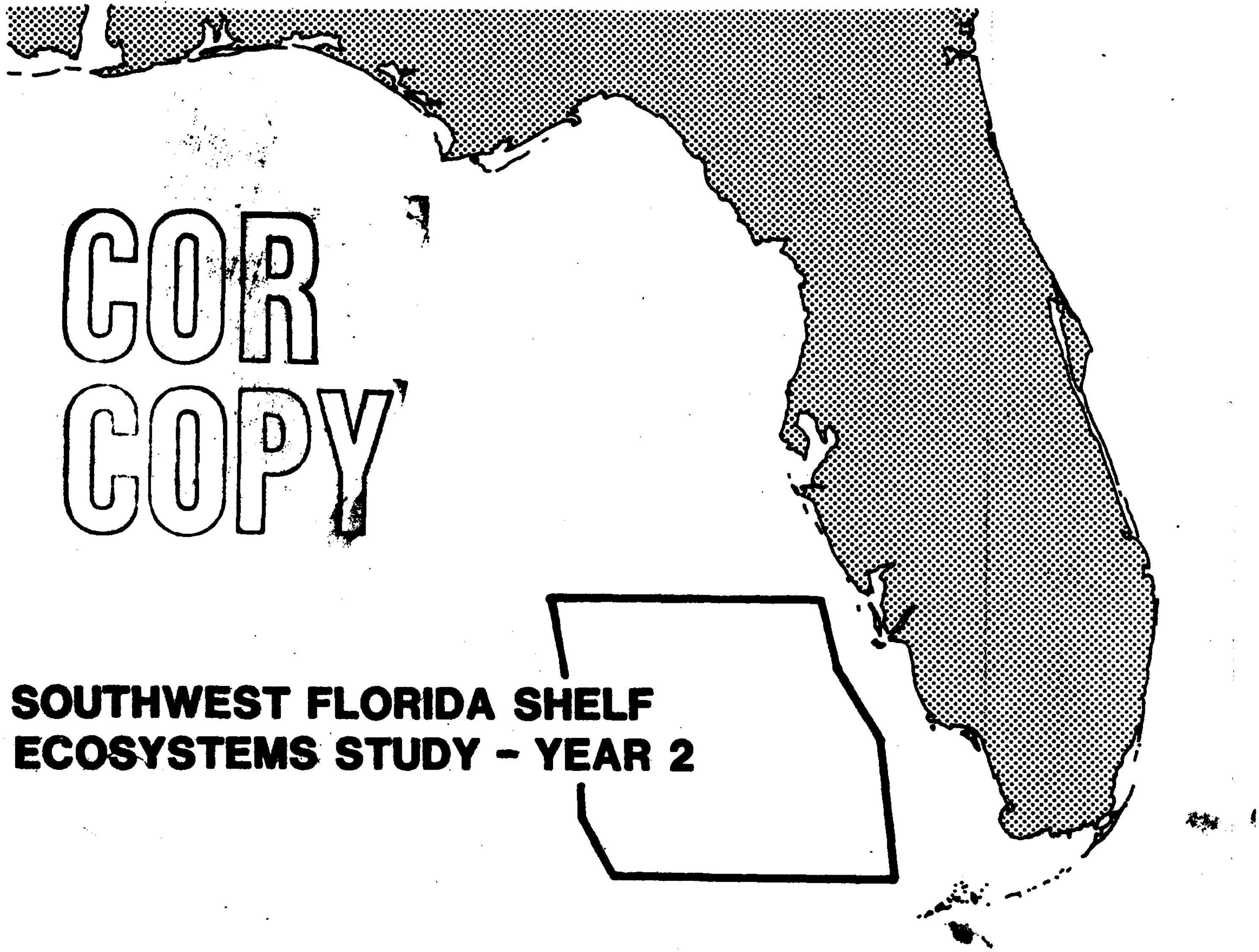
VOLUME 1 - EXECUTIVE SUMMARY

OCS Study
MMS 85-0060



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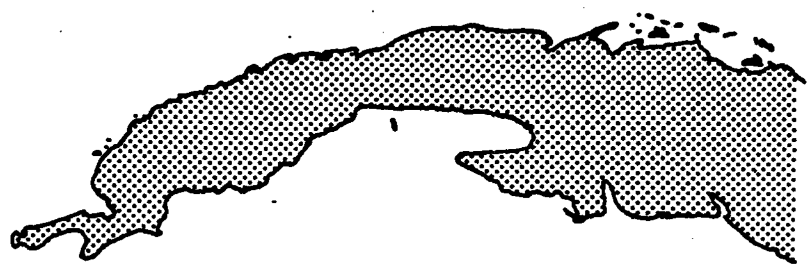
SOUTHWEST FLORIDA SHELF ECOSYSTEMS STUDY - YEAR 2



Prepared for:
U.S. Department of the Interior, Minerals Management Service
Gulf of Mexico OCS Region, Metairie, Louisiana
Contract 14-12-0001-29144
July 1985

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Woodward-Clyde Consultants
Consulting Engineers Geologists and Environmental Scientists

Continental Shelf Associates, Inc.
CSA
"Applied Marine Science and Technology"

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THE SOUTHWEST FLORIDA SHELF
ECOSYSTEMS STUDY
YEAR TWO
FINAL REPORT

Volume 1 - Executive Summary, provides a short, abstracted summary of the principal goals, methods used, and results obtained during the entire study program.

Volume 2 - Final Report I, includes a more complete introduction to the program, a summary of geophysical results, a complete discussion of methods used, and accounts of the physical oceanography and substrates that characterize the southwest Florida shelf.

Volume 3 - Final Report II, includes detailed accounts of the live bottom and soft bottom biota of the shelf.

Volume 4 - Final Report III, presents a synthesis of the physical variables and biological assemblages, outlines the potential impacts of OCS development, and provides lists of literature cited and program acknowledgments.

Volume 5 - Appendix A, provides copies of Year One and Year Two hydrographic and biological sampling cruise logs, sample collection times, station tract plots, and hydrographic and sediment data collected during both study years.

Volume 6 - Appendix B, includes the Master Taxon Code List for all taxa recorded during the program, and computer listings of all soft bottom sample station otter trawl and box core data collected during Years One and Two.

Volume 7 - Appendix C, provides computer listings of the live bottom sample station otter trawl, triangle dredge, and quantitative slide analysis data sets for Years One and Two.

CONTENTS

1.0 INTRODUCTION

Under the U.S. Department of the Interior's accelerated 5-year Minerals Management Service (MMS) Outer Continental Shelf (OCS) leasing program the MMS proposed offering certain tracts in the eastern Gulf of Mexico for lease. The coastal area and broad, shallow continental shelf off southwest Florida have been less thoroughly studied than most other areas around the Gulf of Mexico, and marine environmental information is scarce. Recognizing the possible existence of oil beneath the shelf, the demand for new domestic energy sources, and the scarcity of basic environmental information for the eastern Gulf of Mexico, the MMS initiated in 1980, the multi-year, multidisciplinary, SOUTHWEST FLORIDA SHELF ECOSYSTEMS STUDY PROGRAM.

The overall objectives defined for the Southwest Florida Shelf Ecosystems Study are as follows:

(1) To determine the potential impact of OCS oil and gas offshore activities on "live bottom" habitats and communities, which are integral components of the southwest Florida shelf ecosystem.

(2) To produce habitat maps that show the location and distribution of various bottom substrates. (This was to be done by exploring several widely spaced transects across the southwest Florida shelf.)

(3) To broadly classify the biological zonation across and along the shelf, projecting the percent of the area covered by live/reef bottoms and the amount covered by each type of live/reef bottom.

