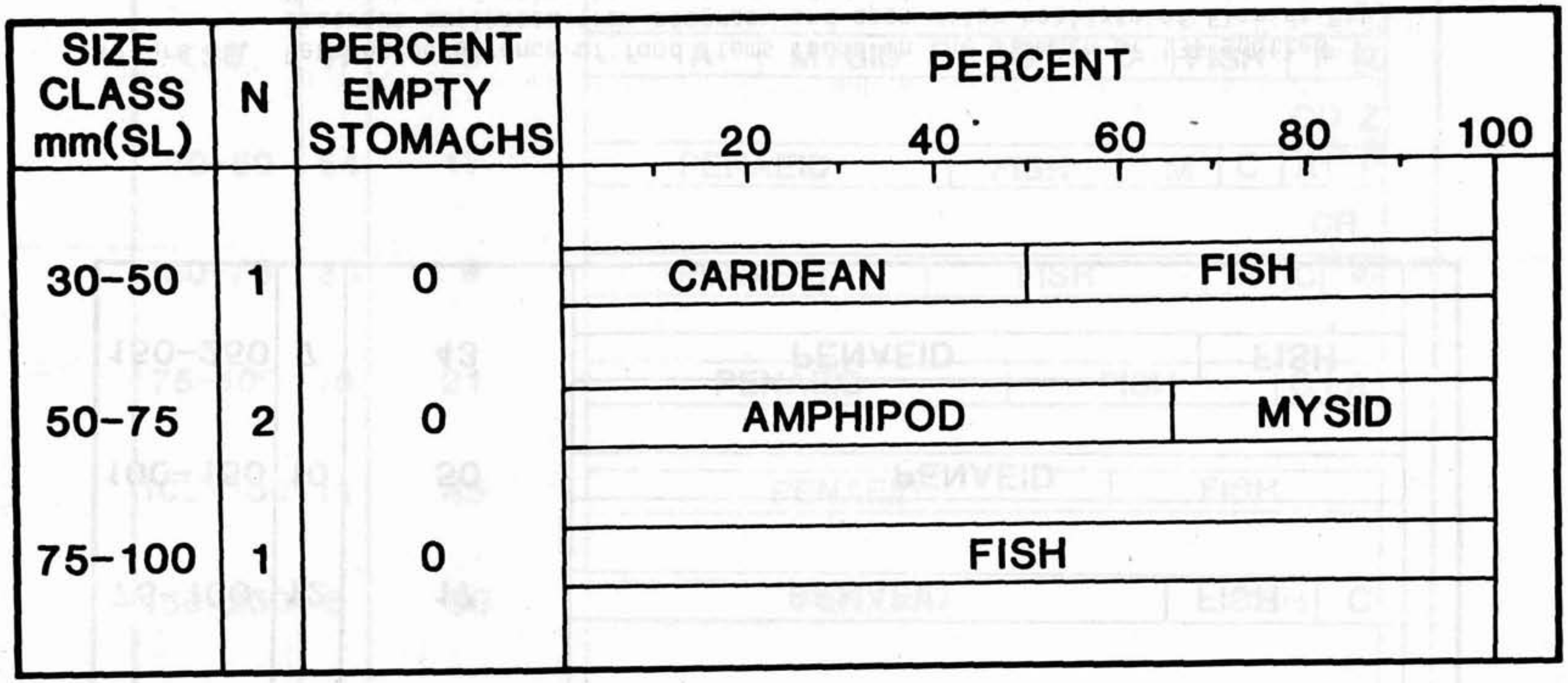


Figure 49. Percent occurrence of food items in stomachs of four spotted seatrout collected from mangrove prop root habitats in Florida Bay. N = number of stomachs examined.

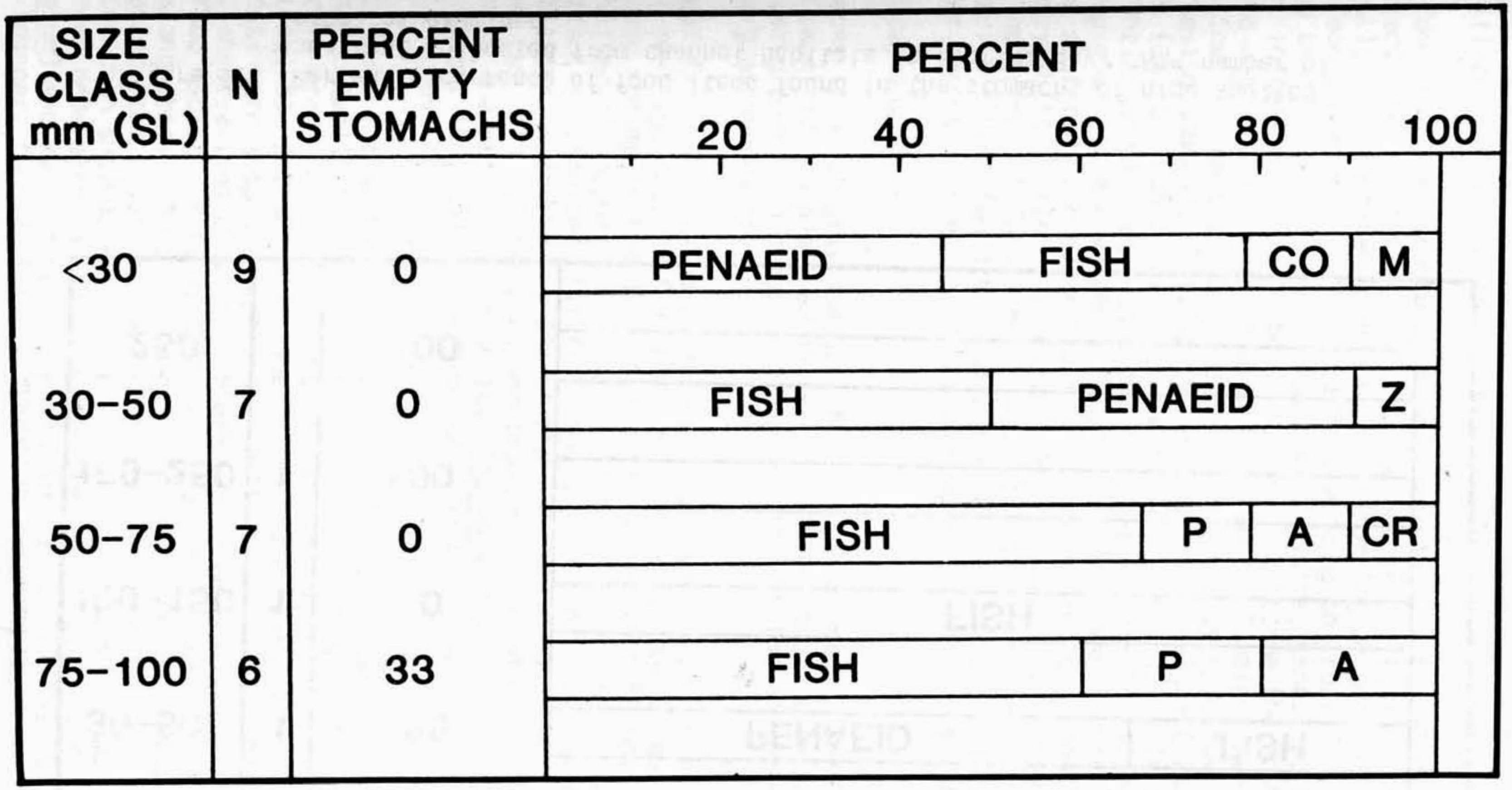


Figure 50. Percent occurrence of food items found in the stomachs of 29 spotted seatrout from Whitewater Bay and Coot Bay. N = number of stomachs examined. Code: A = emphipod; CO = copepod; CR = crab; M = mysid shrimp; P = penaeid; Z = zoea/megalopa.

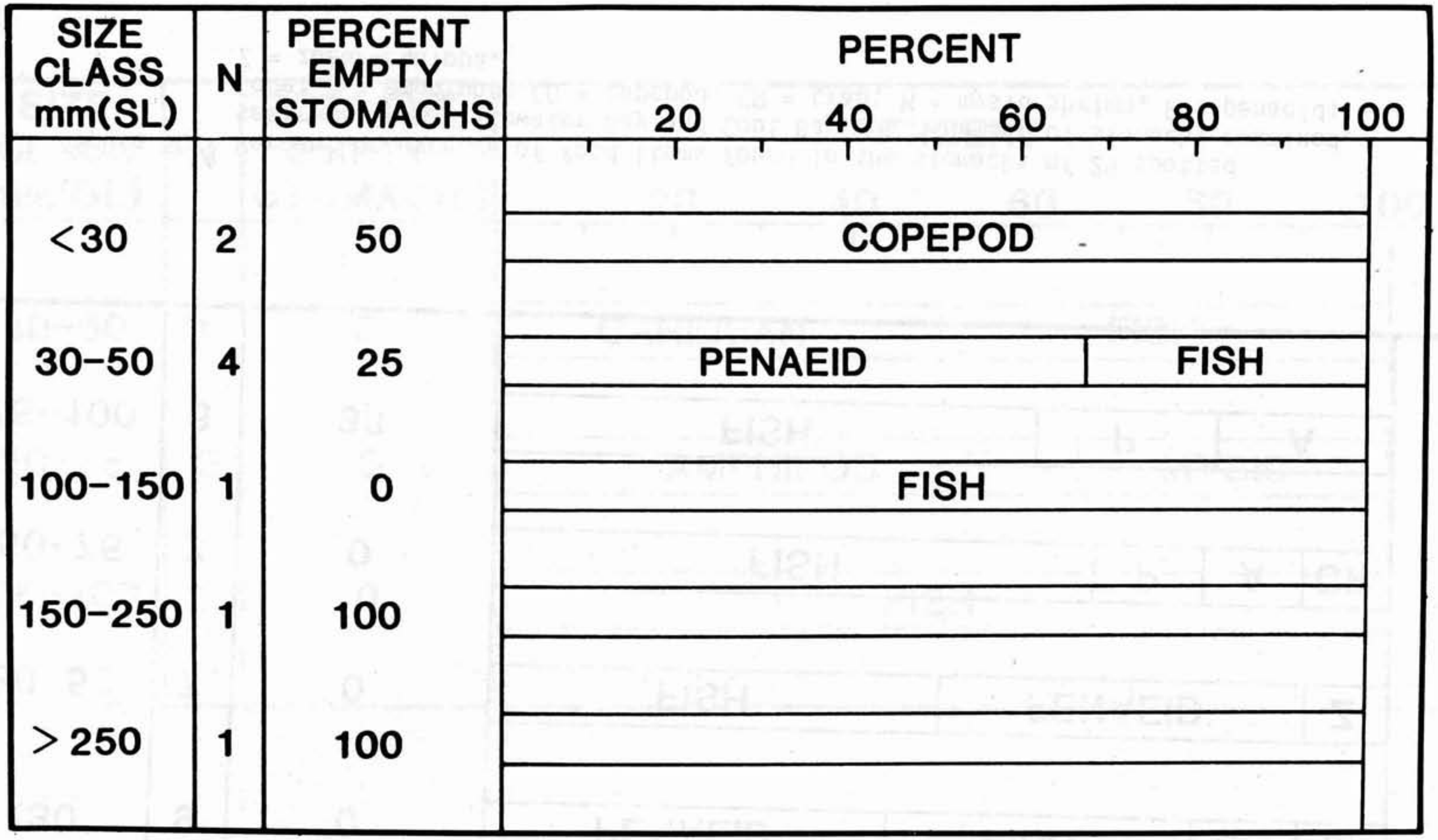


Figure 51. Percent occurrence of food items found in the stomachs of nine spotted seatrout collected from channel habitats in Florida Bay. N = number of stomachs examined.

related to a decrease in feeding frequency with increasing size. The four individuals captured in mangroves had food in their stomachs, suggest that this habitat provides food for trout although the small sample size precludes any significant conclusion regarding trout feeding in mangroves.

The food habits of spotted seatrout reported in this study are exactly as would be predicted from the literature. Perret et al. (1980) list eleven investigations between 1929 and 1975 reporting on spotted seatrout food types and food preferences. Moody (1950), working on trout from Cedar Key, Florida, found that juvenile trout ate copepods, mysids, penaeids, and carideans. As trout increased in size (above 250 mm) fish became the most important component of the diet. Rutherford et al. (1982) in the Flamingo area sampled 60 seatrout less than 271 mm and found the percent frequency of occurrence of prey to be, in decreasing abundance: shrimp (90%), fish (22%), algae (12%), molluscs (8%), crabs (3%) and other (3%). Large trout in their study (> 370 mm) consumed fish and shrimp equally in frequency, and consumed almost twice as much fish as shrimp when percent volume of stomach contents was compared. In our study, we never captured fish above 250 mm that contained food, and thus did not observe a dietary shift to fish. In Florida Bay, Stewart (1961) found that pink shrimp was the principal food item of adult trout. In general, several studies cited by Perret (1980) found that shrimp were more common in seatrout stomachs during summer than during winter; this corresponds to shrimp seasonal abundance.

Gray Snapper

Stomachs from 215 gray snapper, from 26 to 280 mm SL (107.9 mm mean length), were examined and analyzed in seven standard length size classes by three habitat groups. No snapper were examined from the Whitewater Bay/Coot Bay open water/grassbed habitat.

Snapper fed primarily on penaeid and caridean shrimp until they reached a length of 50 mm (Fig. 52). A food component of nearly equal importance to penaeid and caridean shrimp in the diet of snapper larger than 50 mm. Fish species identified in snapper stomachs included rainwater killifish, pipefish, gulf toadfish, goldspotted killifish, goby, seahorse, and silver jenny. Amphipods constituted approximately 20% of the occurrence observations in fish less then 50 mm, but on a volume basis amphipods contributed much less than 5% to the diet of small snapper. Plant material (*Thalassia* blades) appeared in stomachs of fish larger than 150 mm, perhaps as a result of aggressive feeding attacks on prey in grass beds.

As we found for spotted seatrout, the absence of penaeid shrimp in the diet was the major qualitative difference in the gut contents of the snapper taken from mangrove prop root habitats rather than from open water in Florida Bay (see part II) (Fig. 53, 54, and 55). The primary food items for fish from the mangrove habitats were isopods, amphipods, xanthid crabs, caridean shrimp and demersal fish, observations similar to Stark (1971) who carried out a detailed study of the food habits and feeding of gray snapper collected from grass meadows, coral reefs and areas adjacent to mangroves. He reported that small juveniles collected from seagrass areas consumed crustaceans (93%), primarily amphipods and caridean shrimp, while larger juveniles collected near mangroves and in seagrass beds also consumed crustaceans (69%), primarily pink shrimp (*Penaeus duorarum*) and xanthid crabs. Rutherford et al. (1983) reported that juvenile gray snapper, found mainly in grass-bed areas inshore, ate shrimp, crabs, and

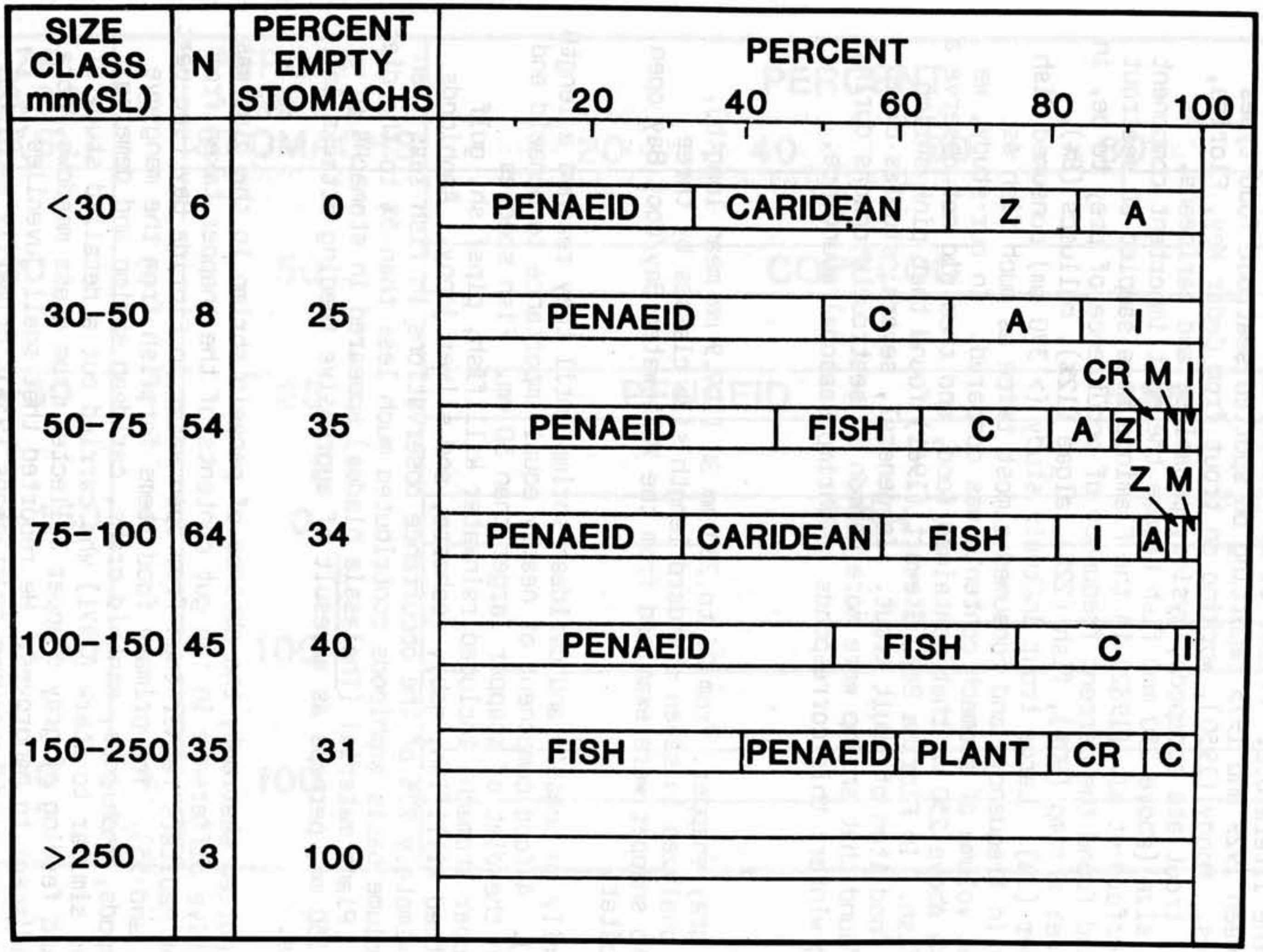


Figure 52. Percent occurrence of food items in the stomachs of 215 gray snapper from all habitats sampled in Everglades National Park. N = number of stomachs examined. Code: A = emphipod; C = caridean shrimp; CR = crab; I = isopod; M = mysid shrimp; Z = zoea/megalopa.

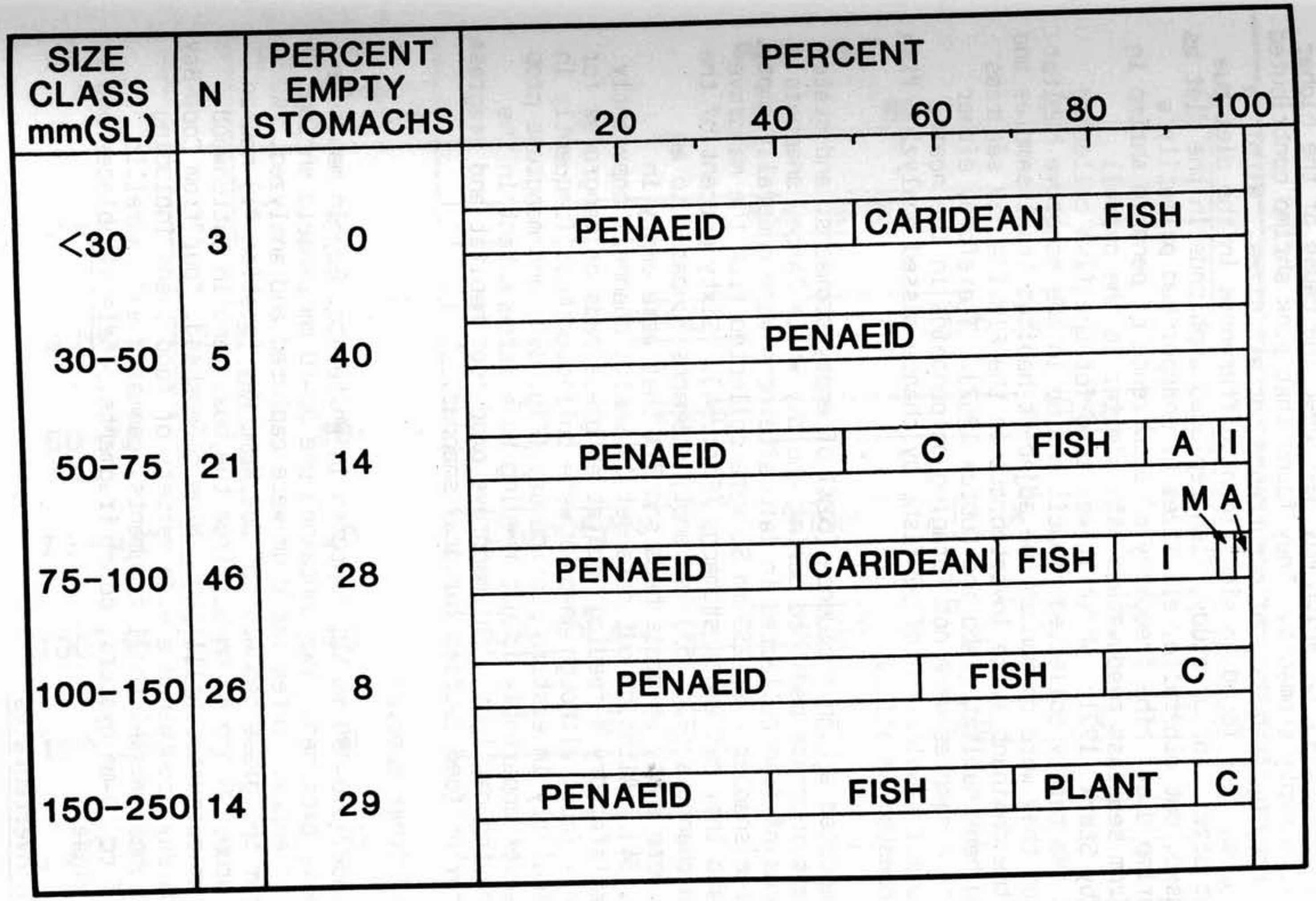


Figure 53. Percent occurrence of food items in the stomachs of 115 gray snapper collected from the open water seagrass habitat in Florida Bay. N = number of stomachs examined. Code: A = emphipod; C = caridean shrimp; I = isopod; M = mysid shrimp.

amphipods, while adults offshore ate mainly fish and shrimp. Sixty five percent of the snappers examined in our study contained food items compared with 42% found by Rutherford et al. (1983). Their fish stomachs were collected from sport fishermen catches at Flamingo which may have been the cause of the higher percentage of fish with empty stomachs. They found that pink shrimp contributed to about 77% of the prey by frequency of occurrence for all sizes. Within a particular fishing area, they found no significant differences in the diet due to season or snapper size. In our study, fish replaced amphipods in the diet as snapper size increased, but otherwise, all sizes of snapper had primarily a penaeid/caridean shrimp diet. The frequency of occurrence of penaeid shrimp in fish we collected from seagrass meadows was 34%, similar to the overall frequency reported by Stark (1971), while it was zero for the fish collected from the mangroves. We rarely collected penaeid shrimp in the mangrove habitat while rotenoning, but they were common in the adjacent habitat trawl samples and are reported to be the dominant large invertebrate in the Florida Bay seagrass meadow/carbonate mud bank habitat (Tabb and Dubrow 1962). Therefore, either snapper in our mangrove samples were not foraging on penaeids in the nearby grass beds, or the small sample size of 32 fish, by chance missed analyzing fish that had recently ingested penaeids.

Stark (1971) also reported a high incidence (52%) of empty stomachs, and stated that juvenile snappers in grass beds fed during the day while larger snappers fed at night; stomachs of fish collected in late afternoon were generally empty. In our study the three snapper over 250 mm SL were collected from the mangrove prop root habitat, and they had empty stomachs (Fig. 54). Sixty percent of the snapper collected in channels (Fig. 55) had empty stomachs compared to an average of 21% that were empty in grass beds and 31% that were empty in mangroves (Figs. 53, 54). Although our data set is small, channels apparently do not provide as satisfactory a feeding habitat as grass beds or mangroves for snapper under 250 mm. Thus, although snapper were collected most frequently in channel areas, particularly in eastern Florida Bay (Fig. 39), and mangrove prop root areas, this species apparently is not feeding to a large extent in the channels, at least during daylight. The mangrove prop root habitat and seagrass meadows appear to provide food sources for gray snapper.

Feeding Habits of Other Species

Stomachs of three snook, 370-390 mm SL, captured in Whitewater Bay in mangrove prop root habitats were examined. Two contained one 50-60 mm penaeid shrimp each and the third was empty. Three red drum were captured and analyzed. A 330-mm individual from the grass bed west of Joe Kemp Key (station #1) had an empty stomach. Two drum, 70 and 82 mm SL, from the boat ramp in Buttonwood Canal, contained 20-mm rainwater killifish. Nine sheepshead, four from Coot Bay and five from Florida Bay, contained a wide variety of food items including serpulid polychaete tubes, mussel shell fragments, gammarid and caprellid amphipods, isopods, 5 to 10-mm oysters, coral fragments, *Thalassia* blades and rhizomes, and brown algae.

Distribution of Macroinvertebrates

Four species of crustaceans that were collected by otter trawl from July 1984 through June 1985 were enumerated and weighed or measured: *Panulirus argus* (spiny lobster), *Callinectes ornatus* (ornate crab), *Callinectes sapidus* (blue

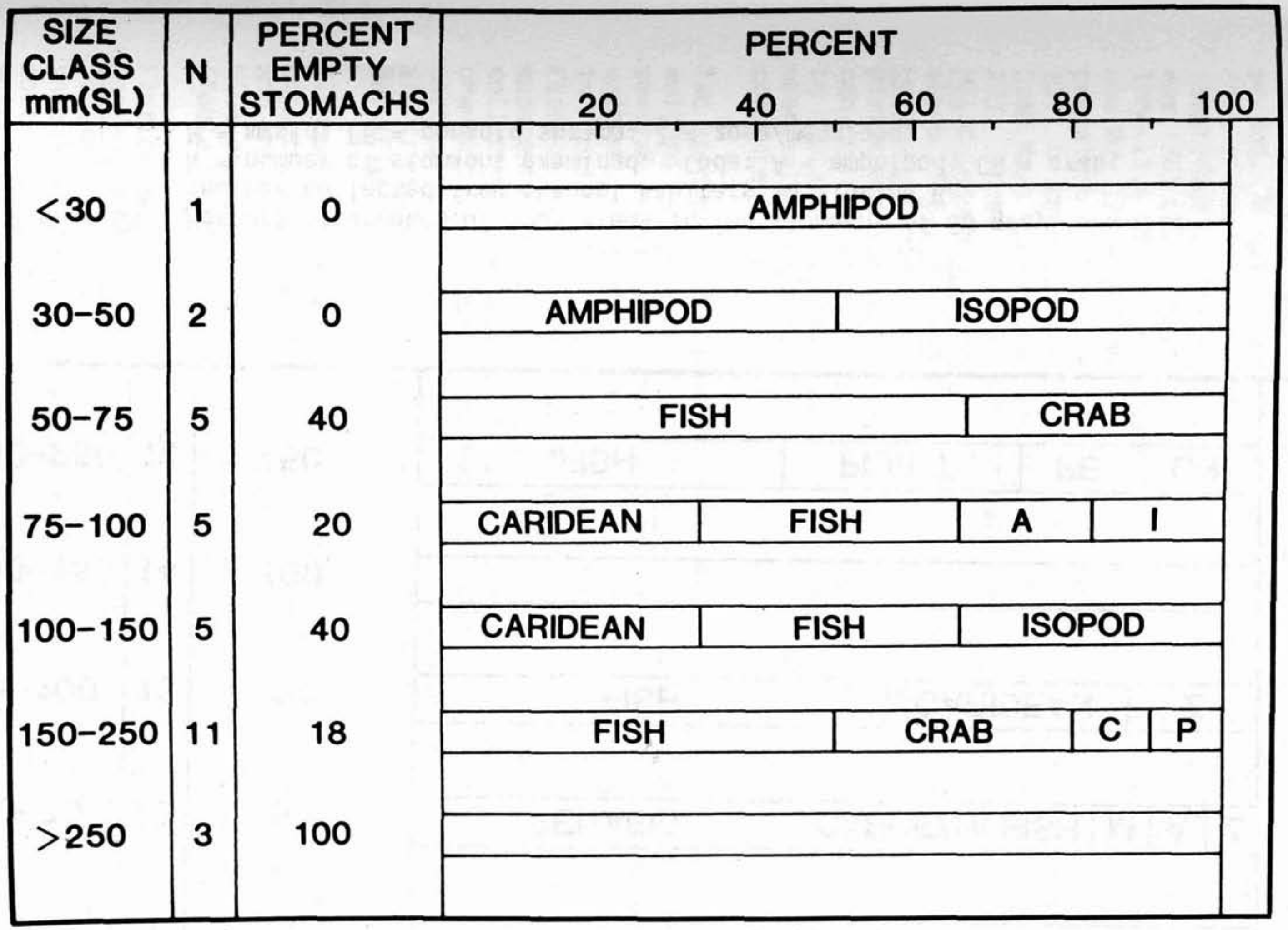


Figure 54. Percent occurrence of food items in the stomachs of 32 gray snapper collected from the mangrove prop root habitat in Everglades National Park. N = number of stomachs examined. Code: A = amphipod; CR = caridean shrimp; I = isopod; P = plant (Thalassia).

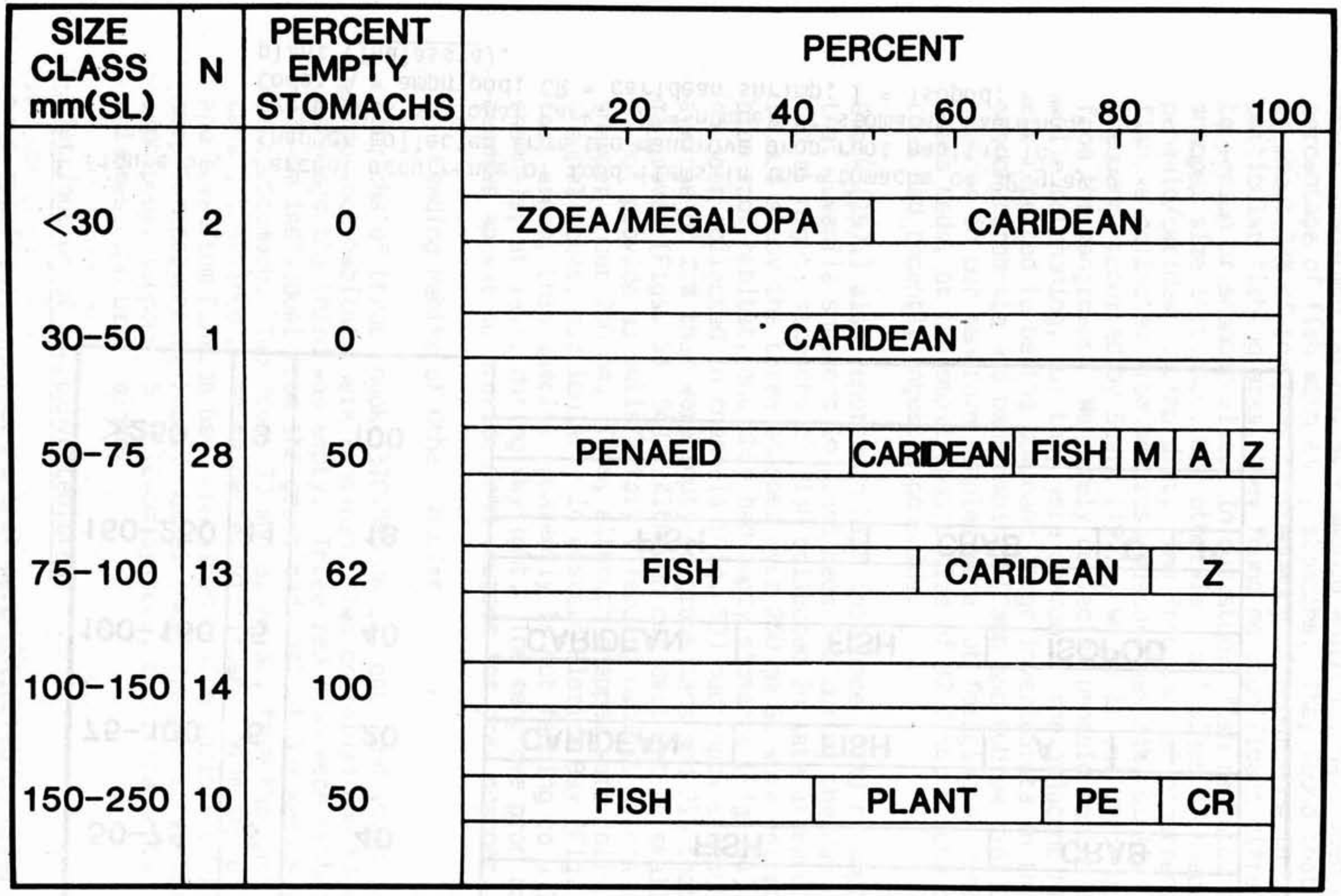


Figure 55. Percent occurrence of food items in the stomachs of 68 gray snapper collected from channel habitats in Florida Bay. N = number of stomachs examined. Code: A = amphipod; CR = crab; M = mysid; PE = penaeid shrimp; Z = zoea/megalopa.

crab), and Penaeus duorarum (pink shrimp). With the exception of C. ornatus, all are of both commercial and recreational importance, and in some instances fishermen do not make a distinction between the two Callinectes species.

Spiny lobsters were taken in five of the seven months of sampling between July 1984 and June 1985 (September, November, January, March and May). During this period, 76 spiny lobster were collected, measured and returned. Total length (tip of horns to tip of telson) ranged from 7.2 cm (March) to 27.5 cm (September). The majority of lobsters were collected in September 1984 (28) and May 1985 (25) (Table 22). Mean monthly individual lengths were: September 1984-13.4 cm; November 1984 - 16.2 cm; January 1985-18.5 cm; March 1985-11.0 cm; and May 1985-23.7 cm. Lobsters within the size captured by our gear were most prevalent (Table 22, Fig. 56) in channels along Twin Key Bank (Channel 21 and 23), in channels cutting through carbonate mud banks between Panhandle Key and Crab Keys (Channel 40 and 34), and in a channel between Bob Allen Keys (Channel 27). These channels are dominated by Thalassia with mixtures of Halodule or Halodule and Syringodium (Fig. 19). One spiny lobster was taken from a pure stand of Syringodium in Man of War Channel (Channel 7) and two from a Halodule-dominated channel (Channel 33), but in general there appeared to be no preference for particular seagrass species. Twenty specimens were taken in non-channel samples, one immediately adjacent to Twin Key Bank and 19 adjacent to Captain Key (Table 22). Both areas are almost pure Thalassia meadows. Our observation of lobsters preferring channel areas to open seagrass meadows is consistent with Hudson et al. (1970).

Two species of callinectid crabs were collected, returned to the laboratory and weighed wet: the ornate crab (C. ornatus) and blue crab (C. sapidus). In several instances, large crabs of the species were returned to the water and not weighed. The ornate crab was most numerous (76 taken), and was collected only in Florida Bay (Fig. 57), whereas blue crabs (35 collected) were present in Florida Bay, Coot Bay and Whitewater Bay (Figs. 57 and 58). C. ornatus apparently moves into shallow waters of the Park during summer since it was collected only from May through September (Table 23). Although collected in channels, this species appeared to prefer seagrass meadows (Table 23), particularly those in the vicinity of Bradley and Joe Kemp Key and those in an arc transcribed by Cross Bank, Whipray Keys and Panhandle Key in eastern Florida Bay (Fig. 57).

Although collected throughout the year, the majority (46%) of blue crabs were collected in July 1984 (Table 24). Only four blue crabs were taken in Coot Bay and Whitewater Bay (Fig. 58) and most were from Halodule beds. In Florida Bay, blue crabs were taken by otter trawl in both channels and seagrass meadows (Table 24, Fig. 57), but never were abundant.