The following paragraphs provide a general perspective on first, second and third year activities within the Study Program:

Year One

During the Year One program, a variety of geophysical, hydrographic, and biological parameters were studied along five east-west transects (Transects A-E) across the southwest Florida shelf (Figure 1-1). Remote sensing geophysical data -- bathymetric, seismic and side scan sonar surveys -- were

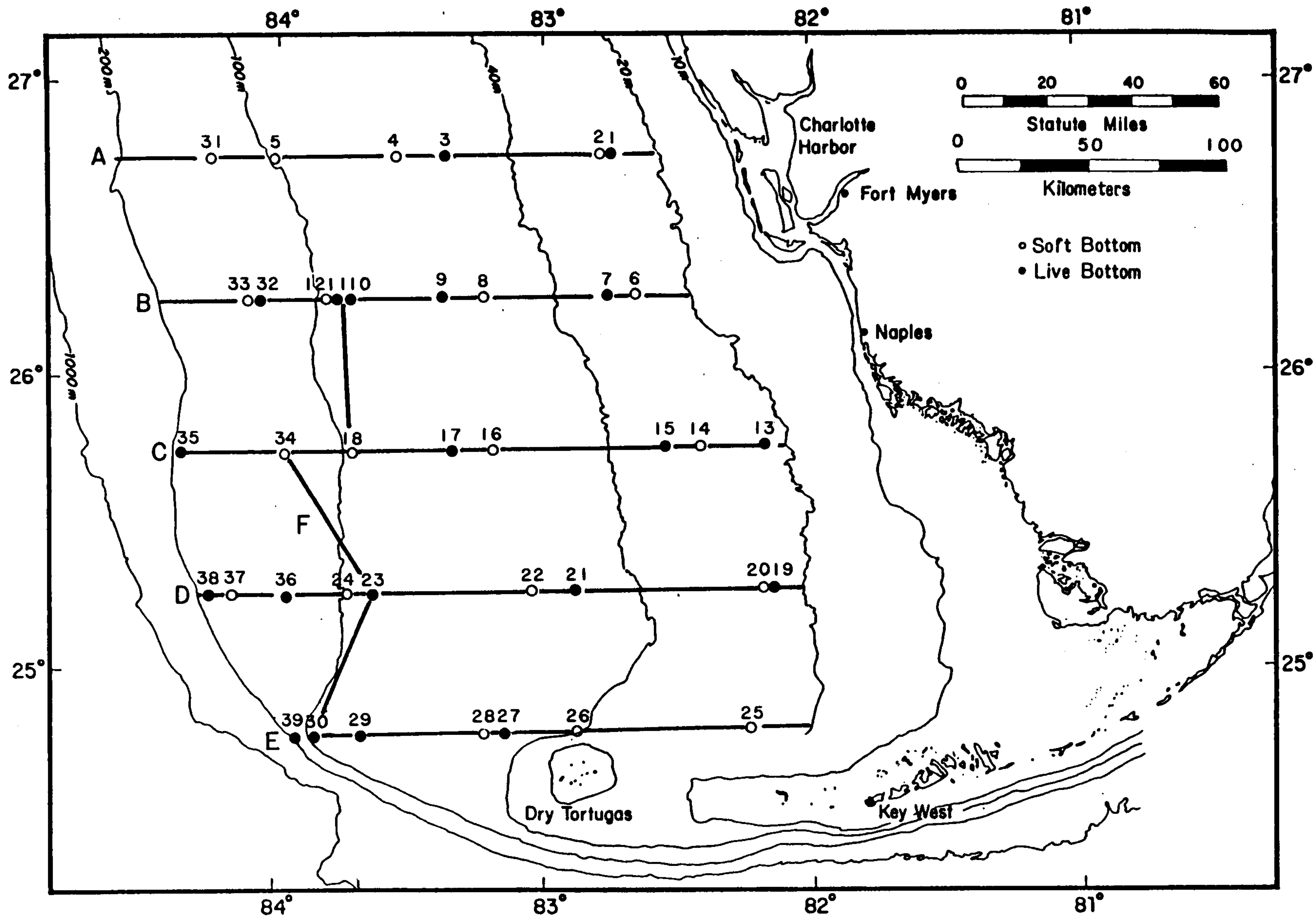


Figure 1-1. Southwest Florida shelf survey transects (A through F) and benthic sampling stations for Year One and Two programs.

collected along each transect from about 40m water depth out to 200m water depth. Visual "ground-truth" data -- combining black and white underwater television and 35mm, still color photography -- were collected in depths between 20 and 200m. Finally, a broad range of hydrographic measurements, water column samples, bottom sediment and benthic biological samples (e.g., triangle dredge, otter trawl and box cores) were collected from fifteen live bottom[1] and fifteen soft bottom[2] stations located along the various cross-shelf study transects (Figure 1-1, Stations 1 to 30). Each of these sampling stations was occupied twice during the Year One program, once during a Fall Cruise (October-November 1980) and again during a Spring Cruise (April-May 1981).

The geophysical and visual data were to be combined with results obtained from benthic sampling to refine the sea floor substrate identifications into interpretations of specific community types, with emphasis on speciation, diversity, biomass, recreational and commercial value.

Year Two

During the Year Two program, geophysical information was collected along a new north-south transect (Transect F), at about 100m water depth, that tied together several of the previously surveyed east-west transects (Figure 1-1). Visual data, again including underwater television and still camera photography, was extended along each east-west transect from 100 to 200m water depths, as well as along Transect F.

Twenty-one of the 30 hydrographic and benthic biological sampling stations occupied during Year One, were resampled twice more, once during a Summer Cruise (July-August, 1981) and again during a Winter Cruise (January-February, 1982). For this set of stations, hydrographic and biological data are now available on a seasonal (quarterly) basis. In addition, nine new hydrographic

[1]Hard bottoms with a rich assemblage of attached epifauna (see fans, sponges, corals, etc.) and fishes; includes rocky outcrops and rocky areas covered with a thin sand veneer.

[2]Soft sediments that support macroinfauna (worms, crustaceans, bivalves, etc.) and free-living epifauna (starfish), but no significant attached epifauna.

and benthic biological stations were established on Transects A through E, in water depths ranging from 100 to 200m (Figure 1-1, Stations 31 to 39).

Overall program objectives for Year Two remained the same as for Year One; however, the volume of biological data available for analysis proved to be about double that originally anticipated. A more complete understanding of possible seasonal changes resulted from combining results of all four seasonal cruises.

Year Two Modification

The Year Two Modification Contract, essentially a third year program, examined potential interactions between the Loop Current and the outer edge of the southwest Florida shelf. Two seasonal hydrographic cruises (April and September 1982) provided data that were synthesized with Year One and Year Two results to yield a hydrographic analysis and atlas of water quality parameters (temperature, salinity, transmissivity, chlorophyll *a*, phosphates, nitrates, nitrites and dissolved silica). Primary productivity measurements taken during both cruises allowed meaningful interpretations to be placed on nutrient and other physio-chemical data. A simultaneous overflight by the NASA Ocean Color Scanner during the April 1982 Cruise allowed chlorophyll and productivity to be estimated throughout the region during the spring bloom, a period of great importance. Additionally, optical oceanographic measurements allowed reduction of the Color Scanner data, and yielded data concerning the apparent unusual depth of significant photosynthetic activity in the area, and the occurrence of turbidity "fronts" encountered during previous cruises.

The overall goal of the Year Two Modification Contract was to synthesize existing and newly obtained hydrographic and primary productivity data into an overview of the driving energetic forces within the southwest Florida shelf regional ecosystem.

This EXECUTIVE SUMMARY is part of the 7-Volume Year Two Final Report, itself the last of some seventeen publications submitted to the MMS under the terms of Woodward-Clyde Consultants' Year One, Year Two, and Year Two Modification study contracts.

2.0 SHELF CHARACTERIZATION

High-resolution, multi-system geophysical surveys, underwater television, and still camera "ground-truth" surveys, conducted during Year One and Year Two Cruises, were used to broadly classify bottom substrates and benthic biological communities across the southwest Florida Shelf. An integrated interpretation of these data sets has already been presented as a MARINE HABITAT ATLAS (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983).

Generalized distributions of the five sea floor substrate types (Rock Outcrops; Thin Sand Over Hard Substrate; Soft Sand Bottom; Coralline Algal Nodule Layer over Sand; and Algal Nodule Pavement with Coral [Agaricia spp.] Accumulations) and nine biological assemblages (two "soft bottom," and seven "live bottom" assemblages) distinguished during the surveys are shown in Figure 2-1. Each biological assemblage "type" includes a distinctive group of dominant organisms readily identified from television observations.

Approximately half the southwest Florida shelf seafloor videotaped and photographed along Transects A through F consisted of Soft Sand Bottom. This bottom type occurred on all transects studied and in all water depths (20 to 200m). The Thin Sand Over Hard Substrate bottom type was intermixed with Soft Sand Bottoms on all transects. Taken together these two substrate categories accounted for nearly 90% of the total area studied.

Rock outcrops were identified in 20m water depths on Transects C and D, at 75 to 80m water depths on Transects C and D, at 75 to 80m depths on Transect B, and scattered across the 100 to 185m depth range on Transects C, D, E, and F. The Coralline Algal Nodule Layer over Sand was scattered along Transects B, D, E, and F, in 62 to 108m water depths. Algal Nodule Pavement with Coral Accumulations was restricted to 64 to 80m water depths on Transect E.

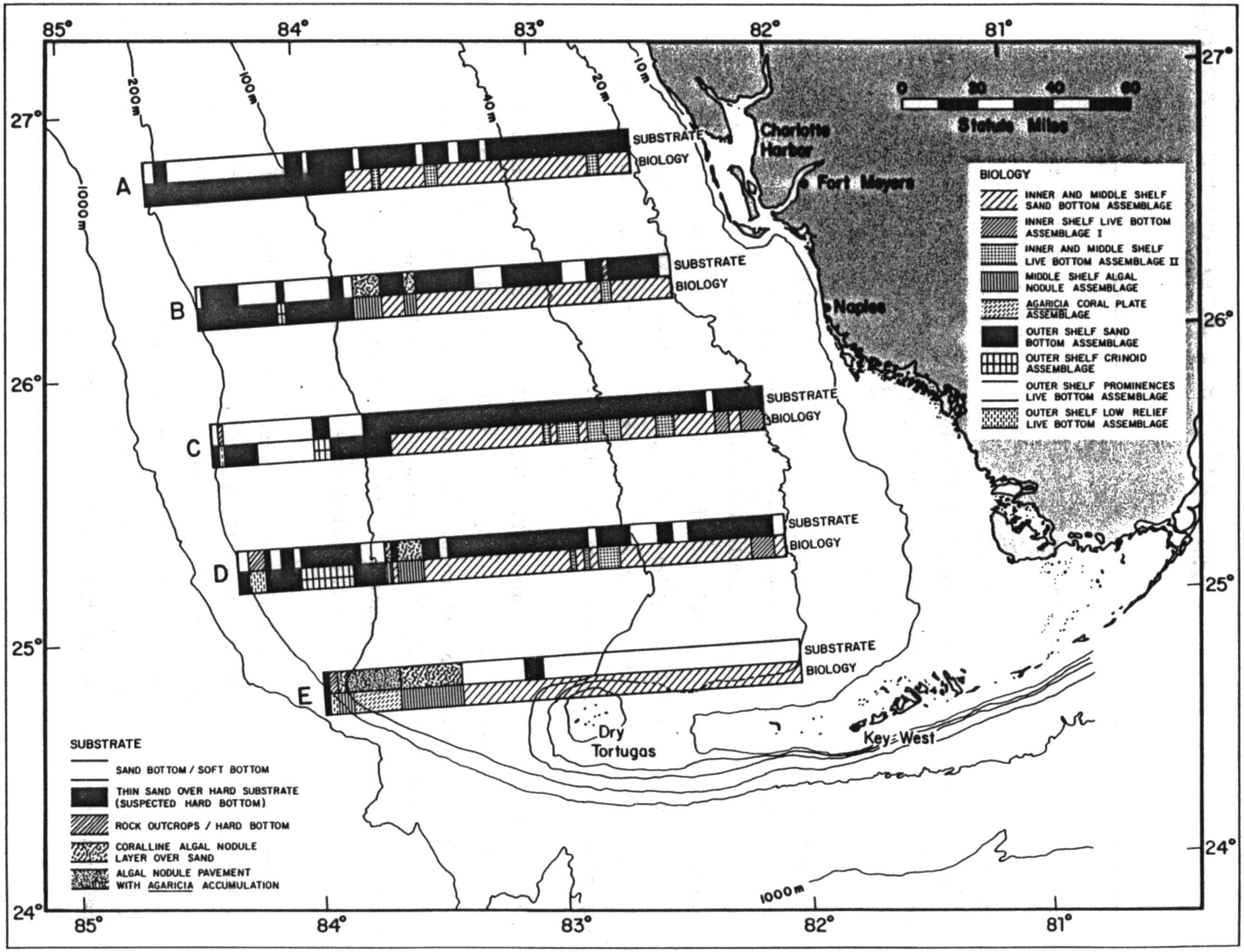


Figure 2-1. Generalized map of marine habitats along Transects A through E.

The Coralline Algal Nodule Layer over Sand and Algal Nodule Pavement with Coral Accumulations Substrates may be deeper water successional stages of the Soft Sand Bottom substrate, as suggested in Figure 2-2.

An across-shelf analysis of the nine biological assemblages (Table 2-1) reveals three readily distinguished major biological depth zones: 20 to 60m, 60 to 90m, and 90 to 200m, respectively.

The 20 to 60m water depth zone contained the Inner and Middle Shelf Sand Bottom Assemblage, the Inner Shelf Live Bottom Assemblage I, and the Inner and Middle Shelf Live Bottom Assemblage II.

The 60 to 90m water depth zone contained the previously mentioned Inner and Middle Shelf Sand Bottom Assemblage and Inner and Middle Shelf Live Bottom Assemblage II. The Outer Shelf Sand Bottom Assemblage occurred in this zone as well as in the 90 to 200m water depth zone. The 60 to 90m water depth zone thus appears to be a transition area between the two shelf sand bottom assemblages. The *Agaricia* Coral Plate Assemblage was restricted to this zone, while the Middle Shelf Algal Nodule Assemblage occurred here, but extended out to 100m water depth on Transect E.

The 90 to 200m bathymetric zone was dominated in percent coverage by the Outer Shelf Sand Bottom Assemblage, with the Outer Shelf Crinoid Assemblage, the Outer Shelf Prominences Live Bottom Assemblage, and the Outer Shelf Low-Relief Live Bottom Assemblage restricted to this depth zone.