Florida Bay is considered the primary nursery area for juvenile pink shrimp, Penaeus duorarum, which enter the Tortugas shrimp fishery (Allen et al. 1980, Schomer and Drew 1982, and references cited therein). Pink shrimp were present in collections in every sample month between July 1984 and June 1985, and were collected in seagrass beds and channels in Florida Bay, in Coot Bay and in Whitewater Bay (Table 25). In both Coot Bay and Whitewater Bay shrimp were most frequently collected from vegetated areas (Fig. 58). In neither area, however, were shrimp abundant within our trawl catches, never exceeding $20 \cdot trawl^{-1}$. Pink shrimp were collected throughout Florida Bay and generally in low numbers at any station; they were in samples at 27 different seagrass and 17 different channel

Table 22. Numbers and size range (measured from tip of horn to tip of telson) of lobster, Panulirus argus, collected from September 1984 through June 1985 in Florida Bay. See Figures 5, 6, and 59 for station locations.

STATION	DATE	NUMBER	SIZE RANGE (cm)
Channel 7	Mar 84	1	18.0
Channel 8	Nov 84	1	16.0
Channel 21	Jan 85	1	21.0
Channel 22	May 85	2	6.5 -11.5
Channel 23	Sep 84	4	11.0 - 27.5
Channel 23	Nov 84	4	10.7 - 26.6
Channel 23	May 85	3	8.7 - 26.0
Channel 27	Mar 85	9	6.6 - 20.0
Channel 33	Nov 84	2	14.6 - 15.1
Channel 34	Sep 84	5	15.0 - 18.0
Channel 34	May 85	6	9.20 - 20.
Channel 35	Sep 84	1	12.5
Channel 40	Nov 84	6	12.8 - 17.4
Channel 40	Jan 85	1	16.0
Channel 40	May 85	7	12.0 - 17.1
Channel 44	May 85	3	16.0 - 23.5
20-7	Sep 84	1	10.0
Captain Key	Sep 84	13	8.5 - 13.5
Captain Key	May 85	6	8.0 - 13.2
		76	

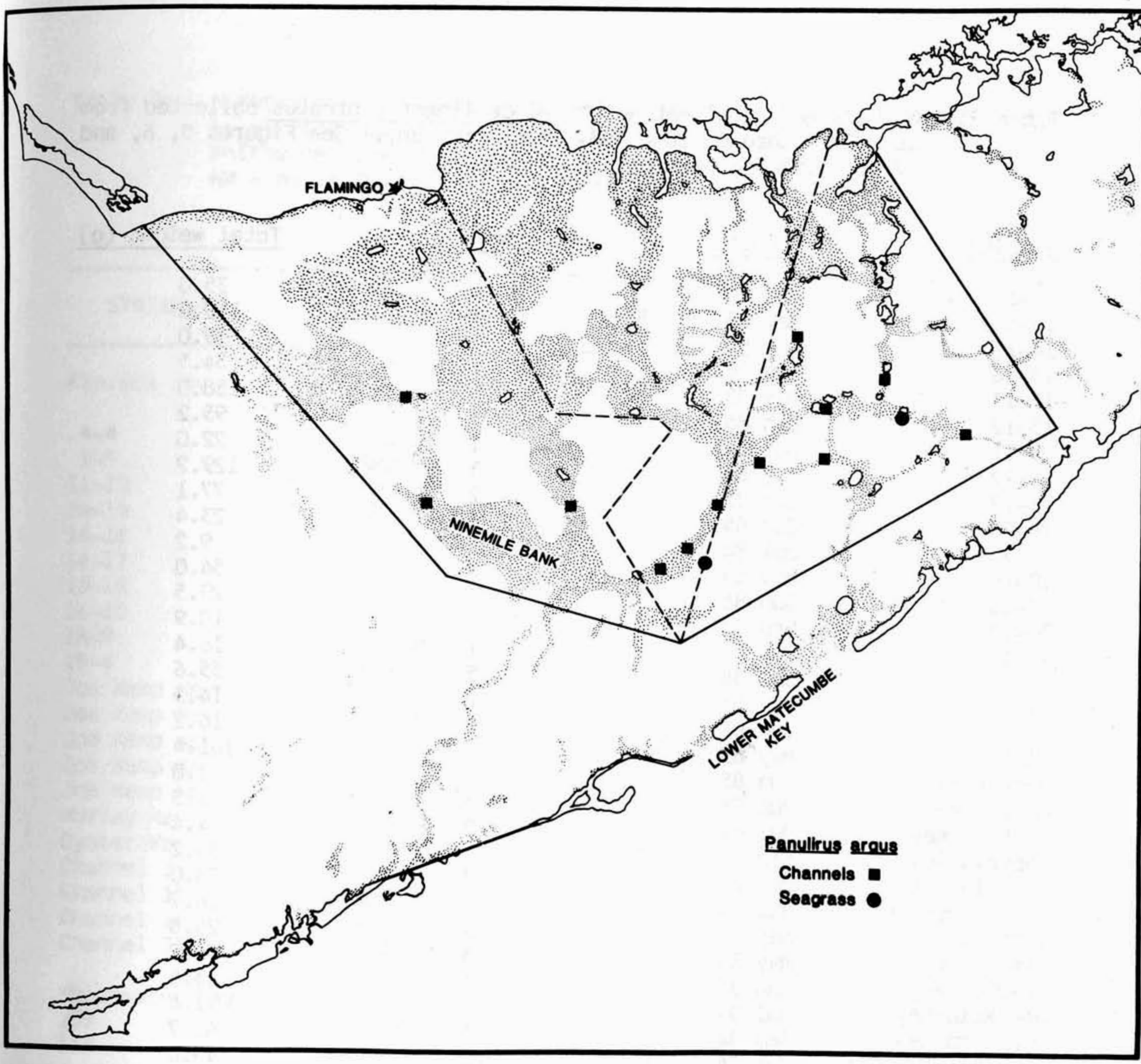


Figure 56. Distribution of spiny lobster collected in Florida Bay.

Table 23. Numbers and total wet weight of Callinectes ornatus collected from July 1984 through June 1985 in Florida Bay. See Figures 5, 6, and 59 for station locations.

Station	Date	Number	Total weight (g)
5-6	Jun 85	1	35.0
10-4	May 85	2	119.0
14-17	Jun 85	1	39.0
15-16	Sep 84	1	54.5
15-13	May 85	5	188.0
15-12	Jun 85	3	95.2
15-11	Jul 85	1	22.0
16-17	May 85	3	129.2
16-17	Jun 85	2	77.1
16-10	Jun 85	1	23.4
18-9	Jul 84	1	9.2
18-16	May 85	2	54.0
19-16	Jun 85	1	29.5
20-12	Sep 84	2	10.9
20-14	May 85	1	16.4
21-12	Jul 84	5	55.6
21-15	May 85	2	14.5
21-15	Jun 85	2	16.2
23-18	May 85	4	161.4
Oyster Key	Jun 85	1	1.0
Murray Key	Jun 85	3	4.5
Captain Key	Jul 84	2	24.4
Captain Key	Sep 84	1	35.2
Captain Key	Jun 84	7	78.0
Crane Key	Jul 84	1	16.7
Crane Key	May 84	2	25.8
Bradley Key	May 85	3	76.2
Bradley Key	Jun 85	1	13.8
Joe Kemp Key	Jul 84	2	71.4
Joe Kemp Key	Sep 84	1	61.7
Channel 32	Jul 84	2	43.0
Channel 32	Jun 85	3	140.5
Channel 35	Sep 84	1	18.1
Channel 41	Sep 84	1	13.8
Channel 41	Jun 85	1	6.8
Channel 22	Jun 85	1	1.0
Channel 38	Jun 85	3	151.9
	TOTAL	= 76	

Table 24. Numbers and total wet weight of Callinectes sapidus collected by otter trawl from July 1984 through June 1985 in Florida Bay, Coot Bay and Whitewater Bay. See Figures 2,3,5 and 6 for station locations. NW = no weight measurement taken.

STATION	DATE	NUMBER	TOTAL WEIGHT (g)
Florida Bay			
4-4	Sep 84	1	143.7
5-9	Sep 84	1	NW
11-10	Sep 84	1	66.5
14-15	Jul 84	1	136.4
14-16	Jul 84	1	68.3
14-17	Sep 84	2	NW
15-16	Jul 84	1	103.6
16-10	Sep 84	1	NW
18-9	Jul 84	2	181.2
19-4	Sep 84	1	71.8
Joe Kemp Key	Jul 84	3	475.2
Joe Kemp Key	Sep 84	1	67.0
Joe Kemp Key	Nov 84	1	NW
Joe Kemp Key	Jan 85	2	1.9
Joe Kemp Key	Mar 85	3	NW
Murray Key	Nov 84	1	0.1
Oyster Key	Jul 84	1	148.5
Channel 32	Jul 84	1	21.0
Channel 12	Jul 84	2	143.6
Channel 14	Nov 84	2	NW
Channel 33	Nov 84	1	NW
Whitewater Bay			
139	Jul 84	1	95.0
155	Nov 84	1	NW
Coot Bay			
32	Jul 84	1	261.7
65	Nov 84	1	NW
	TOTAL	=34	

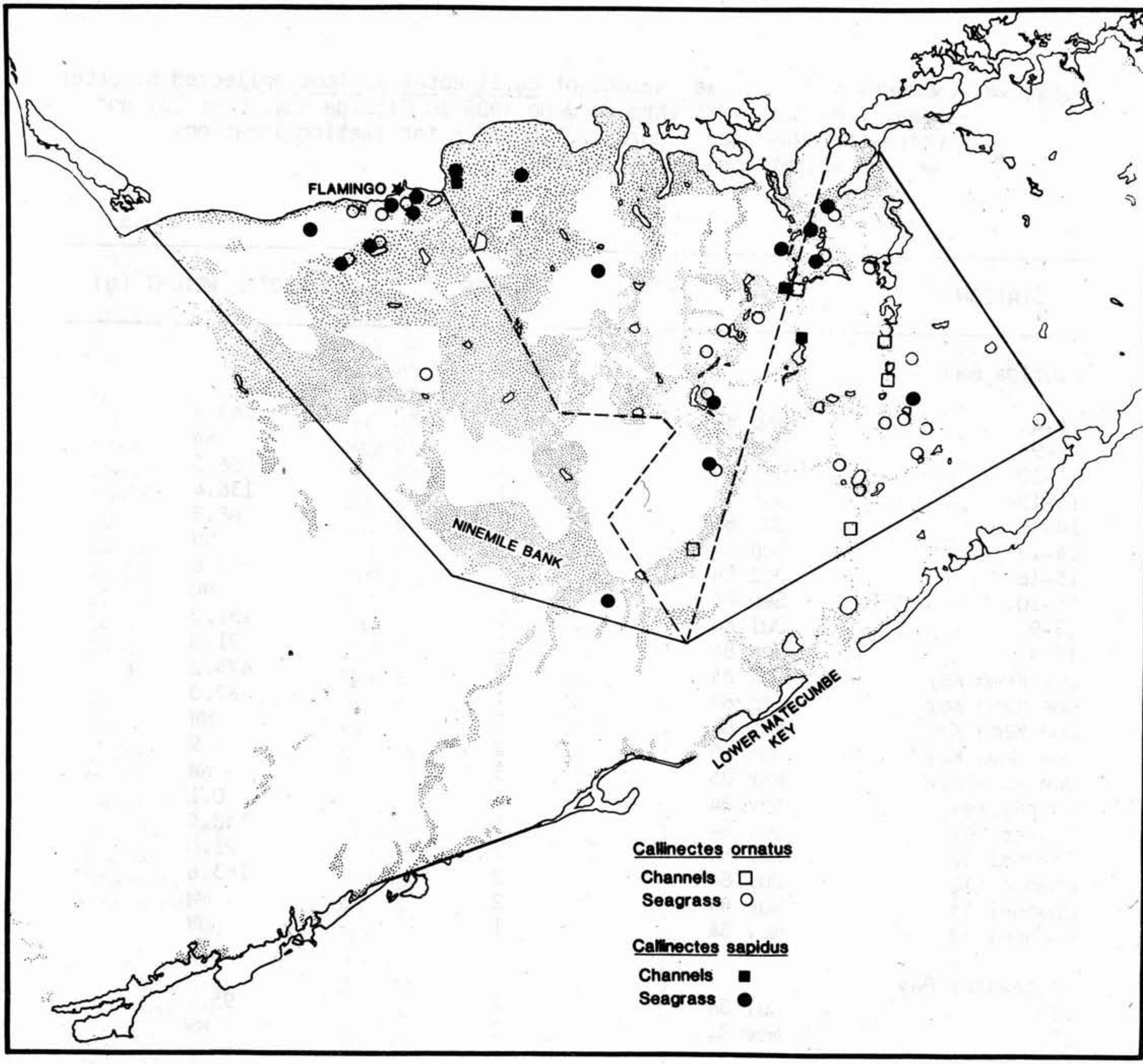


Figure 57. Distribution of ornate crabs and blue crabs collected in Florida Bay.

sites for the stratified random sampling effort (Table 25). They also were taken in trawls made at Joe Kemp Key, Bradley Key, Murray Key, Oyster Key, Captain Key and Crane Key (Table 25). Shrimp were present in Thalassia, Syringodium, Halodule and mixed species meadows, and appeared most abundant at the stratified sample stations in November and March. A relatively large number ($126 \cdot trawl^{-1}$), however, were collected in September 1984 from a pure stand of Halodule in Snake Bight (Station 5-9) (Table 25). Pink shrimp were relatively abundant during all of our routine sampling at Joe Kemp Key #1 and Bradley Key, but they displayed somewhat different trends in seasonal abundance (Table 25). At Joe Kemp Key #1, pink shrimp abundance was maximum in January and March, while at Bradley Key it was maximum in March and May. During 1981-1983, Park Service personnel sampling for shrimp at Joe Kemp Key generally observed peaks in May-June and October-November, rather than during winter as we observed (Table 26).

Overall, pink shrimp in the area we sampled displayed a unimodal distribution in abundance and a bimodal distribution in mean individual length and wet weight. When data from all samples were combined, pink shrimp abundance was observed to be maximum in January and March 1985 (Table 26). This trend is not dissimilar to trends at some stations observed by Park personnel (M. Robblee, ENP, pers. comm.). Estimates of mean individual wet weight and total length, however, displayed bimodal distributions with peaks in November 1984 and March 1985 but a depression of values during an intermediate sampling in January 1985 (Table 26). Allen et al. (1980) also noted a bimodal distribution in abundances of 16-25 mm total length pink shrimp at permanent stations in Florida Bay and the Florida Keys. The observed peaks in this size class occurred in August and November, data points which are 3 months and 4 months earlier than those we observed for 60 and 65 mm (TL) shrimp, respectively (Table 26). It is possible that the 16-25 mm shrimp captured in August and the 60 mm shrimp captured in November are the same cohorts. Likewise, the November 16-25 mm shrimp and 65 mm March shrimp also may be cohorts. If we assume that the shrimp we collected in November and March, were around 15 mm (TL) during the preceeding August and November, respectively, this would imply an average growth rate of about 15 mm per month. This agrees with Eldred et al. (1961) who showed a 15-20 mm monthly growth rate for pink shrimp in Florida waters.

II. FISH COMMUNITIES UTILIZING RED MANGROVE PROP ROOT HABITATS

Mangroves dominate the shorelines of south Florida, constituting an estimated 174,000-202,400 hectares (430,000 to 500,000 acres) of estuarine and coastal habitat (Odum et al. 1982). Fringing forests of red mangroves, Rhizophora mangle, dominate the outer perimeter of protected shorelines and islands (Lugo and Snedaker 1974). The red mangroves that predominate in this fringe habitat have a well-developed prop root system that is flooded semidiurnally by tides and may provide habitat to fishes.

In recent years there has been an increasing recognition of the general importance of the fringing red mangrove habitat to estuarine-dependent fishes (e.g., Heald 1969, Odum 1970, Carter et al. 1973, Lugo and Snedaker 1974, Odum and Heald 1975, Yokel 1975, Weinstein et al. 1977, Odum et al. 1982). By-and-large, the emphasis has been on the detrital contribution of the mangroves to estuaries and to fishes. Mangrove leaves are a primary source of plant detritus in subtropical-tropical systems, and in certain systems many

Table 25. Numbers, total wet weight and average length (measured from rostrum to end of telson) of Penaeus duorarum collected by otter trawl in Florida Bay, Coot Bay and Whitewater Bay from July 1984 through June 1985. See Figures 6, 8, and 59 for station locations.

Station	Date	Number	$\bar{x}$ length (mm)	Total weight (g)
Florida Bay				
3-2	Nov 84	12	68	32.0
5-2	Jul 84	3	47	2.1
5-9	Sep 84	126	50	125.4
5-6	Mar 85	135	67	216.0
5-6	May 85	9	73	25.5
5-6	Jun 85	7	92	30.8
6-2	Sep 84	5	72	14.5
6-2	Jan 85	1	68	2.1
6-3	May 85	12	41	5.7
6-4	Jun 85	2	74	4.1
6-6	Mar 85	124	68	237.6
6-8	Jun 85	6	57	9.5
7-3	Nov 85	30	75	82.3
8-10	Jun 85	4	61	7.0
9-1	Mar 85	3	54	2.8
9-2	Mar 85	1	49	0.7
9-4	Sep 84	4	94	26.0
10-4	May 85	2	41	0.6
10-9	May 85	2	59	3.1
11-1	Jun 85	1	50	1.0
14-9	Nov 84	1	106	8.7
14-13	Jun 85	1	142	19.4
14-16	Mar 85	2	51	2.1
15-9	Sep 85	3	66	9.4
15-12	Jun 85	1	110	7.8
16-1	Sep 85	1	89	4.8
16-10	Sep 85	1	92	5.2
17-11	Nov 84	1	65	1.4
18-16	May 85	1	78	3.0
19-5	Jan 85	4	81	16.2
22-10	Sep 84	1	62	1.5
Joe Kemp Key #1	Jul 84	15	45	16.2
Joe Kemp Key #1	Sep 84	8	50	4.6
Joe Kemp Key #1	Nov 84	46	62	64.5
Joe Kemp Key #1	Jan 85	396	50	255.5
Joe Kemp Key #1	Mar 85	255	66	345.8
Joe Kemp Key #1	May 85	33	61	58.5
Joe Kemp Key #1	Jun 85	14	52	15.8
Joe Kemp Key #2	May 85	30	70	90.0
Joe Kemp Key #3	Jul 84	35	40	20.2
Joe Kemp Key #4	Sep 84	87	51	47.5
Joe Kemp Key #5	Nov 84	60	66	50.0
Joe Kemp Key #5	Jan 85	224	50	183.3
Joe Kemp Key #5	Jun 85	22	50	22.0

Table 25 (Contd).