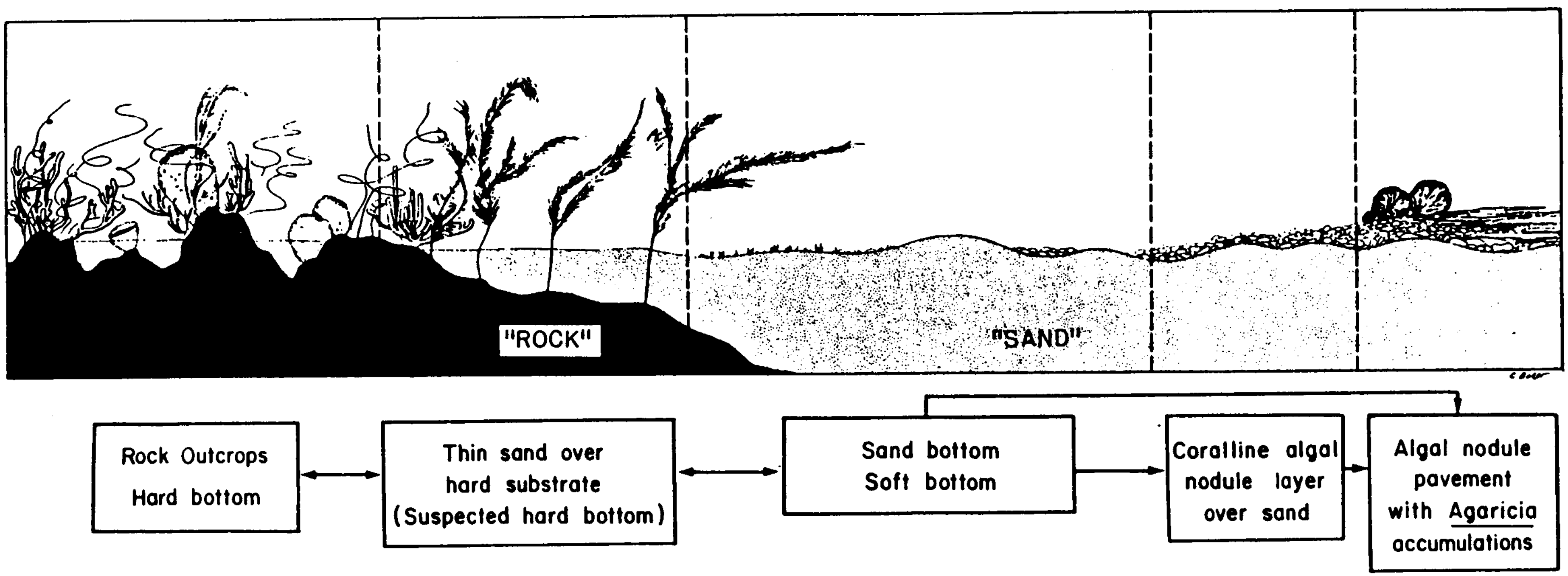


Figure 2-2 . Generalized classification scheme for sea floor substrate types.

Table 2-1. Percent coverage of biological assemblages along combined transects (A through F) in 10-metre depth intervals.

Biological Assemblages	10-Metre Depth Intervals Along Transects 20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	110–120	120–130	130–140	140–150	150–160	160–170	170–180	180–190	190–200
Inner and Middle Shelf Sand Bottom Assemblage	83.2	86.9	77.2	87.9	73.1	41.6												
Inner Shelf Live Bottom Assemblage I	14.1																	
Inner and Middle Shelf Live Bottom Assemblage II	2.7	13.1	22.8	12.1	3.0	2.4	4.1											
Middle Shelf Algal Nodule Assemblage					21.9	38.9	59.5	5.0										
Agaricia Coral Plate Assemblage					2.0	7.7	12.5											
Outer Shelf Sand Bottom Assemblage						9.4	23.9	92.1	91.2	73.4	55.5	37.0	49.2	64.4	78.2	80.2	97.3	90.0
Outer Shelf Crinoid Assemblage								0.4	8.8	21.6	40.9	52.2	8.1		0.9			
Outer Shelf Prominences Live Bottom Assemblage												9.8	31.0	27.7	13.2			
Outer Shelf Low-Relief Live Bottom Assemblage								2.5		5.0	3.6	1.0	11.7	7.9	7.7	19.8	2.7	10.0

3.0 SAMPLING, METHODS, & DATA ANALYSIS

The purpose of the field sampling and data collection phase of the program was to characterize both the water column and benthic environments at specific locations along the previously surveyed study transects (Figure 1-1). This characterization permitted development of between-station and between-cruise comparisons in order to assess the spatial and temporal variability of the marine ecosystem.

Fifteen live bottom and fifteen soft bottom stations were sampled during the Fall (1980) and Spring (1981) Cruises of the Year One Contract and during the Summer (1981) and Winter (1982) Cruises of the Year Two Contract. The Year One and Year Two stations differed, with only 21 common sites being sampled during both programs (Table 3-1). Each station consisting of a 1000m-square block located around a selected station center point. The types of samples and data collected from within each station block are listed in Table 3-2. Analytical procedures performed on the biological data sets are listed in Table 3-3, those performed on the physical data sets in Table 3-4. It is important to note that ALL ANALYSES WERE PERFORMED ON THE CORRECTED-UPDATED, COMBINED YEAR ONE AND TWO DATA SETS. Complete data listings are provided in Volumes 5, 6, and 7 of this report.

Data Analysis proceeded in four successive phases. Once entered into the computerized database, each data set was first checked for accuracy and completeness, then run through several data summary routines (total taxa, faunal density, rank order and relative abundance, species diversity, etc.). Cluster Analysis was next used to classify the various sample sites into groups, according to the similarity or dissimilarity of their species composition and abundance. Since many of the physical variables measured in this study were highly correlated, Principal Components Analysis was used to derive a reduced number of more independent physical (environmental) variables for further study. Weighted Discriminant Analysis was used for the final analytical phase, in which we sought to identify physical variables that might explain the biological separation of sample-site groups indicated by the Cluster Analysis.

Table 3-1. List of stations sampled during the Year One and Year Two programs.

Station	Bottom Type	Depth (m)	Year One: Fall Cruise (1980)	Year One: Spring Cruise (1981)	Year Two: Summer Cruise (1981)	Year Two: Winter Cruise (1982)
1	Live	24	X	X	X	X
2	Soft	25	X	X		
3	Live	50	X	X	X	X
4	Soft	56	X	X	X	X
5	Soft	90	X	X	X	X
6	Soft	26	X	X	X	X
7	Live	30	X	X	X	X
8	Soft	48	X	X		
9	Live	56	X	X	X	X
10	Live	71	X	X		
11	Live	77	X	X	X	X
12	Soft	90	X	X	X	X
13	Live	20	X	X	X	X
14	Soft	26	X	X	X	X
15	Live	31	X	X	X	X
16	Soft	54	X	X	X	X
17	Live	59	X	X		
18	Soft	87	X	X		
19	Live	23	X	X		
20	Soft	22	X	X	X	X
21	Live	45	X	X	X	X
22	Soft	52	X	X	X	X
23	Live	70	X	X	X	X
24	Soft	88	X	X	X	X
25	Soft	24	X	X	X	X
26	Soft	38	X	X		
27	Live	54	X	X		
28	Soft	58	X	X	X	X
29	Live	60	X	X	X	X
30	Live	76	X	X		
31	Soft	142			X	X
32	Live	137			X	X
33	Soft	146			X	X
34	Soft	135			X	X
35	Live	159			X	X
36	Live	127			X	X
37	Soft	148			X	X
38	Live	159			X	X
39	Live	152			X	X

Table 3-2. Samples and data collected during Year I and Year II programs; "X" indicates samples/data were obtained at all Year I or Year II stations (see Table 3-1).

Sample Type	Year I		Year II	
	Fall	Spring	Summer	Winter
WATER COLUMN (all stations)				
STD/DO Profile	X	X	X[1]	X[1]
Salinity Samples (near-surface and near-bottom)	X	X	X1	X[1]
Dissolved Oxygen Samples (near-surface and near-bottom)	X	X	X1	X[1]
Temperature (reversing thermometer)	X	X	X[1]	X[1]
Transmissivity Profile	X	X	X[1]	X[1]
Photometer Profile (daylight only)	X[2]		X[3]	X[3]
Nutrients (inorganic nitrogen, phosphate and silicate)	X	X	X1	X[1]
Chlorophyll a	X	X	X[1]	X[1]
Yellow Substance	X	X		
BENTHIC				
Television Videotapes (black and white; all stations)	X	X	X	X
Still Camera Photographs (35-mm color; all stations)	X	X	X	X
Box Cores (soft bottom stations)	X	X	X	X
Macroinfauna (soft bottom stations)	X	X	X	X
Sediment Grain Size (soft bottom stations)	X	X	X	X
Sediment Total Carbonate (soft bottom stations)	X	X	X[4]	X[4]
Sediment Hydrocarbons (soft bottom stations)	X		X[4]	
Sediment Trace Metals (Ba, Cd, Cr, Cu, Fe, Pb, Ni, Va, Zn; soft bottom stations)	X			
Triangle Dredge Epifauna and Macroalgae (live bottom stations)	X	X	X	X
Otter Trawl Epifauna and Macroalgae (all stations)	X	X	X	X

[1]Samples/data obtained from 15 selected stations.
[2]Data obtained at only 12 stations.
[3]Data obtained at only 7 stations.
[4]Samples only at the 4 "new" deep-water soft bottom stations (Stations 31, 33, 34, and 37).

Table 3-3. Listing of analyses performed on biological data sets.

Analysis Performed	Live Bottom Data Set			Soft Bottom Data Set	
	TDS	OTH	QSA	BCI	OTS
Formatted Listing of Raw Data	X	X	X	X	X
Rank Order and Relative Abundance Tables	X	X	X	X	X
No. of Taxa Captured, by Major Taxonomic Group	X	X	X		
Mean Percent Cover, by Major Taxonomic Group			X		
Mean Percent Total Biotic Cover			X		
Mean Percent Cover for Dominant Taxa			X		
Sampling Methods Comparison, by Major Taxonomic Group	X	X	X	X	X
Total Number of Taxa Captured	X	X	X	X	X
Total Faunal Density				X	
Species Richness, Equitability, Diversity				X	
Cluster Analysis	X	X	X	X	X
Weighted Discriminant Analysis	X	X	X	X	X
Rarefaction Analysis			X	X	
Species Saturation Analysis	X		X	X	

TDS - Live Bottom Triangle Dredge Data

OTH - Live Bottom Otter Trawl Data

QSA - Live Bottom Quantitative Slide Analysis Data

BCI - Soft Bottom Box Core Data

OTS - Soft Bottom Otter Trawl Data

Table 3-4. Listing of physical data sets and computer analyses performed.

Physical Data Set	Analysis Performed: Computerized Database	PCA	SC	WDA
Chlorophyll a (Acid Method)	X		X	
Chlorophyll a (Fluorometer)	X		X	
Chlorophyll a (Trichromatic)	X		X	X
Dissolved Oxygen (Hydrolab)	X		X	
Dissolved Oxygen (Titration)	X		X	X
Inorganic Nitrogen	X	X	X	X
Nitrite	X	X	X	X
Phosphate	X	X	X	X
Silicate	X		X	X
Photometer Readings				
Phaeopigments (Acid Method)	X		X	
Phaeopigments (Fluorometer)	X		X	X
Salinity	X		X	X
Temperature (Hydrolab)	X		X	
Temperature (Reversing Thermometer)	X		X	X
Temperature (Transmissometer)	X		X	
Transmissometer Readings	X		X	X
Yellow Substance Values				
Sediment Grain Size	X	X	X	X
Sediment Hydrocarbons				
Sediment Trace Metals				

PCA - Principal Components Analysis

SC - Simple Correlations

WDA - Weighted Discriminant Analysis

4.0 HYDROGRAPHY

Hydrographic parameters play an important role in determining the biological and ecological features of a marine ecosystem. To assess the ecological characteristics of the southwest Florida continental shelf more accurately, hydrographic data were collected during Year Two Summer (July 16 - August 5, 1981) and Winter (January 28, - February 15, 1982) Cruises in support of benthic biological data collection.

The hydrographic data were plotted on a series of vertical cross sections along study Transects A through E. Plots showing a single parameter across all transects provide an approximately synoptic three-dimensional view of shelf conditions (Figure 4-1), while plots showing the same transect during all four seasonal cruises provide an overview of temporal changes (Figure 4-2).

Summer Cruise Summary

A shallow mixed layer (25m) at the midshelf and offshore stations indicated summer thermal stratification with no intense mixing. The innershelf stations on Transects A and B were also stratified; those on Transects C , D , and E were not (Figure 4-1). The temperature and salinity were higher at Stations 13, 20, and 25 (36.4 o/oo), reflecting summer heating and evaporation in the Florida Bay area. Low salinity pockets (35.6 o/oo) were observed in the upper 30m of midshelf Stations 4, 9, and 22. These low salinity pockets are not uncommon on the shelf, and may represent entrained coastal Mississippi water.

Dissolved oxygen values associated with given water temperatures and salinities were comparable to those found during Year One Fall and Spring sampling. The offshore stations all exhibited near-bottom decreases in oxygen with decreasing temperatures below the mixed layer. No oxygen depletion was observed at any station.