Station	Date	Number	$\bar{x}$ length (mm)	Total weight (g)
Bradley Key	Sep 84	59	53	66.5
Bradley Key	Nov 84	16	58	22.0
Bradley Key	Jan 85	1	98	6.0
Bradley Key	Mar 85	313	60	383.9
Bradley Key	May 85	228	44	130.6
Bradley Key	Jun 85	130	50	105.6
Murray Key	Jul 84	28	48	21.1
Murray Key	Nov 84	1	37	0.3
Murray Key	Jan 85	13	47	7.1
Murray Key	Mar 85	10	38	3.5
Murray Key	May 85	20	45	10.9
Oyster Key	Jul 84	12	48	11.4
Oyster Key	Sep 84	77	55	56.5
Oyster Key	Nov 84	3	39	1.0
Oyster Key	Jan 85	10	45	7.3
Oyster Key	Mar 85	8	61	14.0
Oyster Key	May 85	16	59	13.8
Crane Key	Jun 85	50	41	24.2
Captains Key	Nov 84	1	57	1.1
Captains Key	Jun 85	1	63	1.7
Channel 7	Nov 84	35	60	36.5
Channel 7	Mar 85	1	66	1.7
Channel 8	Nov 84	5	49	4.2
Channel 8	Jun 85	4	44	2.2
Channel 9	Jul 84	1	44	0.4
Channel 12	Jul 84	5	40	2.3
Channel 13	Mar 85	4	66	6.4
Channel 14	Nov 84	115	50	102.8
Channel 16	Mar 85	96	66	146.8
Channel 21	Jan 85	1	127	12.6
Channel 22	Jun 85	1	35	0.4
Channel 23	Jul 84	2	58	2.5
Channel 23	Sep 84	3	64	6.6
Channel 23	Nov 84	5	67	6.9
Channel 27	Mar 85	19	62	30.8
Channel 29	Jan 85	4	82	18.0
Channel 31	Jun 85	5	109	43.8
Channel 37	Mar 85	38	72	61.8
Channel 38	Jun 85	3	38	0.9
Channel 40	Jan 85	1	90	4.3
Channel 40	May 85	1	71	2.3
Channel 41	Jun 85	1	63	1.3

Table 26. Total number and wet weight of <u>Penaeus duorarum</u> and weighted individual mean wet weights and lengths. Data are for shrimp collected from July 1984 through June 1985 in Florida Bay, Coot Bay and Whitewater Bay using an otter trawl. Values in parentheses represent the number of stations at which penaeid shrimp were collected.

Month	Number	Wet weight (g)	Mean Weighted Individual Weight (g)	Mean Weighted Individual Length (mm)
Jul 1984 (9)	102	84.8	0.83	46
Sep 1984 (17)	389	384.9	0.99	53
Nov 1984 (22)	364	489.2	1.34	60
Jan 1985 (14)	662	534.5	0.81	51
Mar 1985 (21)	1057	1783.8	1.68	65
May 1985 (13)	326	348.4	1.07	54
Jun 1985 (22)	265	305.2	1.15	51

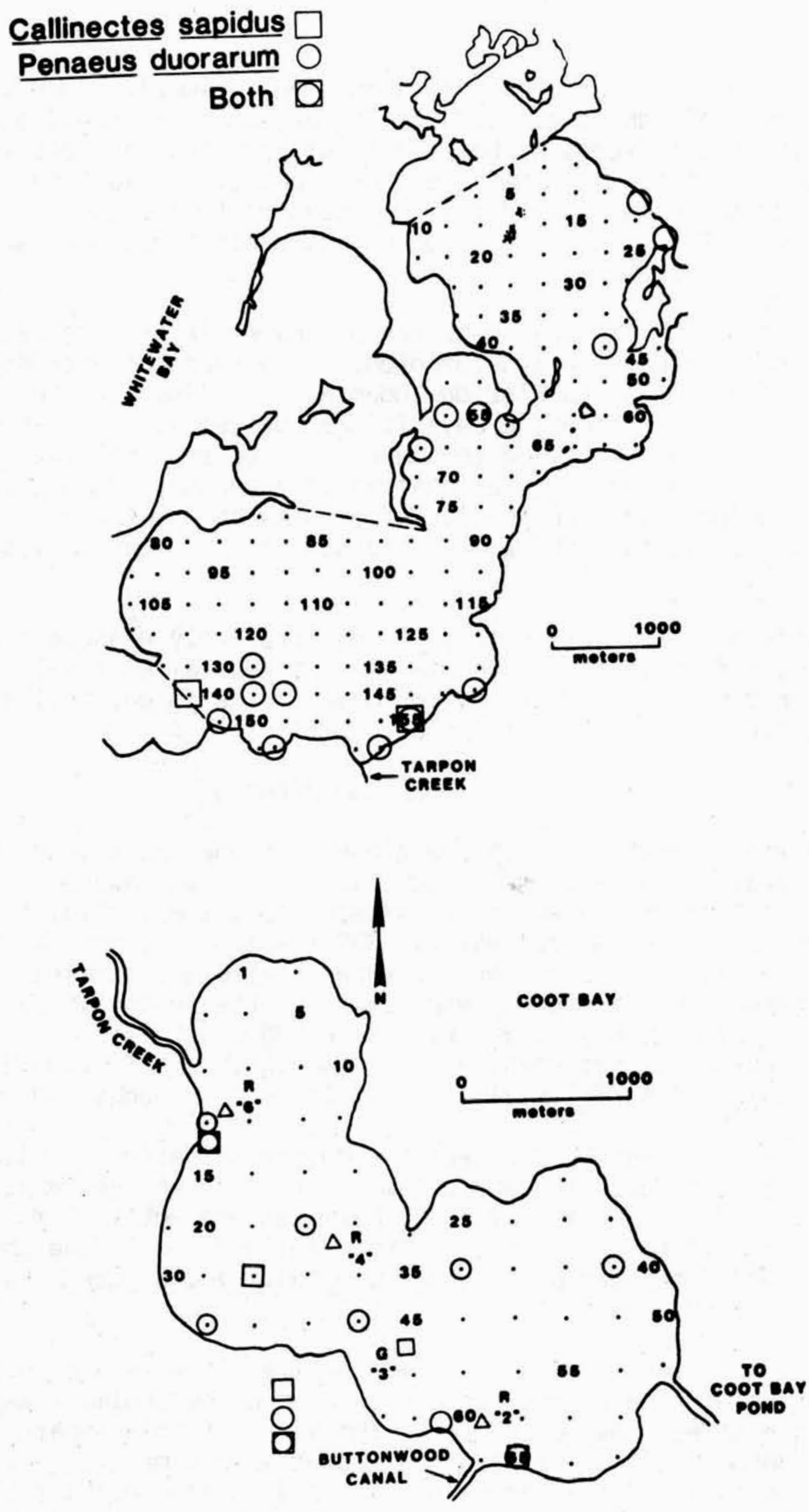


Figure 58. Distribution of blue crabs and penaeid shrimp in eastern Whitewater Bay (upper) and Coot Bay (lower).

consumers appear to depend primarily on mangrove-derived detrital carbon as an energy source (Zieman et al. 1984). The presence of decaying plant matter and invertebrate detritivores probably provide rich food sources for foraging fishes, but quantitative data on energy transfer are lacking. Since dense aquatic vegetation can interfer with predators (e.g., Boesch and Turner 1984, Orth et al. 1984), the mangrove prop root habitat also may serve as a refuge for fish and invertebrates.

The use of fringing mangrove habitats by commercial and recreational fishery organisms has not been well documented. In a recent review of the ecology of mangrove systems in south Florida, Odum et al. (1982) pointed out that while fish communities of estuarine bays fringed by red mangroves have been sampled and described, fish utilizing the mangrove prop root habitat have not been quantitatively sampled. Visual observations abound, but quantitative data are lacking. Undoubtedly, the paucity of information on the mangrove habitat has been partly due to the inherent difficulty in quantitatively sampling this habitat type.

The objectives of this study were to quantitatively measure the fish communities utilizing the fringing red mangrove habitat over a relatively broad area; and compare these fish communities with those in the immediately adjacent habitat characterized by rooted aquatic plants.

AREA AND METHODS

Our study was conducted within Everglades National Park in south Florida. Eight permanent stations were established, two each in Whitewater Bay, Coot Bay, northwestern Florida Bay and southeastern Florida Bay (Fig. 59). Whitewater Bay stations were located approximately 1000 m apart in a northeastern embayment near East River. Coot Bay stations were located approximately 1800 m apart between Tarpon Creek and Buttonwood Canal on the southwestern shore. In northwestern Florida Bay, sites were selected about 1500 m apart on the shores of Murray Key and Oyster Keys, while in southeastern Florida Bay stations were chosen on the shores of Captain Key and Crane Key, about 3000 m apart.

We used several criteria to select the mangrove stations. All stations were intertidal to subtidal with about 1 m water depth at the leading edge of mangrove prop roots at high tide. A berm was present 5-10 m shoreward of this leading edge, and the prop root habitat continued up to the shoreline. The sites were all dominated by _Rhizophora mangle_, and adjacent to each area were seagrass habitats.

In March 1984, areas were selected and sample sites were prepared. Pipes (2.5-cm diameter, 2.8-m long) were driven into the sediment 4-8 m apart at the leading edge of each mangrove area. The width of this separation was dictated by the expanse of prop roots issuing from a single mangrove clump. Next, a 0.5 m path was cleared to the berm from each stake perpendicular to the shoreline. This activity entailed cutting prop roots to the sediment surface as well as removing some overhanging limbs so that a net could be positioned to prevent ingress and egress of fish. The data reported are for eight sample periods between May 1984 and May 1985.

All sampling was carried out during daylight at high tide $\pm$ 2 h using the following procedure. In each instance, a 32 m x 2 m net with 3-mm mesh was

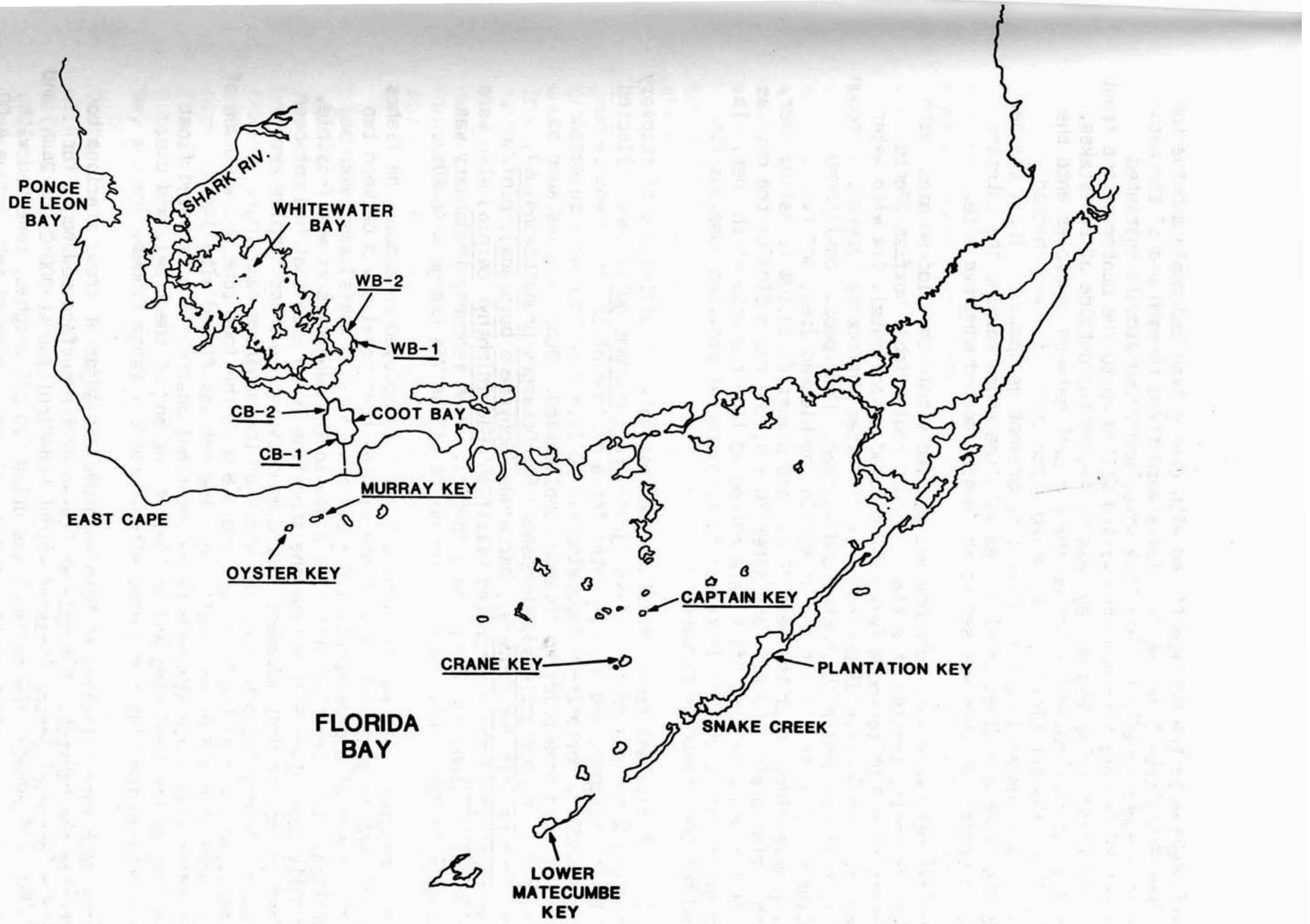


Figure 59. Diagram of Florida Bay and adjacent area showing the location of mangrove sample sites in Whitewater Bay, Coot Bay, northwestern Florida Bay and southeastern Florida Bay (underscored).

used. The bottom of the net was fitted with 6-mm galvanized chain and the top of the net with a cork line; wooden staffs were fixed to each end of the net. Boats were brought to within 5 m of the site, and 2 individuals initiated deployment of the net. The net was carried rolled up to the center of the front stakes, unfurled, and spread out by passing around the outside of the stakes. Each individual then moved the net up the cut path between mangroves onto the shore, pulling the net tight as they moved. The chain line was checked immediately and pushed into the sediment to prevent escapement. Thus, the net blocked the front and sides of each area with the shore forming the interior border. A second net then was set at the nearby second mangrove site.

Once the two nets were set, rotenone was applied within the blocked area, with only one site being treated at a time. Liquid emulsifiable Noxfish (Penic Corp) containing 5.0% rotenone (w/w) was diluted approximately 1:4 with water from the area and usually dispensed below the water surface by sprayer, although on occasion it was applied by bucket and stirred. Four people positioned themselves adjacent to the net and/or within the blocked area, and fish surfacing were dipped over the next 30 min and preserved in 10% formalin. Very few fish surfaced after 20 min, and after 30 min, the chain line of the net was gently lifted and additional fish were collected from the wall of the net. It was our experience that this latter collecting process provided numerous fish that had not been taken by dipping.

We carried out mark and recapture studies to estimate our efficiency of recovery using the block net procedure. Silver jenny (Eucinostomus gula) were collected by trawl, fin clipped, and held in water for a minimum of 15 min to ensure no immediate handling mortality. Approximately 30 live fish then were released into each blocked area prior to rotenone application. Other species such as gray snapper (Lutjanus griseus), sheepshead (Archosargus probatocephalus), pigfish (Orthopristis chrysoptera), barracuda (Sphyraena baracuda), pinfish (Lagodon rhomboides) and goldspotted killifish (Floridichthys carpio) also were used, but silver jenny was the primary species. Mean recovery in January was 58% (range = 33-82%), while on other occasions it was 75% (range = 66-88%).

After each mangrove site was sampled, a trawl was deployed to sample the fishes of the adjacent seagrass habitat. A one minute otter trawl towed between two boats at a speed of approximately 2.0 $\pm$ 0.2 m/s (3.5-4.5 knots) was taken at each station. This trawl was taken as close to the mangroves as was feasible, and normally took place 8-10 m from the shoreline in an area that had not been disturbed by earlier boat movement to the mangrove site; these samples were taken approximately 1-1.5 h after the start of the mangrove samplings. The trawl measured 3.4 m at the head rope and 3.8 m at the foot rope and was made of 6-mm bar mesh with a 3-mm mesh tail bag. The net was fitted with 3-mm galvanized tickler chain strung between the trawl boards. One tethered float was deployed at the beginning and another at the end of the trawl, and the distance between the floats measured with an optical range finder.

Ancillary data were collected at both mangrove and adjacent trawl stations to characterize the habitat. A sample was taken of the surface sediments for analysis of organic content (loss of weight upon ignition at 500°C for 24 h) and for silt-clay content. The sediment was dried (70°C), weighed, rewetted with saturated sodium hexametaphosphate, and wet sieved. Material retained on 4.00 mm (shell) and 0.063 mm (sand) sieves was redried and the difference between initial total dry weight and the sum of these two size fractions taken as a measure of silt-clay content; this is a modification of ASTM (1963). Water temperature and salinity, and sediment depth (by penetration with a marked pole) also were measured. Adjacent to the mid-point of the trawl path a diver took three, 100-cm^2 quadrate samples of bottom vegetation for species identification, shoot enumeration, and determination of decalcified (5% phosphoric acid) dry weight biomass.

In January 1985, additional measurements of the root systems were made at each mangrove site. All mangrove roots at the level of the water surface (at mid-tide) were counted; prop roots exposed in the upper intertidal zone of each area also were enumerated. In addition, the diameter of 50 prop roots issuing from one or two randomly selected main roots off the trunk were measured using vernier calipers. The average diameter of prop roots at the mid-tide water surface and the number of prop roots were used to estimate the prop root surface area of the site occupied by prop roots. The circumference of each measured root also was calculated as an indication of potential surface available for epibiotic growth and for grazing by fishes. All measurements were made at a water depth of approximately 0.5 m at the leading edge of the mangrove prop roots. Thus, in some instances, measurements were made at or near the sediment-water interface close to shore.

Collected fish were identified to species and counted. The maximum, minimum and standard length of a "typical" individual species was measured and the total wet weight of each species was determined. In the case of gray snapper (Lutjanus griseus) standard lengths of all individuals were recorded. Stomach contents of gray snapper collected in the mangroves were identified to major taxonomic groups: copepods, amphipods, isopods, shrimp, crabs, and fish; only crustaceans and fish were observed in snapper stomachs. The number and length of each food item was recorded. Gravimetric analysis was not appropriate because of a wide range in digestive decomposition and/or regurgitation caused by preservation time. These analyses were compared to similar analyses made on gray snapper collected from seagrass meadows and channels in Coot Bay, Whitewater Bay and Florida Bay collected within the same time frame in a separate phase of our study (US NMFS Beaufort Laboratory 1985). These latter samples were taken by two-boat otter trawl.

Day-night comparisons were conducted during June and September 1985. Only September data are presented here since all sites were visited in September. Two approaches were employed during the day-night sampling. In September 1985, one station in Coot Bay and one in Whitewater Bay were sampled during day while the second station of each pair was sampled at night. A second approach was used at the four sites in Florida Bay. Each site was used for either a day or a night sampling and approximately 60 h later each station was sampled in reverse. Thus, a day and a night sample were taken at each of the four Florida Bay sites. A total of six comparisons were made, four in Florida Bay and one each in Coot Bay and Whitewater Bay in September 1985.

During the afternoon, prior to sampling a site at night, four 100 watt lights with reflectors were placed in the mangroves at each corner of the site and a fifth was suspended in the center of the area to be enclosed. Headlamps were used by the individuals deploying the blocknet. Once the area was blocked with the sample net, the lights were turned on, powered with a portable generator. Sampling was otherwise identical to the daylight technique, and tagged fish recoveries did not differ between day and night.

RESULTS AND DISCUSSION

Habitat Characteristics

The areas sampled ranged from generally low salinity and turbid to high salinity and clear. Coot Bay and Whitewater Bay sampling areas were characterized by low to intermediate salinities with a range of 5.5 o/oo in November 1984 to 20.0 o/oo in June 1985, and averages of 13.5 o/oo and 16.3 o/oo, respectively (Tables 27 and 28). Both areas also are characterized by "brown water" presumably resulting from dissolved organic matter leaching from mangroves. The Flamingo and upper Florida Keys sides of Florida Bay were characterized by high salinity water averaging 33 o/oo during our sampling period (range 27-42 o/oo). The area in the vicinity of Murray Key and Oyster Keys in the northwestern part of Florida Bay is highly turbid as a result of suspension of fine carbonates (Tabb and Dubrow 1962). In contrast, water clarity was always high at Crane Key and Captain Key in the southeastern region of the Florida Bay. Additional characteristics of Whitewater, Coot and Florida Bays have been described by numerous individuals (e.g., Ginsburg 1956, Tabb and Manning 1961, Tabb and Dubrow 1962, Schomer and Drew 1982, Zieman 1982).

Characteristics of mangrove and adjacent seagrass sites varied regionally (Tables 27 and 28). Blocked mangrove areas varied in size by 2.7-fold with the largest in Coot Bay and the smallest in Whitewater Bay. At all sites, red mangrove prop roots dominated the physical structure of the blocked habitat with a range of from 660 to 2293 prop roots or from 13.7 to 45.0 prop roots per m^2 of blocked area (Table 27). With the exception of the more northerly Whitewater Bay mangrove site (WB-2; Fig. 59), the total number of mangrove prop roots was related to the size of the area blocked. At the four Florida Bay sites, the area of open water within each blocked area that was outside the mangrove prop roots was similar, 16.3-20.5 m^2. Thus, of the two smaller sites (Captain Key and Murray Key) water interdigitated with prop roots represented half the blocked area while at the two larger sites water interdigitated with mangrove prop roots occupied >60% of the blocked area. Similar measurements were not taken in Coot Bay or Whitewater Bay. At the surface of the water at mid-tide (or sediment if the area was exposed at the time of measurement), prop root diameter ranged from 0.8-4.9 cm with the mean for individual stations ranging from 2.3-3.2 cm. These prop roots occupied a total of 0.3-1.6 m^2 of water surface area at the sites and had collective perimeters ranging from 0.48-2.16 m (Table 27); this latter measure may be indicative of the surface available for browsing fishes to graze.

At the trawl sites, located approximately 8-10 m from the mangrove fringe, submerged aquatic plants were prevalent. *Ruppia maritima*, widgeon grass, occurred at both of the low salinity areas in Whitewater Bay and Coot Bay, but did not occur in Florida Bay (Table 28). This plant also was more abundant at the Whitewater Bay areas than at Coot Bay, and during most of the study was characterized by having shoots extending to the water surface at the southernmost Whitewater Bay site (WB-1). Occasionally, large quantities of the alga *Chara hornemanni* also were present in Whitewater Bay. *Halodule wrightii*, Cuban shoalgrass, was present at both Coot Bay sites, and at Murray Key and Oyster Key (Table 28). The density and biomass of shoalgrass was much greater at the latter two sites than at the lower salinity Coot Bay areas. A third species, *Thalassia testudinum*, turtlegrass, was present only in Florida Bay and was most abundant at the Crane Key and Captain Key sites (Table 28) where it

Table 27. Characteristics of the mangrove habitats sampled for fishery communities WB = Whitewater Bay, CB = Coot Bay.

Characteristic	Mangrove Station							
	WB-1	WB-2	CB-1	CB-2	Murray	Oyster	Crane	Captain
Sediment								
% organic matter	31	38	34	40	10	7	26	10
% silt-clay	25	34	28	32	60	31	44	47
Depth (m)	0.9	0.7	1.3	1.4	0.4	2.0	1.7	2.0
Water depth (m)	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Total Blocked Area (m^2)	21.7	53.8	58.2	30.7	35.4	51.0	47.6	35.3
Open water (m^2)[1]	NC	NC	NC	NC	16.3	20.5	16.5	16.5
Mangrove Roots								
Total No.	660	735	1745	803	942	2293	1443	915
$\overline{X}$ Dia. (cm)	2.3	2.8	2.4	2.3	2.9	3.0	3.2	2.6
Surface area (m^2)	0.27	0.45	0.79	0.33	0.63	1.63	1.19	0.49
Perimeter (m)	0.48	0.65	1.32	0.58	0.86	2.16	1.45	0.75
Salinity (o/oo)	13.1	13.6	16.3	16.3	30.0	33.4	33.9	35.5

NC = not completed

[1] This is a calculation of the area of each blocked habitat that does not have mangroves. The difference between the total and this value is the area of each blocked habitat surrounded by mangrove prop roots.

Table 28. Characteristics of fringing seagrass stations sampled adjacent to mangrove prop root habitat sampled. RM = _Ruppia maritima_; HW = _Halodule wrightii_; TT = _Thalassia testudinum_; CH = _Chara hornemanni_.

Characteristic	Station							
	WB-1	WB-2	CB-1	CB-2	Murray	Oyster	Crane	Captain
Sediment								
% organic matter	19	20	11	15	14	13	7	11
% silt clay	57	53	48	51	70	67	30	51
Depth (m)	0.4	0.5	1.0	0.9	1.9	1.3	1.3	1.5
Water depth (m)	1.1	1.1	1.2	0.9	0.9	0.8	1.2	1.1
Plant Components								
Species	RM	RM	HW	HW	HW	HW	TT	TT
shoots/m^2	3310	493	580	750	2110	1970	1340	750
g dry weight/m^2	52.1	26.0	2.1	3.2	31.8	34.9	102.0	83.7
Species (cont'd)	CH	CH	RM	RM	TT			
shoots/m^2	-	-	38	460	30			
g dry wt/m^2	26.3	10.9	0.3	1.1	8.9			
Salinity (o/oo)	13.2	13.5	16.3	16.3	31.0	33.4	34.4	35.5

grew into the outer edge of the mangrove prop root habitat. Adjacent to Crane Key, turtlegrass was dense but fairly short, resulting in only a slightly higher dry weight biomass than occurred at Captain Key, which displayed almost half the number of short shoots per m^2. Thus, there was a great deal of variability in plant species composition, shoot density and biomass at paired sample sites as well as among regions.

Sediments varied in organic content and silt-clay content both within and between habitat types. Both Coot Bay and Whitewater Bay mangrove sediments were similar and had high organic contents ranging from a mean of 31-40% (Table 27), while adjacent seagrass areas had values markedly lower (Table 28). The high and similar organic contents in the mangrove imply a quiescent environment with a build up of peat. Murray Key, Oyster Keys and Captain Key, on the other hand, had comparatively low organic matter values. Greater tidal amplitude and current was measured at Murray Key and Oyster Keys than elsewhere and, thus, these areas may be flushed of detrital matter more than other stations. Sand and shell particle sizes dominated the sediments of all mangrove habitats except Murray Key. The sediments in the adjacent seagrass was dominated by silt-clay particle sizes except at Crane Key.

Relative Abundance of Fish

A total of 18,482 fish distributed among 87 species and 39 families were collected from the mangrove and adjacent trawl stations between June 1984 and May 1985. Table 29 provides a listing of species and total numbers collected between June and May 1985; May 1984 data have been omitted from this table and subsequent analyses to avoid confounding temporal and site differences since we were unable to sample Crane Key and Captain Key sites in May 1984. Substantially greater numbers and biomass of fish were collected from the mangrove sites than from the adjacent seagrass habitats, with approximately 75% of the numbers (Table 29) and 68% of the wet weight biomass of fish (36.8 of the total 54.2 kg) being taken from the mangroves.

Data on numbers and biomass for each site and sample date were converted to density and standing crop per m^2 for further comparisons by dividing total values by respective areas sampled by the two gears. The areas of each mangrove site ranged from 21.7 m^2 to 58.2 m^2 (Table 27). The area covered by the otter trawl in 1 min ranged from 260 m^2 to 540 m^2 and averaged 351 m^2 (SE = 7.7; N = 62). The effective opening of the otter trawl of approximately 3 m was used in calculating area sampled. Numbers and biomass of fish per unit area were summed over the survey periods and evaluated using ANOVAs. The model for the ANOVAs was that for a split plot design where the "whole-plot" factor was regions in the Park sampled (e.g., Whitewater Bay, Coot Bay, northwestern Florida Bay and southeastern Florida Bay), and the subplot factor was sampled habitat (mangrove vs. adjacent seagrass). Because of heterogeneity of variances, the data were transformed to logarithms prior to calculations.

There were significantly higher numbers and biomass of fish per m^2 in the mangrove habitats than in the immediately adjacent fringing seagrass habitats (Table 30a, b). The average (geometric mean) density of fish collected in the mangroves ($8.0/m^2$) was about 35-times that collected in the immediately adjacent habitat ($0.22/m^2$) on an areal basis. There was no evidence of an interaction between region and habitat type or of differences among the four regions (Table

Table 29. List of families and species of fish collected in mangrove prop root and adjacent seagrass sites in Coot Bay, Whitewater Bay, and Florida Bay during June 1984-May 1985 and the total numbers of each species collected.

Family-Species	Mangrove	Trawl	Total
Dasyatidae [Stingrays]			
Dasyatis americana - southern stingray	1	1	2
Elopidae [tarpons]			
Elops saurus - ladyfish	-	1	1
Anguillidae [Freshwater eels]			
Anguilla rostrata - American eel	1	-	1
Ophichthidae [snake eels]			
Myrophis punctatus - speckled worm eel	1	-	1
Clupeidae [Herrings]			
Brevoortia smithi - yellowfin menhaden	-	1	1
Harengula jaguana - scaled sardine	70	15	85
H. humeralis - redear sardine	119	-	119
Jenkinsia lamprotaenia - dwarf herring	56	16	72
Engraulidae [Anchovies]			
Anchoa hepsetus - striped anchovy	356	11	367
A. mitchilli - bay anchovy	808	968	1776
Synodontidae [lizardfishes]			
Synodus foetens - inshore lizardfish	8	30	38
Ariidae [sea catfishes]			
Arius felis - hardhead catfish	-	46	46
Batrachoididae [toadfishes]			
Opsanus beta - gulf toadfish	79	25	104
Gobiesocidae [clingfishes]			
Gobiesox strumosus - skilletfish	58	-	58
Exocoetidae [flyingfishes]			
Chriodorus atherinoides - hardhead halfbeak	-	2	2
Hyporhamphus unifasciatus - halfbeak	1	-	1
Belonidae [needlefishes]			
Strongylura marina - Atlantic needlefish	4	-	4
S. notata - redfin needlefish	82	-	82
S. timucu - timucu	46	4	50

Table 29 (Cont'd)

Family-Species	Mangrove	Trawl	Total
Cyprinodontidae [killifishes]			
Cyprinodon variegatus - sheepshead minnow	6	-	6
Floridichthys carpio - goldspot killifish	1465	37	1502
Fundulus confluentus - marsh killifish	6	-	6
F. grandis - gulf killifish	181	-	181
F. similis - longnose killifish	42	-	42
F. seminolis - seminole killifish	1	-	1
Lucania parva - rainwater killifish	1222	280	1502
Poeciliidae [livebearers]			
Gambusia affinis - mosquitofish	92	-	92
Poecilia latipinna - sailfin molly	226	-	226
Atherinidae [silversides]			
Atherinomorus stipes - hardhead silverside	4608	-	4608
Hypoatherina harringtonensis - reef silverside	5	-	5
Membras martinica - rough silverside	409	-	409
Menidia peninsulae - tidewater silverside	179	44	223
Syngnathidae [pipefishes]			
Hippocampus erectus - lined seahorse	-	9	9
H. zosterae - dwarf seahorse	2	18	20
Syngnathus dunckeri - pugnose pipefish	-	19	19
S. floridae - dusky pipefish	2	30	32
S. louisianae - chain pipefish	-	5	5
S. scovelli - gulf pipefish	219	145	364
Centropomidae [snooks]			
Centropomus undecimalis - snook	3	1	4
Centrarchidae [sunfishes]			
Lepomis macrochirus - bluegill	1	-	1
L. punctatus - spotted sunfish	1	-	1
Carangidae [jacks]			
Caranx hippos - crevalle jack	1	-	1
Oligoplites saurus - leatherjacket	4	-	4
Selene vomer - lookdown	-	1	1
Lutjanidae [snappers]			
Lutjanus griseus - gray snapper	27	5	32
L. synagris - lane snapper	1	11	12
L. apodas - schoolmaster	1	-	1
Gerreidae [mojarras]			
Eucinostomus argenteus - spotfin mojarra	505	251	756
E. gula - silver jenny	1901	1961	3862

Table 29 (Cont'd)

Family-Species	Mangrove	Trawl	Total
Haemulidae [grunts]			
Haemulon aurolineatum - tomtate	-	8	8
H. parrai - sailors choice	8	1	9
H. plumieri - white grunt	-	5	5
H. sciurus - bluestriped grunt	2	-	2
Orthopristis chrysoptera - pigfish	-	57	57
Sparidae [porgies]			
Archosargus probatocephalus - sheepshead	6	12	18
Calamus arctifrons - grass porgy	-	1	1
Lagodon rhomboides - pinfish	14	304	318
Sciaenidae [drums]			
Bairdiella chrysoura - silver perch	-	86	86
Cynoscion nebulosus - spotted seatrout	2	32	34
Menticirrhus littoralis - gulf kingfish	-	1	1
Pogonias cromis - black drum	2	-	2
Sciaenops ocellatus - red drum	1	-	1
Scaridae [parrotfishes]			
Sparisoma rubripinne - redfin parrotfish	-	1	1
Mugilidae [mullets]			
Mugil cephalus - striped mullet	32	-	32
M. curema - white mullet	45	1	46
Sphyraenidae [barracudas]			
Sphyraena barracuda - great barracuda	35	6	41
Clinidae [clinids]			
Paraclinus fasciatus- banded blenny	4	-	4
Blenniidae [combtooth blennies]			
Chasmodes saburrae - Florida blenny	2	-	2
Callionymidae [dragonets]			
Callionymus pauciradiatus - spotted dragonet	10	4	14
Gobiidae [gobies]			
Bathygobius soporator - frillfin goby	21	-	21
Gobiosoma bosci - naked goby	116	27	143
G. robustum - code goby	441	5	446
Lophogobius cyprinoides - crested goby	11	-	11
Microgobius gulosus - clown goby	326	72	398

Table 29 (Cont'd)

Family-Species	Mangrove	Trawl	Total
Acanthuridae [Surgeonfishes]			
Acanthurus chirurgus - doctorfish	1	-	1
Triglidae [searobins]			
Prionotus scitulus - leopard searobin	1	-	1
P. tribulus - bighead searobin	2	-	2
Bothidae [lefteye flounders]			
Paralichthys lethostigma - southern flounder	-	1	1
P. albigutta - gulf flounder	-	1	1
Soleidae [soles]			
Achirus lineatus - lined sole	2	2	4
Trinectes maculatus - hogchoker	-	4	4
Cynoglossidae [tonguefishes]			
Symphurus plagiusa - blackcheek tonguefish	1	-	1
Balistidae [triggerfishes]			
Aluterus schoepfi - orange filefish	-	1	1
Monacanthus ciliatus - fringed filefish	-	5	5
M. hispidus - Planehead filefish	-	8	8
Tetraodontidae [puffers]			
Sphoeroides nephelus - southern puffer	-	9	9
Diodontidae [porcupinefishes]			
Chilomycterus schoepfi - striped burrfish	-	2	2

30a). The densities of fish collected in the red mangrove prop root habitat exceeded those from the adjacent habitat in all 62 collections (Table 31a). Analysis of biomass on an areal basis similarly detected significant differences among habitats and no evidence of an interaction between region and habitat or of differences among regions (Table 30b). The average biomass of fish in the mangroves (15.0 g/m^2) was about 19 times greater in the mangroves than in the adjacent habitat (0.8 g/m^2). The biomass of fish taken from the mangroves exceeded those values from the adjacent seagrass meadows in 57 of the 62 samples, and the occasions when values for the adjacent habitat exceeded the mangroves were at Coot Bay (Table 31b). Here, catches of hardhead catfish (Arius felis) were responsible for the higher seagrass-trawl standing crops of fish. Fish taken from the mangroves were considerably smaller than those taken from the adjacent seagrass area, i.e., 1.9 g (wet weight) $fish^{-1}$ vs. 3.5 $g \cdot fish^{-1}$. In as much as we might expect some larger fish to be more adept at avoiding the trawl even at this high tow speed but not less susceptible to the rotenone, the actual difference in mean size may be greater than the data indicate.