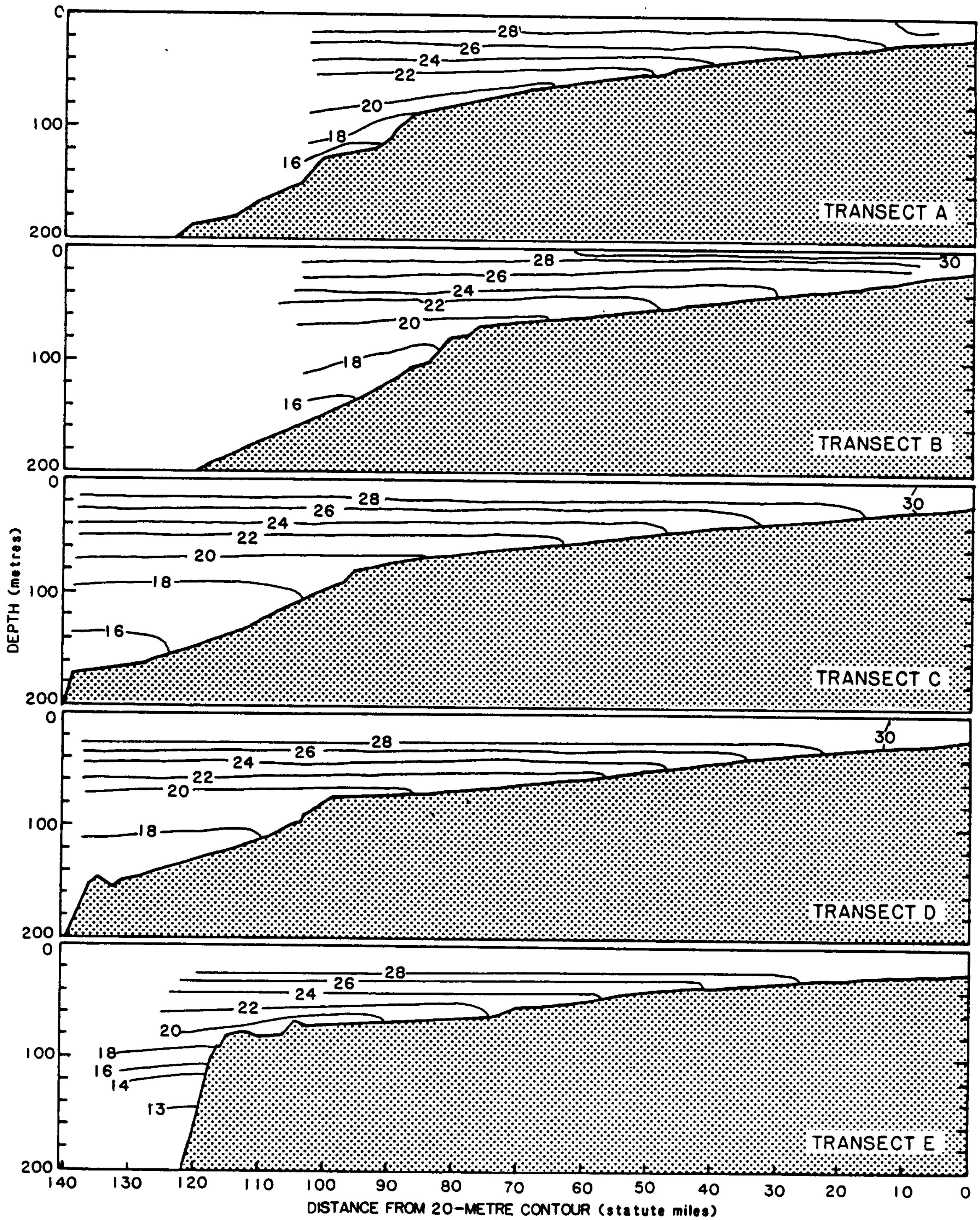


Figure 4-1. July-August 1981 temperature (°C) cross-sections.

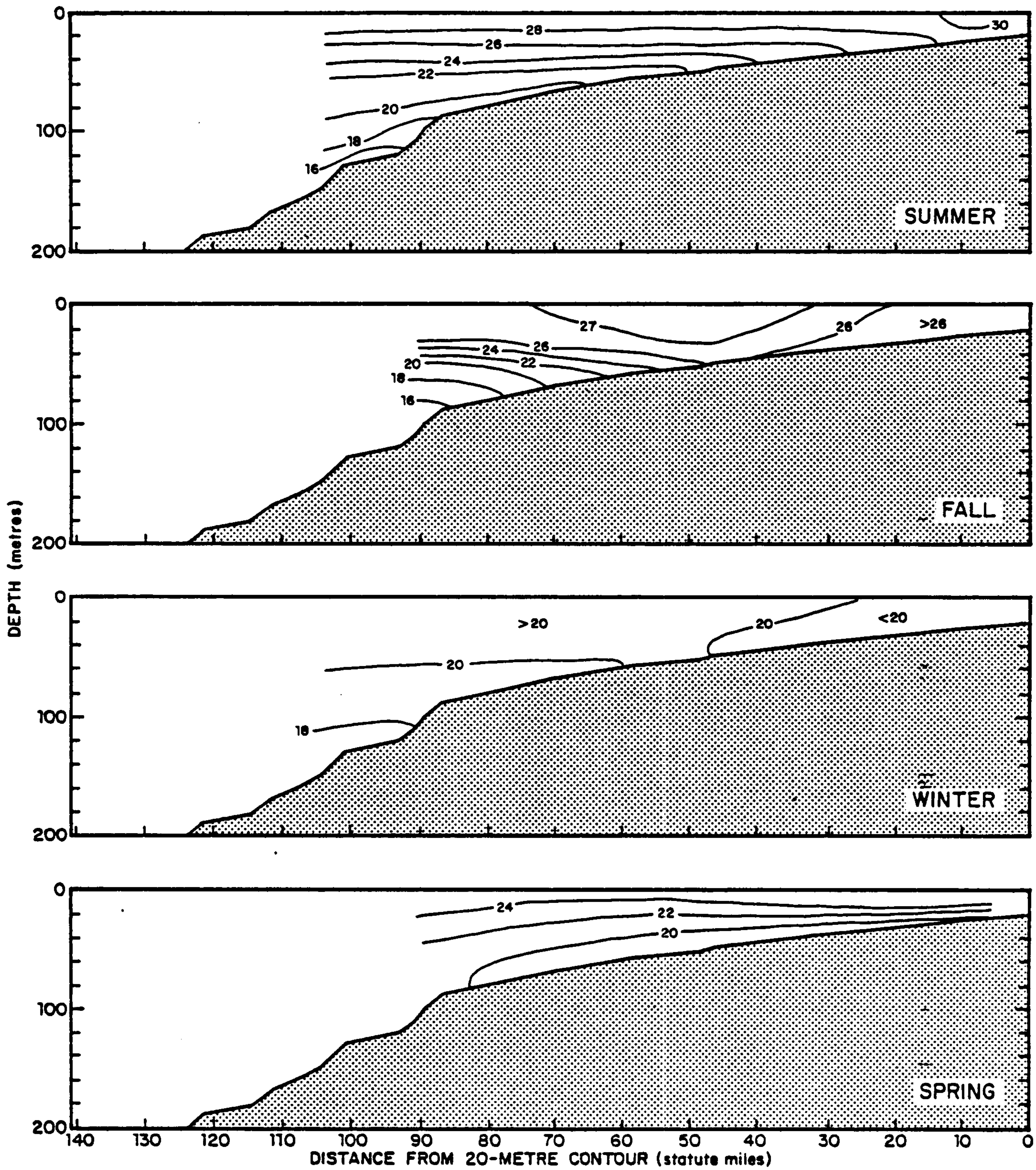


Figure 4-2 . Seasonal temperature (°C) distributions on Transect A.

High transmissivity values (generally >90%) indicated very clear waters over the entire study area. A slight increase in turbidity was observed at the inner shelf stations, probably due to coastal influences such as mixing, increased phytoplankton growth and high resuspension potential. There were no indications of intense bottom resuspension due to currents.

Dissolved nutrients were limiting in the surface mixed layer during the Summer Cruise. PO_4-P was less than 0.1 μM above the thermocline and did not exceed 1.2 μM below the thermocline. NO_2-NO_3-N concentrations were generally less than 0.3 μM in the mixed layer. The offshore stations on Transects A and B had higher concentrations (0.5 to 1.0 μM) near the surface, but nutrients were still limiting for phytoplankton growth as observed in Chlorophyll (Chl) a values at these stations. Increases in both PO_4-P and NO_2-NO_3-N concentrations occurred with decreasing temperature and increasing depth.

The contribution of nutrients to phytoplankton abundance was reflected in Chl a concentrations throughout the water column. During the Summer Cruise offshore stations had Chl a maxima at subsurface depths. The upper depths of the maxima were found at 50 to 80m, with the higher concentrations often extending below 100m. When comparing these depths to the one-percent light attenuation depths (50 to 70m) at the offshore stations, it is apparent that the phytoplankton standing crop was maximizing at or below the one-percent attenuation depths and at the top of the nutricline. Above these depths the waters were nutrient-limited and Chl a values decreased to <0.1 mg/m^3. Station 35 had a high Chl a maximum (>0.5 mg/m^3) between 37 and 127m depths, which corresponded to a salinity maximum and a high NO_2-NO_3-N pocket. This was undoubtedly the result of upwelling from greater depths, bringing nutrients into the photic zone and stimulating phytoplankton growth.

The midshelf stations did not appear impacted by higher offshore nutrients, but a near-bottom increase in Chl a was observed at all stations; nutrient regeneration could be responsible. The surface waters of the innershelf stations were higher in Chl a than the corresponding mid and outer shelf waters, probably reflecting coastal influences and greater mixing potential.

Winter Cruise Summary

Satellite derived positions of the Loop Current during the Winter Cruise indicated that a Loop Current filament had penetrated the study area and was affecting Stations 33 (Transect B) and 35 (Transect C) directly during sampling. The effect of this filament was most readily observable at Station 35, where warmer Loop Current waters penetrated to the bottom. Outershelf Stations 31, 38, and 39 were not being affected by the filament directly while sampled, but were certainly being affected by the dynamics of the system. A large meander of shelf water was influencing Stations 38 and 39. This type of meander is common for this area and may have enhanced upwelling at these two southern stations. It is apparent that the Loop Current proper, when flowing along the shelf slope isobaths, induces upwelling of colder nutrient-rich waters, but when directly impinging on a given location can suppress this deep water upwelling. It can be assumed that as the Loop Current (and associated filament eddies) moves toward or away from the shelf in conjunction with the along-shore flow, deep water upwelling can be further suppressed or enhanced.

During the Winter Cruise, the surface thermal mixed layer generally extended to 30 to 40m depths at the outer shelf stations, while the midshelf stations on Transects A, B, and C had minor stratification (Δ T = 1-2°C) from surface to bottom. The midshelf stations on Transects D and E were more stratified (Δ T = 3-4°C) primarily due to warmer surface waters at those stations. Bottom temperatures at the midshelf station only ranged from 19.5 to 21.6°C and did not suggest any major bottom influences at any of the midshelf stations. Similar patterns were observed in salinity values. Salinities were essentially homogeneous at the innershelf stations. The salinities at the midshelf and innershelf stations were predominantly 36.4 o/oo. At stations 13, 20, 22, and 28, the values exceeded 36.5 o/oo.

Transmittance values were high (~90%) throughout the study area, with slight decreases in clarity near the bottom. Offshore Station 33 had a sharp near-bottom nepheloid layer (high turbidity), suggesting currents dynamic enough for bottom sediment resuspension. Innershelf Station 25 also had a near-bottom nepheloid layer, most likely induced by local tidal action.

When Chlorophyll a concentrations were compared with nutrient concentrations, it was apparent that the Winter Cruise Chl a maximum (at the outward midshelf stations) occurred in conjunction with the location of the top of the nutricline. If the 0.3 mg/m^3 level is used as a basis for the maximum envelope, then the Chl a maxima were found between 34 and 84m and the envelopes extended from 15 to 40m in vertical widths. Offshore Station 35 had a Chl a maximum at 60m and a secondary maximum at 127m. This was related to the warm water Loop Current impingement reflected in all the measured variables. Near-bottom increases were observed at the midshelf stations in conjunction with temperature decreases and nutrient increases. Station 22 had the maximum Chl a concentration (0.73 mg/m^3) for the entire Winter Cruise and corresponded to the lowest midshelf temperature, highest midshelf salinity and highest midshelf NO_2-NO_3-N concentrations. The innershelf stations generally had near-bottom increases in Chl a, but they were less than those observed midshelf. The severe drought occurring during 1981-82 may have decreased any coastal water influence to these areas, further decreasing the standing crop.

Seasonal Summary Overview

This section draws together data from all four seasonal cruises and presents a seasonal characterization of the southwest Florida Shelf study area.

Temperature -- Surface values range from 28° to 30°C in summer to ~20°C in winter. The strongest thermoclines were observed in spring and summer (Figure 4-2). This is typical as the spring warming surface waters mix vertically into the water column. During the Spring Cruise the thermocline was shoreward of the innershelf (20m isobath) stations. As summer heating intensified, the shoreward extent of the thermocline was mixed out to deeper isobaths (~20 to 30m). A strong thermocline was observed at the midshelf stations (50m isobath) during both Spring and Summer Cruises. Fall temperature data reflect the transition to winter conditions. Cold fronts begin to penetrate the study area, cooling surface waters and mixing the thermocline in a shoreward direction. During the winter regime the mixed surface layer extends deeper, from the 10 to 30m depths found during the spring, summer, and fall regimes, to 40 to 60m depths.

Salinity -- The total range of salinity varied only 2 o/oo (35 to 37 o/oo) over the entire study area. Lower salinity lenses (relative to the surrounding waters) were observed on the mid to outer shelf during the Summer, Fall and Winter Cruises. The most significant lenses were observed during the Fall Cruise, extending to 20m in depth and having minimum salinities of <35.6 o/oo. Also during the Summer, Fall, and Winter Cruises, the general trend in the upper 40m was an increase in salinity in the shoreward direction.

Fall and Spring Cruises exhibited "normal" salinity patterns relative to seasonal climatological events. Fall salinities were stratified while the spring salinities were partitioned in a cross-shelf direction, a result of winter mixing. Halocline boundaries generally coincided with thermocline isolines.

Transmissivity -- Transmittance values (generally >90%) indicated the predominance of clear waters over the entire study area. Winter Cruise measurements showed the least variation, probably a result of winter mixing events, while the greatest isoline structure was observed during the Fall Cruise. This cruise also yielded the lowest transmittance values. This decrease in water clarity correlated with higher Chlorophyll a values, suggesting phytoplankton increases as a major contributor to the reduced transmittance. Occasional near-bottom increases in turbidity, suggested bottom resuspension from current activity.

Dissolved Oxygen -- No clear seasonal patterns were evident. Surface values ranged from 5.47 to 7.01 ml/l. Offshore near-bottom oxygen values were the lowest observed during the four cruises, generally being 4 to 5 ml/l.

Dissolved Nutrients -- Phosphate (PO_4-P), nitrite-nitrate (NO_2-NO_3-N) and silica (S_iO_2) were measured. With few exceptions the surface mixed layers had low concentrations of nutrients. However, concentrations increased below the pycnocline, occurring below the salinity maximum and with decreasing temperatures. The source of these nutrients lies in the open Gulf of Mexico waters, below 200m depths. The higher nutrient concentrations varied among transects and were most likely affected by local and mesoscale events.

Chlorophyll a -- Chlorophyll *a* concentrations ranged from <0.1mg/m^3 to <1.5mg/m^3. In temperate waters Chl *a* concentrations are generally highest in the spring and fall, as waters warm and mix, respectively. In the sub-tropical-tropical waters of the southwest Florida shelf this was not evident. Generally, the mixed layer had concentrations of <0.1mg/m^3 and could be considered oligotrophic during all seasons. Nearshore Chl *a* increases were occasionally observed, suggesting a coastal contribution to the standing crop. The most significant and consistent higher levels of Chl *a* (0.3 to 1.0 mg/m^3) were found as subsurface maxima within the pycnocline (40 to 100m) during all four cruises. When comparing these depths to the light penetration data it is apparent that the phytoplankton standing crop was maximizing at or below the one-percent attenuation depth and at the top of the nutricline. Above these depths the sources of nutrients necessary for the photosynthetic process declined and a corresponding decrease in Chl *a* was observed.

5.0 SUBSTRATES

Since substrate plays an important role in determining the benthic biological assemblage present at a particular location, sea floor substrate surveys were conducted at each sampling station during various seasonal cruises. Underwater television videotapes and 35mm still camera photographs were used to characterize each of the 20 live bottom and 19 soft bottom sampling stations (Figure 5-1). Each station's location, depth and bottom relief, general substrate type, substrate composition, and sedimentary structures were described.