We recognize that some of the differences observed between densities and standing crops of fish collected in the two habitats may be the result of differences in the efficiency of the two gears used. Our estimates of the efficiency of the block net-rotenone technique are based on tagged fish released into each blocked area prior to rotenone application. These estimates provided a mean recovery of approximately with a mean of 58% in January and 75% thereafter. In January when water temperatures were about 17-20°C, fish tended to sink rather than surface when rotenone was applied. We have no estimate for the efficiency of the two-boat otter trawl. Trawl efficiencies vary among species and sizes of fish. Kjelson and Colby (1977) estimated that the gear efficiency of a 6.1 m otter trawl towed by a single boat at about 0.8 m/s during the day ranged from 16-69% for juvenile pinfish and spot. Increasing the tow speed as we did to 1.8 to 2.2 m/s should have reduced the ability of fish to avoid the trawl, but even if the trawl had an efficiency of only 20%, our data would still imply much lower fish densities and standing crops in the adjacent seagrass meadows then in the mangrove habitats. The use of two boats greatly aids in attaining and maintaining this speed in trawling through grass beds as well as in maintaining the doors open to the maximum possible extent. The estimates of density obtained by this trawl method (1 min, 2 boat, 3.5-4.5 knots) over submerged grass beds are not dissimilar to those obtained throughout Florida Bay, Coot Bay and Whitewater Bay in over 250 trawls (2 min, 2 boat) over both vegetated and unvegetated bottoms (Part I of this report). We conducted some preliminary trials using a 4.0 m^2 Wegener ring and rotenone in the fringing seagrass habitat, but this approach normally yielded very low numbers of fish per ring and very low diversity. The estimates we obtained for the fringing seagrass areas, while low, are in the range collected from other meadows in Florida: 0.2-2.0 m^2 in Biscayne Bay seagrass beds (Sogard 1982); 0.3-1.5 m^2 in Apalachee Bay and <0.6 m^2 in Indian River (computed by Sogard et al. MS In press). Sogard et al. (In press), however, reported mean densities of 11 $fish \cdot m^2$ on several carbonate banks in Florida Bay using 1 m^2 in throw traps.

We observed an overall seasonal trend in both mean numbers and biomass of fish at mangrove and adjacent seagrass sites. The overall density and standing crop of fish were maximum in fall in the mangrove habitat; this habitat type also displayed the greatest month-to-month variation in mean values (Fig. 60). There was an increase in abundance during autumn and again in spring; mean

Table 30a. Analysis of variance of total numbers of fishes per square meter taken in the surveys conducted between June and May. The data are transformed to logarithms of total number + 1.0 prior to the calculations.

Source	df	Mean Square	F
Among Regions	3	0.4002	2.57
Among Blocks	1	0.0067	
Mainplot Error	3	0.1554	
Mangrove vs. Seagrass	1	11.4274	94.73*
Region X Mangrove-Seagrass	3	0.6129	5.08
Subplot Error	4	0.1206	

Table 30b. Analysis of variance of total biomass of fishes per square meter taken in the surveys conducted between June and May. The data were transformed to logarithm of total biomass + 1.0 prior to the calculations.

Source	df	Mean Square	F
Among Regions	3	0.4398	3.54
Among Blocks	1	0.4379	
Mainplot Error	3	0.1244	
Mangrove vs. Seagrass	1	15.3934	93.94*
Region X Mangrove-Seagrass	3	0.5330	3.05
Subplot Error	4	0.1745	

* p = < 0.0007

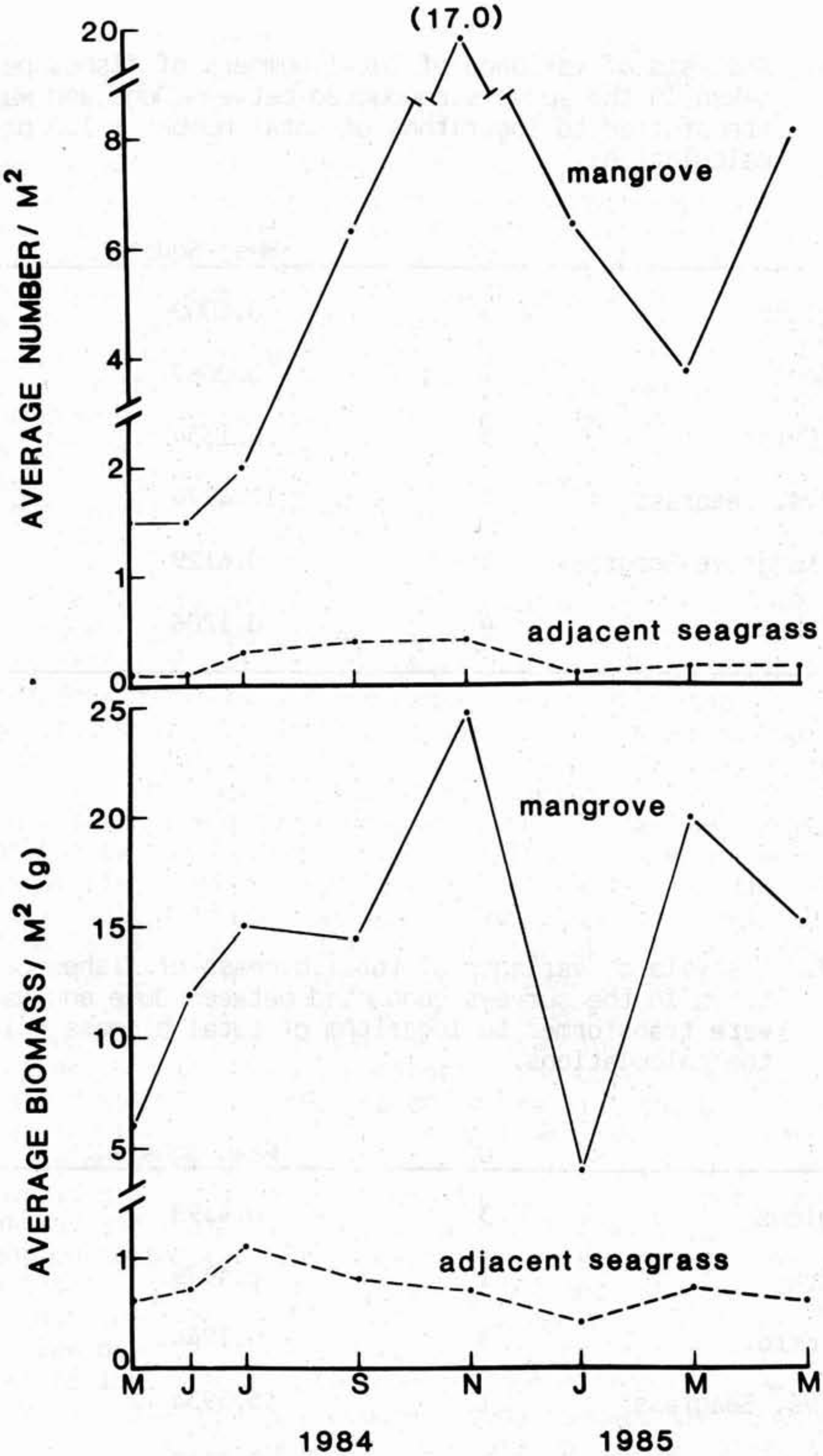


Figure 60. Average abundance and biomass of fishes (per m^2) taken from eight mangrove prop root habitats and eight adjacent seagrass habitats in Everglades National Park.

biomass also increased in autumn but decreased between March and May 1985. The precipitous decrease in the mean standing crop biomass of fishes collected among the mangrove prop roots in January 1985 coincided with a predominance of early stage juvenile (17-21 mm, standard length) silver jenny (Eucinostomus gula), rainwater killifish (Lucania parva) and sailfin molly (Poecilia latipinna), and a decrease in the average wet weight per individual (0.6 g). These data suggest spawning occurs during late autumn for these species in the Florida Bay area, and that the mangrove prop root habitat may provide refuge from predators. Although small individuals also were present two months later in March, the average individual was larger and ranged in size from 27-47 mm for silver jenny, 19-27 mm for rainwater killifish and 22-35 mm for sailfin molly further suggesting that this habitat may be important in the growth and survival of these species. In the adjacent seagrass habitat there was a slight trend for density and standing crop values to be higher in summer and decrease during fall. The wet weight of an average individual was minimum in November (1.9 g). Small (< 20 mm) silver jenny and rainwater killifish were present in the seagrass habitat during January and March, but larger individuals (> 30 mm) were the rule. We believe that the abundance of early stage juvenile silver jenny, rainwater killifish and sailfin molly among the red mangrove prop roots relative to the adjacent seagrass habitat implies a major refuge role for the prop root habitat.

Species Composition and Habitat Comparisons

The ten dominant species for the overall study period (June 1984-May 1985) in decreasing order of abundance were: hardhead silverside (Atherinomores stipes), silver jenny, bay anchovy (Anchoa mitchilli), goldspotted killifish, rainwater killifish, spotfin mojarra (E. argentus), code goby (Gobiosoma robustum), striped anchovy (A. hepsetus), gulf pipefish (Syngnathus scovelli), and clown goby (Microgobius gulosus). Silver jenny, bay anchovy and gulf pipefish were more abundant in the adjacent seagrass meadows than in the mangrove sites. The other seven dominants, however, were relatively more abundant among the mangrove prop roots (Table 29), and hardhead silverside were taken only among the mangrove prop roots. Only a few of these ten species are listed among the dominant species in previous collections in Florida Bay, Coot Bay and Whitewater Bay, although most occur frequently but not in abundance (Tabb and Manning 1961, 1962; Odum et al. 1982; Sogard et al. in press). We believe that this general lack of information on prevalent species in south Florida is in part due to the paucity of information on mangrove and shore communities in south Florida. Carter et al. (1973), however, do report that the mojarras (Eucinostomus spp.), were among the dominant species collected in areas of the Ten Thousand Islands, Florida.

The overall composition of the mangrove-fish community collected during the day was more diverse than that we collected in the immediately adjacent seagrass habitat. The families Atherinidae, Cyprinodontidae, Gerreidae, Engraulidae and Gobiidae were represented most abundantly among the mangrove prop roots, while the Gerreidae, Engraulidae, Cyprinodontidae and Sparidae were most prevalent in the seagrass (Table 29). Thirty-six species were collected exclusively in the fringing mangrove habitat while 24 species were taken exclusively in adjacent waters. Another 27 species were collected in both habitats (Table 29). Thirty-one species were collected only once and 17 of these were collected in the mangroves. Based on a few day-night comparisons (see later), the diversity in the mangrove habitat appear to increase at night.

Table 31a. Density of fish (number m^2) collected from mangrove and adjacent seagrass sites in Everglades National Park, Florida.

Site/Habitat	Date							
	M	J	J	S	N	J	M	J
	1984					1985		
Murray Key								
Mangrove	1.2	1.8	2.8	5.9	5.5	3.0	2.3	3.7
Seagrass	0.07	0.05	1.4	0.57	0.19	0.14	0.21	0.73
Oyster Keys								
Mangrove	0.9	0.7	1.3	4.8	8.3	8.9	0.8	2.5
Seagrass	0.09	0.32	0.25	0.82	0.12	0.08	0.22	0.22
Crane Key								
Mangrove	NS	1.4	1.0	14.7	9.8	4.4	11.7	30.5
Seagrass	NS	0.01	0.09	0.30	0.26	0.03	0.00	0.03
Captain Key								
Mangrove	NS	1.5	0.3	3.2	86.6	27.7	2.5	0.9
Seagrass	NS	0.02	0.06	0.15	0.26	0.05	0.01	0.16
Whitewater Bay - 1								
Mangrove	3.1	2.8	5.4	4.5	12.4	1.5	9.3	17.5
Seagrass	0.09	0.02	0.10	0.17	0.05	0.09	0.14	0.17
Whitewater Bay - 2								
Mangrove	1.9	1.4	1.1	2.2	3.3	2.3	1.8	4.2
Seagrass	0.21	0.09	0.05	0.05	0.00	0.19	0.20	0.07
Coot Bay - 1								
Mangrove	0.9	1.0	2.6	9.0	2.7	1.9	0.3	3.7
Seagrass	0.14	0.03	0.12	0.21	0.63	0.02	0.21	0.39
Coot Bay - 2								
Mangrove	0.8	0.6	1.4	6.5	7.4	1.4	0.9	4.0
Seagrass	0.09	0.22	0.37	0.71	1.4	0.05	0.08	0.03

NS = no sample

Table 31b. Wet weight standing crop of fish (g/m^2) collected from mangrove and adjacent seagrass sites in Everglades National Park, Florida.

Site/Habitat	M	J	J	S	N	J	M	J
	1984					1985		
Murray Key								
Mangrove	5.8	26.2	58.1	9.8	3.0	0.4	78.3	8.1
Seagrass	0.2	0.4	5.9	1.0	0.5	0.3	0.7	2.8
Oyster Keys								
Mangrove	4.8	38.6	52.1	22.6	5.0	1.9	1.3	8.7
Seagrass	0.1	0.3	0.7	0.7	0.3	0.1	0.6	0.8
Crane Key								
Mangrove	NS	2.3	0.9	26.4	9.3	3.4	11.9	50.0
Seagrass	NS	0.01	0.3	0.8	0.6	1.3	0.0	0.08
Captain Key								
Mangrove	NS	1.3	0.9	2.7	108.1	19.0	2.3	2.4
Seagrass	NS	0.01	0.2	1.0	0.4	0.7	0.01	0.1
Whitewater Bay- 1								
Mangrove	20.4	1.1	4.0	11.8	23.4	2.4	57.9	26.6
Seagrass	0.1	0.004	0.3	0.3	0.05	0.05	0.6	0.6
Whitewater Bay- 2								
Mangrove	1.5	0.5	1.7	6.7	1.7	0.6	9.5	2.4
Seagrass	0.6	0.1	0.03	0.02	0.0	0.4	0.1	0.5
Coot Bay - 1								
Mangrove	1.8	21.8	0.9	15.4	11.2	2.4	0.4	1.7
Seagrass	0.4	3.5	1.0	1.4	2.8	0.4	0.08	0.7
Coot Bay - 2								
Mangrove	1.2	0.8	1.3	6.6	6.9	2.2	0.2	9.4
Seagrass	2.2	1.1	3.2	1.1	1.3	0.03	3.0	0.1

NS = no sample

Fish communities among the geographic regions and between the mangrove and adjacent seagrass habitats were compared using data on 56 species that were collected from at least two of the eight sampling areas during the course of this study. Our initial analysis was based on the presence and absence of species. We used the absolute value of the correlation as a measure of similarity (BMDP 1983), and followed a complete or maximum distance linkage rule as recommended by Gauch (1982) in forming clusters. There was a clear separation of the mangrove and adjacent seagrass fish communities we collected during daylight (Fig. 61). With the exception of the adjacent seagrass communities in Coot Bay and Whitewater Bay (Fig. 61), replicates within a given habitat and region resembled one another more closely than communities within that habitat in other geographical regions.

Eleven species were collected in every region and in both habitats. Three of these species, silver jenny, rainwater killifish and spotfin mojarra, were collected at every one of the 16 sites and were among the dominants we collected during the study (Table 29). The mojarras (Eucinostomus spp.) are reported to be dominant species in the mangrove-lined bays in the Ten Thousand Islands (Carter et al. 1973; Colby et al. 1985), and Tabb and Manning (1961), sampling in Whitewater Bay, Coot Bay, and Florida Bay, reported the two mojarra present but not abundant in the brackish waters of Coot Bay and Whitewater Bay. In our collections, however, both were among the dominants in the mangrove and adjacent seagrass fish communities, with densities in Coot Bay and Whitewater Bay frequently exceeding those at the high salinity sites in Florida Bay. The rainwater killifish, reportedly abundant in low salinities (Tabb and Manning 1961; Carter et al. 1973), was most abundant in our study among the mangrove prop roots and was collected in greater abundance in higher salinity in southeastern Florida Bay sites at Crane Key than at either of the lower salinity Coot Bay or Whitewater Bay sites. Other species, normally associated with grass flats or bay bottoms (e.g., pinfish, code goby, gulf pipefish) and open water conditions (e.g., bay anchovy, timucu) were taken in both habitats. Juvenile gray snapper, an important recreational species in Everglades National Park, was taken in both mangrove and seagrass habitat types but most frequently in the mangrove prop root area. The only site we did not collect gray snapper among the mangroves was at Murray Key, and our only samples of gray snapper in the adjacent seagrass meadows were at Captain Key and Crane Key. Although densities of gray snapper were low, when one considers the linear extent of mangrove fringe present in south Florida, the prop root habitat must be considered important to the production of this sportfish.

There were fourteen species of fish collected on more than one occasion (Fig. 61). The hardhead silverside was the most abundant fish collected, and was taken almost exclusively from mangrove habitats in Florida Bay at Crane Key and Captain Key during autumn and spring; this species did appear once in Whitewater Bay collections, and therefore does not show up on this figure. Two killifish and one needlefish were collected in all four geographic regions. Both species of killifish were reported as rare in the area by Tabb and Manning (1961) and were not collected in the bay system of the Ten Thousand Island region by Carter et al. (1973) or Colby et al. (1985); it must be remembered that none of these investigations sampled the mangrove habitat per se. Among these mangrove sites, the sailfin molly, mosquitofish (Gambusia affinis) and skilletfish (Gobiesox strumosus) did not appear to be restricted by salinity, being collected at the high salinity southeastern Florida Bay mangrove sites as well as at the much lower salinity mangrove sites (see Table 1a, b for salinity values) in Coot Bay

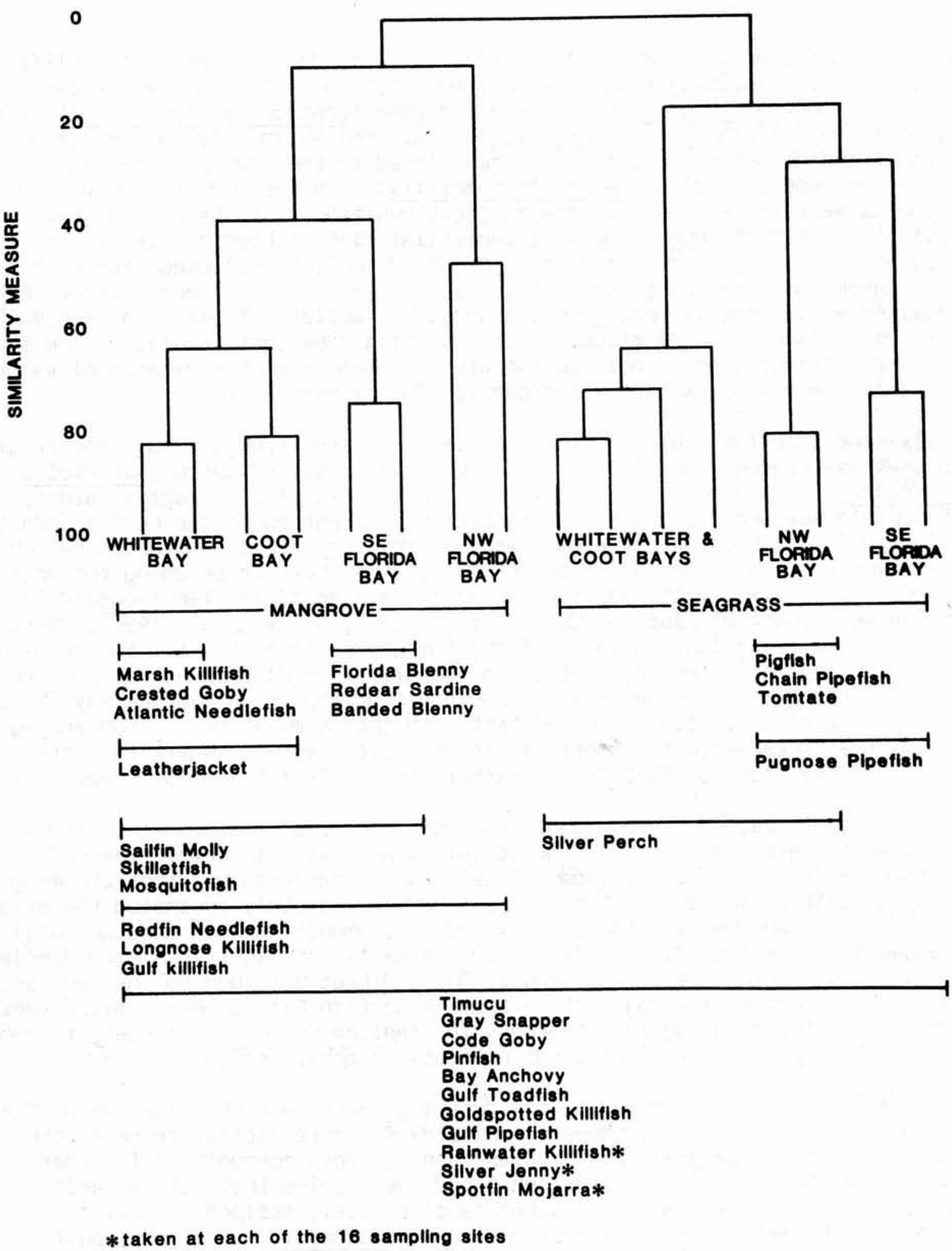


Figure 61. Cluster analysis of sixteen sample sites in Everglades National Park based on occurrence of 56 species of fish. Species common to the various regions and habitats are shown in the lower portion of the figure.

and Whitewater Bay. Odum et al. (1982), however, do not report the sailfin molly from low salinity mangrove-lined habitats in south Florida. Marsh killifish (Fundulus confluentus), crested goby (Lophogobias cyprinoides) and Atlantic needlefish (Strongylura marina), all collected only in low numbers among the mangrove prop roots, were restricted to the low salinity sample sites, while the redear sardine (Harengula humeralis) (119 individuals) as well as two blennies were present only in the mangrove habitats near the Florida Keys (high salinity). Mullet (Mugil spp.), a commercial fish in Florida Bay, was collected only at Oyster Keys and Murray Key. Of the 72 mullet collected (Table 29), 71 were taken among the mangrove prop roots, but, in this instance we know that trawling would under-sample juvenile and adult mullet. These fish presumably feed on sediments and detritus. Thus, our data show that several of the species using the fringing prop root habitat are of commercial or recreational value, while many are important forage organisms for predatory fish.

Unlike the prop root community, no species collected from the adjacent seagrass habitat was present in all four sampling regions. Silver perch (Bairdiella chrysoura) was the most ubiquitous, being collected in all seagrass areas except at Captain Key and Crane Key. This species is reported as the most abundant sciaenid in the Florida Bay area (Tabb and Manning, 1961). Although not one of the dominant fish collected in our study, it was shown to be among the most abundant organisms in the mangrove-lined bay system of the Ten Thousand Islands on the west coast of Florida (Carter et al. 1973; Colby et al. 1985). Several species (i.e., pigfish, chain pipefish, tomtate) were restricted to the high salinity seagrass sites adjacent to the mangroves in Florida Bay or just to those fringing seagrass meadows we sampled in northwestern Florida Bay (Fig. 61). Their distribution was consistent with the observation of Tabb and Manning (1961) that these species generally are most prevalent on vegetated bottoms in high salinity areas of Florida Bay rather than in Coot Bay or Whitewater Bay.

A second analysis, based upon logarithms of species abundances, resulted in a somewhat different grouping of the 16 sampling sites (Fig. 62). The major difference from our first approach (analysis of presence) was that the mangrove fish communities in northwestern Florida Bay more closely resembled the seagrass communities than they did the other mangrove communities when data on total abundance were employed. Interestingly, these two stations were more similar to the seagrass communities of Whitewater Bay and Coot Bay than to the seagrass communities immediately adjacent to them in western Florida Bay. With several exceptions, there was again a tendency for replicates to more closely resemble one another than samples from other habitats or other regions.

Examination of the species abundance data suggested that the main reason the two mangrove communities of northwestern Florida Bay more closely resemble the adjacent fringing seagrass communities than mangrove communities in other regions was that these two sites contained few species that were markedly abundant in the other mangroves sites sampled, i.e., striped anchovy, mosquitofish, skilletfish, naked goby (Gobiosoma bosci), code goby, gulf toadfish (Opsanus beta), clown goby (Microgobius gulosus), and sailfin molly. These two sites also contained certain species, such as the inshore lizardfish (Synodus foetens), that were otherwise found only in fringing seagrass sites.

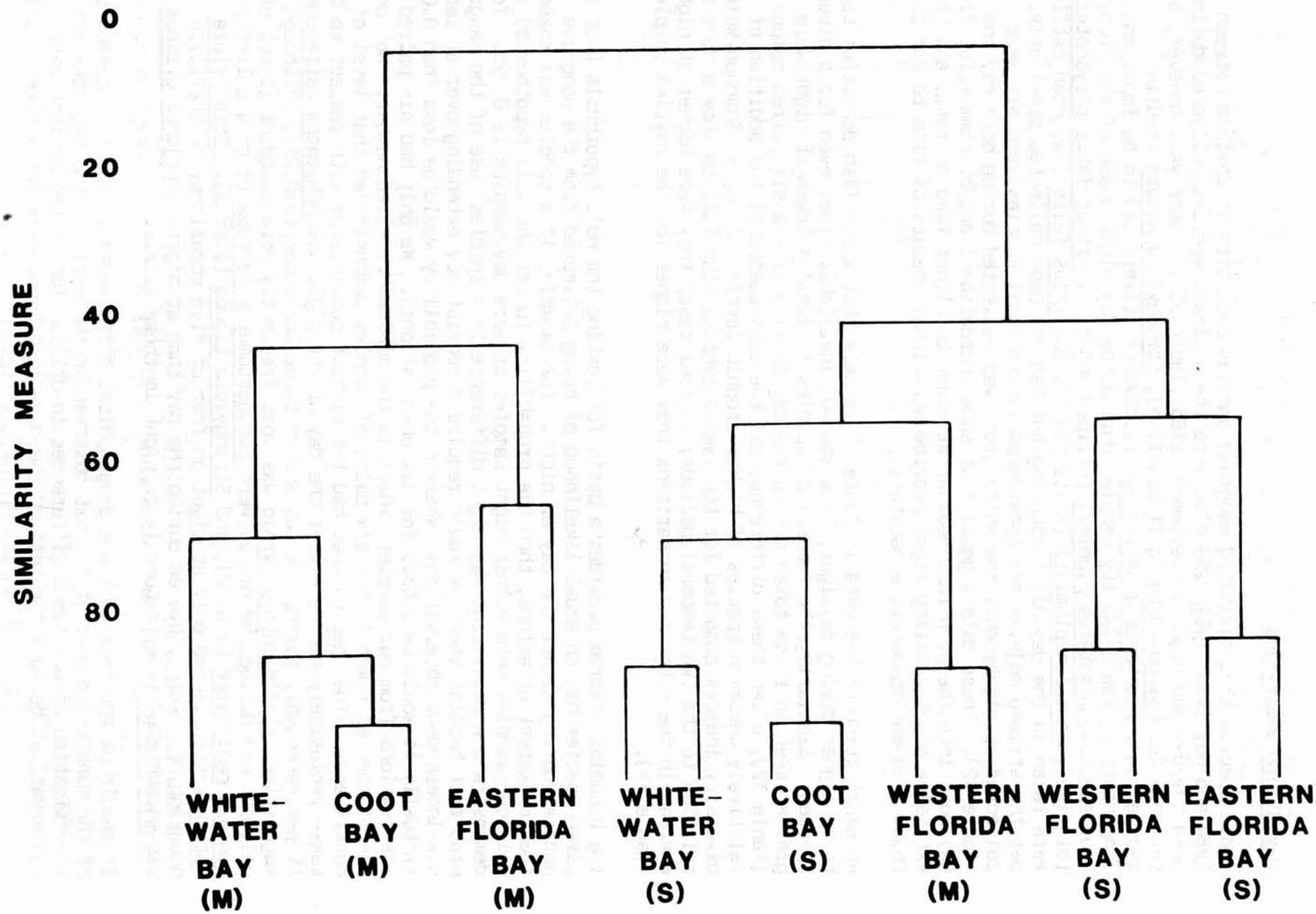


Figure 62. Cluster analysis of 16 samples sites in Everglades National Park based on logarithm of abundance of 56 fish species. Mangrove and seagrass sites denoted by (m) and (s), respectively.

Day-Night Comparisons

Those species that dominated mangrove samples collected in daytime between June 1984 and May 1985 (Table 29) also were the dominant species collected during both the day and night in September 1985 (Table 32). There was, however, a tendency for Opsanus beta (gulf toadfish), Strongylura notata (redfin needlefish), and Menidia peninsulae (tidewater silverside) to be important components of the community sampled during the day-night phase of the study. Four species, Diapterus plumieri (striped mojarra), Orthopristis chrysoptera (pigfish), Haemulon plumieri (white grunt), and Arius felis (hardhead catfish) were taken in the day-night sampling but had not been collected previously. All but the striped mojarra are considered recreational species, and all were collected at night; only the white grunt was collected during both day and night (Table 32). These data suggest that some recreational and/or commercial fish may move into the prop root habitat at night to either feed or rest, and that extensive night sampling might provide additional species of fish to our list of those frequenting mangrove habitats.

An examination of the data in Table 32 reveals that while fish densities tended to be higher during daylight, this was not invariably true, even for a given species. Similarly, the numbers of species in samples taken at night were greater than in those taken during the day in five of the six paired comparisons (Table 32); often these differences are the consequence of the addition of relatively uncommon species of higher trophic levels. Finally, Shannon-Weiner diversity indices computed for the twelve samples also fail to show a consistent relation to the two temporal periods; in four cases they were higher at night whereas in the other two comparisons they were higher for the daytime samples (Table 32).

The binomial theorem provides a basis for testing the null hypothesis that a given species has an equal likelihood of being collected from the mangrove habitat during either the day or night. For example, if a species was taken on four different occasions, then the probability (under the null hypothesis) that all four samples were either night samples or were day samples is 0.125. To demonstrate a consistent day-night difference in a species' use of the mangrove prop root habitat then, we would require a consistency extending over at least six independent observations, wherein the probability would be less than 0.05 (actually it would be 0.0313 for six observations). We only had six paired observations from our samples, which is the minimum required number. Not one of the 34 species taken in the six pairs of samples demonstrated that level of consistency. The species that had the highest consistency with respect to being taken exclusively during either the day or the night was Sphyraena barracuda. It was taken only during the day and on three occasions ($p=0.25$). Although only suggestive, Floridichthys carpio was most frequently more abundant (5 our of 6 collections) during the day as were Eucinostomus argenteus (3 of 4 collections), Menidia peninsulae (2 of 2), and Strongylura timucu (2 of 3). Strongylura notata was collected only at night on four of five occasions; on the fifth occasion more were captured during the day than at night. Lutjanus griseus also was encountered more frequently at night in these trials.

It should be apparent that the geographical differences in the fish communities of the mangrove prop-root habitat observed in the earlier sampling make our investigation of day-night differences in utilization of the habitat very conservative, because the test of the day-night hypothesis for a given species

Table 32. Density of fish (no. m^{-2}) collected in day-night sampling in Everglades National Park in September 1985.

	Whitewater Bay		Coot Bay		Murray Key		Oyster Keys		Captain Key		Crane Key	
	Day (9/6/85)	Night (9/6/85)	Day (9/6/85)	Night (9/6/85)	Day (9/5/85)	Night (9/7/85)	Day (9/7/85)	Night (9/5/85)	Day (9/8/85)	Night (9/10/85)	Day (9/10/85)	Night (9/8/85)
Anguilla rostrata	-	-	3	-	-	-	-	-	-	-	-	-
Harengula jacuana	-	28	-	-	-	-	-	-	-	-	-	-
Anchoa hepsetus	23	-	-	-	-	-	-	-	-	-	-	-
Anchoa mitchilli	129	28	6	-	-	2	-	47	-	6	-	-
Arius felis	-	-	-	2	-	-	-	-	-	-	-	-
Opsanus beta	5	2	36	7	-	-	-	-	6	11	-	6
Gobiosox strumosus	-	-	-	2	-	-	-	-	3	-	-	-
Strongylura notata	9	6	-	4	-	8	-	-	-	17	-	13
Strongylura timucu	-	-	10	2	-	-	-	-	-	-	2	-
Floridichthys carpio	65	22	42	22	271	44	63	264	241	-	456	132
Fundulus grandis	-	-	3	-	23	13	-	-	-	14	-	-
Fundulus similis	-	2	-	-	-	2	2	27	-	-	-	-
Lucania parva	2	6	10	2	-	-	-	2	-	-	2	122
Gambusia affinis	5	-	-	-	-	-	-	-	-	-	-	-
Poecilia latipinna	5	-	-	-	-	-	-	-	-	-	-	-
Atherinomorus stipes	-	-	-	-	-	-	-	-	14	99	330	193
Menidia peninsulae	51	19	13	2	-	-	-	-	-	-	-	-
Syngnathus scovell	9	14	57	17	-	-	-	2	6	-	-	2
Oligoplites saurus	5	1	-	2	-	-	-	-	-	-	-	-
Lutjanus griseus	-	2	-	-	-	-	2	6	-	-	-	2
Lutjanus synagris	-	-	-	-	-	-	-	-	3	-	-	-
Eucinostomus argenteus	-	-	-	3	21	-	27	-	14	-	-	-
Eucinostomus gula	447	48	75	103	92	84	165	41	77	-	177	197
Diapterus plumieri	-	-	-	-	-	-	-	2	-	3	-	-
Haemulon plumieri	-	-	-	-	-	-	-	-	3	-	-	2

Table Continued

	Whitewater Bay		Coot Bay		Murray Key		Oyster Keys		Captain Key		Crane Key	
	Day (9/6/85)	Night (9/6/85)	Day (9/6/85)	Night (9/6/85)	Day (9/5/85)	Night (9/7/85)	Day (9/7/85)	Night (9/5/85)	Day (9/8/85)	Night (9/10/85)	Day (9/10/85)	Night (9/8/85)
Orthopristis chrysoptera	-	-	-	-	-	-	-	-	-	-	-	8
Archosargus probatocephalus	-	2	-	2	-	-	2	-	-	-	-	-
Lagodon rhomboides	-	-	-	-	-	2	-	-	-	-	6	-
Mugil curema	-	-	-	-	-	-	6	6	-	-	-	-
Sphyraena barracuda	-	-	-	-	2	-	-	-	3	-	3	-
Gobiesoma robustum	18	7	94	82	-	-	-	-	37	-	-	6
Lophogobius cyprinoides	46	13	-	-	-	-	-	-	-	-	-	-
Microgobius gulosus	124	100	36	74	-	-	-	-	11	-	21	23
Achirus lineatus	-	-	3	-	2	-	6	6	-	-	-	-
Total No. of individuals	943	300	388	326	411	155	273	403	418	150	997	706
No. of species	15	16	13	15	6	7	8	10	12	6	8	12
Shannon-Weinner diversity	1.76	2.14	2.10	1.78	0.97	1.22	1.15	1.21	1.43	1.14	1.18	1.69

Table 32 Concluded

requires a consistency of behavior over six paired comparisons. In this case, this means the test is only appropriate and applicable to those ubiquitous species that were found in all geographical locations encompassed by the study since only six paired comparisons were made. The fact that the geographical differences confounded the day-night comparisons implies that a better strategy for a future investigation would be to confine sampling to one general locale and to increase the number of paired day-night collections well beyond a minimum number of six. The use of rotenone may have influenced the results, although this was not apparent from an examination of Table 32. In areas where there is sufficient-tidal amplitude, the block net technique can be used without rotenone provided that a reservoir or cod end of the net is placed on the outer-most side in which to collect fish.

Ogden and Zieman (1977), McFarland et al. (1979), Zieman (1982), and Robblee and Zieman (1984), have described interactions among reef and seagrass communities, and noted that fish exhibit both diurnal and nocturnal patterns of migration from reefs and exploitation of adjacent seagrass meadows. Ogden and Zieman (1977) reported that foraging out from reefs during the day is primarily by small (< 15 cm) or large (> 40 cm) herbivorous fish and that nocturnal feeding migrations occur primarily among carnivorous fish species. They also suggest that intermediate-sized fish (20-40 cm) appear to be excluded from daylight feeding in seagrass meadows by predatory fish and the lack of sufficient hiding space within the 2-dimensional seagrass canopy. Starck and Davis (1966) noted that many fish species may not be present or present only in low numbers over potentially available forage areas due to the absence of diurnal resting areas such as patch reefs. In support of this hypothesis, Zieman (1982) noted that when artificial reefs were placed in the Virgin Islands they were rapidly colonized by juvenile grunts indicating the importance of shelter in the vicinity of the seagrass feeding grounds.

In a review of seagrass-mangrove interactions, Zieman (1982) pointed out that, although it is known that some species of fish recruit initially into seagrass habitats and move into mangrove-dominated areas as juveniles, little information was available on the interaction between mangrove habitats and seagrass meadows. It is well known that mangrove-lined estuaries and bays are utilized by a wide variety of juvenile and adult fish (e.g., Odum et al. 1982, Colby et al. 1985), and we have earlier (Thayer et al. In press a) hypothesized that relations observed between seagrass and coral habitats also may exist in the mangrove-seagrass dominated systems.

The fish species we collected among the red mangrove prop roots were primarily small forage species or juveniles of large-sized species (e.g., S. barracuda, S. timucu, L. griseus, S. notata, A. rostrata). Occasional large adults were collected but this was not a common occurrence. Most of the individuals collected were less than 15 cm and should be able to exploit adjacent seagrass beds during daylight because the grass blades can provide protective refuge. Most of the species we collected among the mangrove prop roots during the day also were present in our limited night sampling. It is possible that the prop root habitat serves as a refuge during the day even for these small species and that members may forage out into the adjacent seagrass meadows at night. It is possible that the prop root habitat serves as a refuge during the day even for these small species and that members may forage out into the adjacent seagrass meadows at night. A few species, however, were only present at night. The day-night comparisons we conducted were sufficiently few in number that they do not provide significant consistent results on diurnal or nocturnal patterns of use, although they are suggestive in some cases. Hypotheses can be developed and tested based on these data.

Conclusions

Within the geographical area encompassed by our study, the intertidal fringing red mangrove prop root habitat and immediately adjacent seagrass meadows support different fish communities during daylight and night hours. Despite the fact that both sampling techniques employed were less than 100% efficient, the data show fringing red mangrove prop root habitat is of major importance for a wide variety of fishes. This habitat appears to support an overall greater density and standing crop biomass of fishes than the adjacent fringing seagrass habitat. Several species utilizing the mangroves are of commercial and recreational importance, while many are forage foods for predatory fishes. There also appear to be trends toward higher abundances of fishes among the prop roots during daylight and a greater diversity of fishes at night. It seems likely that increasing the sample size either by sampling additional examples of each habitat within each region, or by extending the sampling period in time, might, to some extent, blur some of the boundaries of the fish communities that have emerged from this analysis. It is nevertheless clear that these two major habitats fulfill different functions for different species of fishes during the day and that both are essential to the viability of fish production in this region.

The data do demonstrate that forage fishes predominate and that, as would be expected, juveniles of high trophic level carnivores represent only a small fraction of the organisms utilizing this habitat. Although the numerical abundance of commercial and recreational fish utilizing this prop root habitat was never large, when one considers the fact that 60-70% of tropical shorelines are mangrove-lined, they must be viewed as an important nursery area. The importance of the forage fish component to piscivorous fish and birds cannot be overstated. Since the maintenance of fishery resources requires adequate spawning, feeding and refuge habitat, it is probable that the cumulative loss of fringing mangroves to any development eventually will result in reduced fishery populations in subtropical and tropical environments. A great deal more is to be learned about the role of mangroves in the production of fishery organisms, and the techniques and data we have presented provide a basis on which to develop testable hypotheses.

Overall losses of mangroves in south Florida have not been great but there have been substantial losses in specific locations (Odum et al. 1982). Because degradation of these habitats is continuing to occur both through natural and man-induced events, it is important that we recognize the values of fringing mangroves as nursery areas for commercial and recreational fishes and their food resources in order to predict impacts of alterations before they occur. Efforts need to be expended to evaluate this and more extensively flooded mangrove habitats for their relative value to fish and crustaceans.

ACKNOWLEDGMENTS

This study is part of a larger study on early life history of fish funded through a cooperative agreement between the National Park Service's Everglades National Park and the National Marine Fisheries Service, Southeast Fisheries Center, Beaufort Laboratory. Numerous individuals spent many hours discussing sampling approaches, collecting samples while swatting mosquitoes, and in analyzing the samples and data. Particular thanks are expressed to Michael LaCroix, Patti McElhaney, Keith Rittmaster, Don Field, Jud Kenworthy, and Dave Peters of the Beaufort Laboratory and Jim Tilmant, Mike Robblee, Ed Rutherford and Peggy Harrigan of Everglades National Park. Herb Gordy drew the figures and Jeanie Fulford typed the paper. We also express our thanks to William Odum for comments and with whom we had discussions concerning approaches to sampling mangrove habitats, and Samuel Snedaker, and Armando de la Cruz and Michael Robblee for reviewing parts of the manuscripts.

LITERATURE CITED

Adams, S.M. 1976. The ecology of eelgrass, Zostera marina (L.), fish communities. I. Structural analysis. J. Exp. Mar. Biol. Ecol. 22: 269-291.

Allen, D.M., J.H. Hudson, and T.J. Costello. 1980. Postlarval shrimp (Penaeus) in the Florida Keys: Species, size, and seasonal abundance. Bull. Mar. Sci. 30: 21-33.

American Society for Testing and Materials. 1963. Standard methods for particle size analysis of soils. A.S.T.M. designation D422-63. American Society for Testing and Materials, Philadelphia, Pa.

Beaufort Laboratory., 1987. Ichthyoplankton and juvenile fish studies in Everglades National Park: Executive Summary. Everglades National Park. 7 p.

Bloom, S.A., S.L. Santos and J.G. Field. 1977. A package of computer programs for benthic community analyses. Bull. Mar. Sci. 27:577-580.

BMDP statistical software. 1983. University of California Press, Berkeley, 733 p.

Boesch, D.F., and R.E. Turner. 1984. Dependence of fishery species on salt marshes: The role of food and refuge. Estuaries 7: 460-468.

Carter, M.R., L.A. Burns, T.R. Cavinder, K.R. Duggen, P.C. Fore, D.B. Hicks, H.L. Revelles, and T.W. Schmidt. 1973. Ecosystem analysis of the Big Cypress Swamp and estuaries. U.S. Environmental Protection Agency, Atlanta, Ga.

Chester, A.J., R.L. Ferguson and G.W. Thayer. 1983. Environmental gradients and benthic macroinvertebrate distributions in a shallow North Carolina estuary. Bull. Mar. Sci. 33: 282-295.

Colby, D.R., G.W. Thayer, W.F. Hettler, and D.S. Peters. 1985. A comparison of forage fish communities in relation to habitat parameters in Faka Union Bay, Florida and eight collateral bays during the wet season. NOAA Tech. Memo. NMFS-SEFC-162. 87 p.

Eldred, B., R.M. Ingle, K. D. Woodburn, R.F. Hutton and H. Jones. 1961. Biological observations on the commercial shrimp, Penaeus duorarum Burkenroad, in Florida waters. Fla. Board Cons. 3: 1-139.

Fonseca, M.S., and J.S. Fisher. 1986. A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and restoration. Mar. Ecol. Pror. Ser. 29:15-22.

Fonseca, M.S., J.C. Zieman, G.W. Thayer and J.S. Fisher. 1983. The role of current velocity in structuring eelgrass (Zostera marina L.) meadows. Est. Coast. Shelf Sci. 17: 367-380.

Gauch, H.G., Jr. 1982. Multivariate analysis in community ecology. Cambridge University Press., New York. 298 p.

Ginsburg, R.N. 1956. Environmental relationships of grain size and constituent particles in some south Florida carbonate sediments. Bull. Am. Assoc. Petrol. Geol. 40: 2384-2427.

Heald, E.J. 1969. The production of organic detritus in a south Florida estuary. Ph.D. thesis, University of Miami, Fla. 110 p.

Heck, K.L., Jr., and R.J. Orth. 1980. Structural components of eelgass (Zostera marina) meadows in the lower Chesapeake Bay - decapod crustacea. Estuaries 3: 289-295.

Hellier, T.R. 1962. Fish production and biomass studies in relation to phytosynthesis in the Laguna Madre of Texas. Publs. Inst. Mar. Sci. Univ. Texas. 8: 212-215.

Hoese, H.D., and R.S. Jones. 1963. Seasonality of larger animals in a Texas grass community. Publs. Inst. Mar. Sci. Univ. Texas. 9: 37-46.

Hudson, J.H., D.M. Allen, and T.J. Costello. 1970. The flora and fauna of a basin in central Florida Bay. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. 604: 1-14.

Kenworthy, W.J., J.C. Zieman, and G.W. Thayer. 1982. Evidence for the influence of seagrasses on the benthic nitrogen cycle in a coastal plain estuary near Beaufort, North Carolina (USA). Oecologia 54: 152-158.

Kjelson, M.A., and D.R. Colby. 1977. The evaluation and use of gear efficiencies in the estimation of estuarine fish abundance, p. 416-424. In M.A. Wiley (ed.), Estuarine Processes, Vol. 2. Academic Press, New York.

Kjelson, M.A., and G.N. Johnson. 1978. Catch efficiencies of a 6.1-meter otter trawl for estuarine fish populations. Trans. Am. Fish Soc. 107: 246-254.

Lugo, A.E., and S.C. Snedaker. 1974. The ecology of mangroves. Annu. Rev. Ecol. Syst. 5: 39-64.

Massman, W.H., E.C. Ladd, and H.N. McCurcheon. 1952. A surface trawl for sampling young fishes in tidal rivers. Trans. 17th N. Am. Wildl. Conf. 386-392.

McFarland, W.N., J.C. Ogden and V.N. Lythgoe. 1979. The influence of light on the twilight migration of grunts. Environ. Biol. Fishes. 4:9-22.

Moody, W.D. 1950. A study of the natural history of the spotted seatrout, Cynoscion nebulosus, in the Cedar Key, Florida area. Q.J. Fla. Acad. Sci. 12: 147-171.

Nixon, S.W., and C.A. Oviatt. 1972. Preliminary measurements of midsummer metabolism in beds of eelgrass, Zostera marina. Ecology 53: 150-153.

Odum, W.E. 1970. Pathways of energy flow in a south Florida estuary. Ph.D. thesis, University of Miami, Fla. 162 p.

Odum, W.E., and E.J. Heald. 1975. The detritus-based food web of an estuarine mangrove community, p. 265-286. In L.E. Cronin (ed.), Estuarine Research, Vol. 1. Academic Press, New York.

Odum, W.E., C.C. McIvor, and T.J. Smith, III. 1982. The ecology of the mangroves of south Florida: A community profile. U.S. Fish Wildl. Serv., Biol. Serv. Prog. FWS/OBS-81/24. 144 p.

Ogden, J.C. and J.C. Zieman. 1977. Ecological aspects of coral reef-seagrass bed contacts in the Caribbean. Proc. 3rd Int. Symp. Coral Reefs. Univ. Miami. Miami, FL. 3:377-382.

Orth, R.J., and K.A. Heck, Jr. 1980. Structural components of eelgrass (Zostera marina) meadows in the lower Chesapeake Bay fishes. Estuaries 3: 278-288.

Orth, R.J., K.L. Heck, Jr., and J. van Montfrans. 1984. Faunal communities in seagrass beds: A review of the influence of plant structure and prey characteristics on predator-prey relationships. Estuaries 7: 339-350.

Perret, W.S., J.E. Weaver, R.O. Williams, P.L. Johnson, T.D. McIlwain, R.C. Raulerson, and W.M. Tatum. 1980. Fishery profiles of red drum and spotted seatrout. Gulf States Marine Fisheries Commission. Pub. No. 6: 60 p.

Powell, A.B., D.E. Hoss, W.F. Hettler, D.S. Peters, Larry Simoneaux, and Stephanie Wagner. 1987. Abundance and distribution of ichthyoplankton in Florida Bay and adjacent waters. South Florida Res. Cent. Report SFRC-87/01.

Powell, G.V.N., S.M. Sogard and J.G. Holmquist. 1986. Ecology of shallow water bank habitats in Florida Bay. Final Report to Everglades National Park, Contract No. CX5280-3-2339. 259 p.

Robblee, M.B. and J.C. Zieman. 1984. Diel variation in fish fauna of a tropical seagrass feeding ground. Bull. Mar. Sci. 34:335-345.

Rutherford, E., E. Thue, and D. Duker. 1982. Population characteristics, food habits and spawning activity of spotted seatrout, Cynoscion nebulosus, in Everglades National Park, Florida. South Florida Res. Cent., Rept.-668-48 p.

Rutherford, E.S., E.B. Thue, and D.G. Buker. 1983. Population structure, food habits, and spawning activity of gray snapper, Lutjanus griseus, in Everglades National Park. South Florida Res. Cent. Rept. SFRC-82/02. 41 p.

Schomer, N.S., and R.D. Drew. 1982. An ecological characterization of the lower Everglades, Florida Bay and the Florida Keys. U.S. Fish Wildl. Serv. Biol. Serv. Prog. FWS/OBS-82/58.1. 246 p.

Schmidt, T.W. 1979. Ecological study of fishes and the water quality characteristics of Florida Bay, Everglades National Park, Florida. Everglades National Park, Final Project Report No. RSP-EVER-N-36. 145 p.

Snapinn, S.M. and J.D. Knoke. 1984. Classification error rate estimators evaluated by unconditional mean square error. Technometrics 26:371-378.

Sogard, S.M. 1982. Feeding ecology, population structure, and community relationships of a grassbed fish, Callionymus pauciadiatus, in southern Florida. M.S. thesis, U. Miami, Coral Gables. 103 p.

Sogard, S.M., G.V.N. Powell and J.G. Holmquist. In press. Epibenthic fish communities on Florida Bay banks: Relationships with seagrass cores and physical environment. Mar. Ecol. Prog. Ser.

Starck, W.A., II. 1971. Biology of the gray snapper, Lutjanus griseus (Linneaus), in the Florida Keys. Stud. Trop. Oceanogr. (Miami). 10. 150 p.

Starck, W.A., II, and R.E. Schroeder. 1970. Investigations on the gray snapper, Lutjanus griseus. Stud. Trop. Oceanogr. Miami 10: 224 p., 44 figs.

Stewart, K.W. 1961. Contributions to the biology of the spotted seatrout (Cynoscion nebulosus) in the Everglades National Park, Florida. M.S. Thesis, Univ. Miami, Coral Gables: 103 p.

Stoner, A.W. 1980. The role of seagrass biomass in the organization of benthic macrofaunal assemblages. Bull. Mar. Sci. 30: 537-551.

Stoner, A.W. 1982. The influence of benthic macrophytes on the foraging behavior of pinfish, Lagodon rhomboides (Linnaeus). J. Exp. Mar. Biol. Ecol. 58: 271-284.

Stoner, A.W. 1983. Distribution ecology of amphipods and tanaidaceans associated with three seagrass species. J. Crust. Biol. 3: 505-518.

Tabb, D.C., and D.L. Dubrow. 1962. The ecology of northern Florida Bay and adjacent estuaries: Part I - Aspects of the hydrology of northern Florida Bay and adjacent estuaries. Fla. Board Conserv. Mar. Res. Lab. Tech. Ser. 39: 6-38.

Tabb, D.C., and R.B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957 through September, 1960. Bull. Mar. Sci. Gulf Caribb. 11: 552-649.

Tabb, D.C., and R.B. Manning. 1962. The ecology of northern Florida Bay and adjacent estuaries: Part II - Aspects of the biology of northern Florida Bay and adjacent estuaries. Fla. Board Conserv. Mar. Res. Lab. Tech. Ser. 39: 39-79.

Thayer, G.W., D.R. Colby, and W.F. Hettler. Jr. 1987. Utilization of the red mangrove prop root habitat by fishes in south Florida. Mar. Ecol. Prog. Ser. 35:25-38.

Day-Night Comparisons

Those species that dominated mangrove samples collected in daytime between June 1984 and May 1985 (Table 29) also were the dominant species collected during both the day and night in September 1985 (Table 32). There was, however, a tendency for Opsanus beta (gulf toadfish), Strongylura notata (redfin needlefish), and Menidia peninsulae (tidewater silverside) to be important components of the community sampled during the day-night phase of the study. Four species, Diapterus plumieri (striped mojarra), Orthopristis chrysoptera (pigfish), Haemulon plumieri (white grunt), and Arius felis (hardhead catfish) were taken in the day-night sampling but had not been collected previously. All but the striped mojarra are considered recreational species, and all were collected at night; only the white grunt was collected during both day and night (Table 32). These data suggest that some recreational and/or commercial fish may move into the prop root habitat at night to either feed or rest, and that extensive night sampling might provide additional species of fish to our list of those frequenting mangrove habitats.

An examination of the data in Table 32 reveals that while fish densities tended to be higher during daylight, this was not invariably true, even for a given species. Similarly, the numbers of species in samples taken at night were greater than in those taken during the day in five of the six paired comparisons (Table 32); often these differences are the consequence of the addition of relatively uncommon species of higher trophic levels. Finally, Shannon-Weiner diversity indices computed for the twelve samples also fail to show a consistent relation to the two temporal periods; in four cases they were higher at night whereas in the other two comparisons they were higher for the daytime samples (Table 32).

The binomial theorem provides a basis for testing the null hypothesis that a given species has an equal likelihood of being collected from the mangrove habitat during either the day or night. For example, if a species was taken on four different occasions, then the probability (under the null hypothesis) that all four samples were either night samples or were day samples is 0.125. To demonstrate a consistent day-night difference in a species' use of the mangrove prop root habitat then, we would require a consistency extending over at least six independent observations, wherein the probability would be less than 0.05 (actually it would be 0.0313 for six observations). We only had six paired observations from our samples, which is the minimum required number. Not one of the 34 species taken in the six pairs of samples demonstrated that level of consistency. The species that had the highest consistency with respect to being taken exclusively during either the day or the night was Sphyraena barracuda. It was taken only during the day and on three occasions ($p=0.25$). Although only suggestive, Floridichthys carpio was most frequently more abundant (5 our of 6 collections) during the day as were Eucinostomus argenteus (3 of 4 collections), Menidia peninsulae (2 of 2), and Strongylura timucu (2 of 3). Strongylura notata was collected only at night on four of five occasions; on the fifth occasion more were captured during the day than at night. Lutjanus griseus also was encountered more frequently at night in these trials.

It should be apparent that the geographical differences in the fish communities of the mangrove prop-root habitat observed in the earlier sampling make our investigation of day-night differences in utilization of the habitat very conservative, because the test of the day-night hypothesis for a given species