Live Bottom Stations

Underwater television indicated the occurrence of six major substrate types at live bottom stations. These were Rock Outcrops/Hard Bottom, Thin Sand over Hard Substrate, Sand Bottom/Soft Bottom, Coralline Algal Nodule Layer over Sand, Algal Nodule Pavement with Agaricia Accumulations, and Coarse Rubble (dead) with Attached Crinoids. The first five types, previously categorized during the Year One and Two ground-truthing cruises, were described in Section 2.0. The sixth category, however, was only observed during the Year Two biological sampling program at a single deep-water site (Station 38). All substrate types except Sand Bottom/Soft Bottom were indicative of live bottom areas. The relative abundance of different substrate types at each 1000m-square live bottom station (percent cover, averaged for total television coverage, all cruises) is listed in Table 5-1.

The majority of live bottom sites were primarily composed of a mixture of Thin Sand over Hard Substrate and Sand Bottom/Soft Bottom substrates. All stations at water depths from 20 to 60m were of this group. Also included were three outer shelf stations (32, 35 and 36) on Transects B, C and D. The coralline algal nodule substrate type predominated at three locations (Stations 10, 11 and 23) at 70 to 80m depths on Transects B and D.

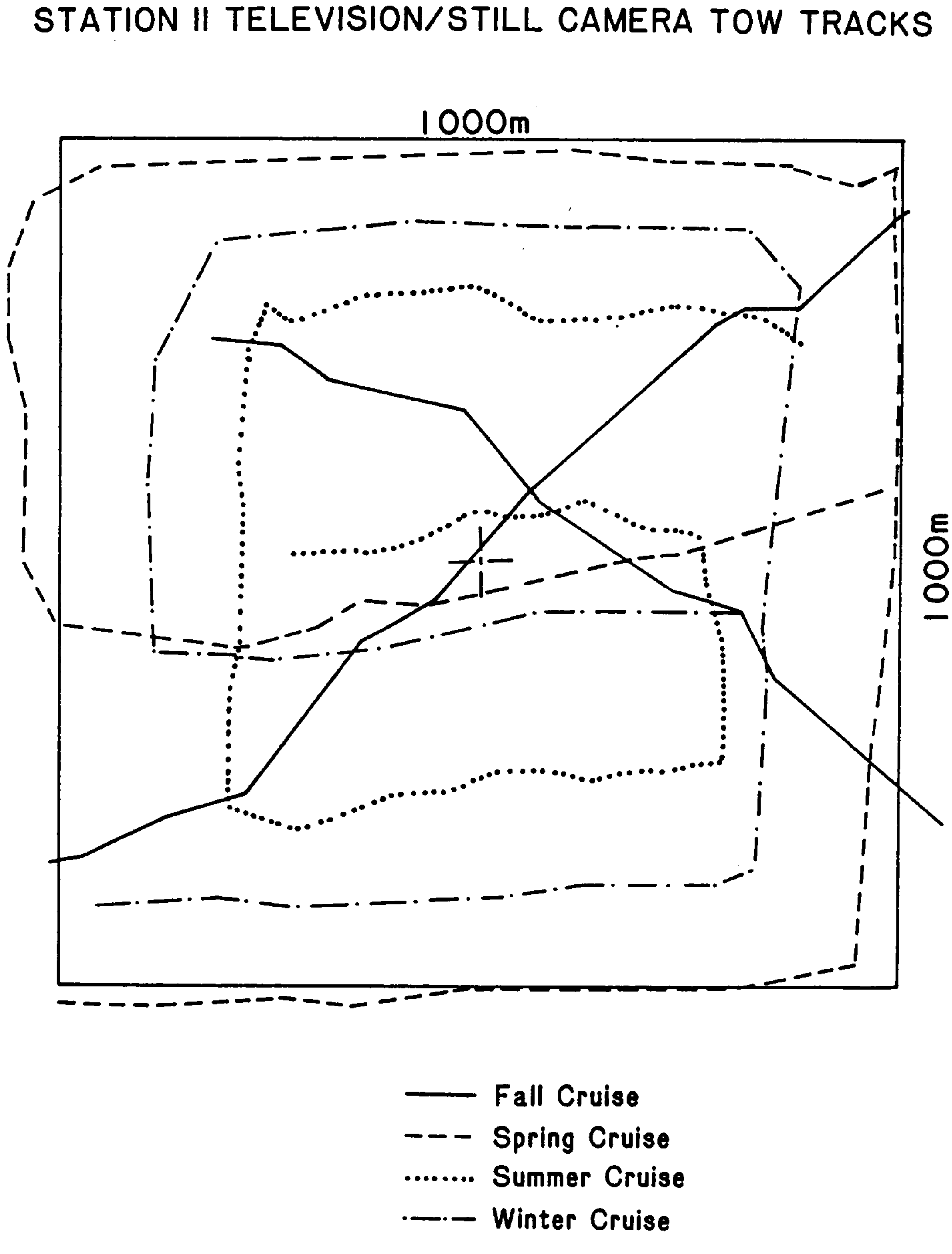


Figure 5-1. Example of total station area examined by underwater television/still camera sled tows during the combined Year One and Two programs.

Table 5-1. Substrate types observed on videotape at live bottom sampling stations during the Year One and Year Two programs (values represent average percent cover, all cruises). See Figure 1-1 for station locations.

Transect/ Station	Rock Outcrops/ Hard Bottom	Thin Sand over Hard Substrate	Sand Bottom/ Soft Bottom	Coralline Algal Nodule Layer over Sand	Algal Nodule Pavement with *Agaricia* Accumulations	Coarse Rubble (dead) with Attached Crinoids
A-1	0.2	56.8	43.0			
A-3		33.6	66.4			
B-7	0.1	29.2	70.7			
B-9		80.5	19.5			
B-10	1.6		45.4	53.0		
B-11	0.6		43.2	56.2		
C-13		42.4	57.8			
C-15	0.8	57.2	42.0			
C-17		24.3	75.7			
D-19		34.9	65.1			
D-21		73.3	25.5			
D-23			2.7	97.3		
E-27		13.9	86.1			
E-29					100.0	
E-30					100.0	
B-32	0.1	49.0	50.9			
C-35	0.6	89.5	9.9			
D-36	0.3	32.0	67.7			
D-38						100.0
E-39	100.0					

The southwestern portion on the study area, containing the remaining four stations, was anomalous in terms of hard bottom substrate types. At Stations 29 and 30 (62 and 76m depths, respectively), Algal Nodule Pavement with Agaricia Accumulations was the only substrate present. Station 39 (152m depth) appeared to be composed entirely of Rock Outcrops/Hard Bottom. An entirely "new" substrate type, which had not been observed prior to the Year Two biological cruises, was revealed at Station 38 (159m depth). Here, the entire station block was covered by a coarse rubble (dead) substrate accompanied by large numbers of attached crinoids.

At the majority of live bottom sites, still camera closeups indicated substrates were composed of mixtures of sand and rock, shell or dead algal rubble. Stations 29 and 30, in the southwestern portion of the study area were exceptions. There, an algal nodule pavement was predominant.

Soft Bottom Stations

Underwater television videotapes and still camera slides were collected as at live bottom stations. The majority of substrate information at the soft bottom sites, however, was provided by surficial sediment samples. These were collected by box core and analyzed for grain size, percent carbonates hydrocarbons, and trace metals.

As expected, videotapes showed the Sand Bottom/Soft Bottom substrate type to predominate at all soft bottom sites. Only three stations (12, 28 and 33) exhibited any measurable coverages by live bottom substrate. Rock Outcrops/ Hard Bottom was observed over less than one percent of the total area video taped at each of these locations.

Surficial sediment sample analysis yielded grain sizes classified as sand at all but two stations. Finer grained, sandy silt predominated at Stations 25 and 26, located in the southeastern portion of the study area. Grain size analyses also indicated poor sorting of sediments throughout the shelf. Sediments at inshore sites (Stations 2, 14, 20 and 25) appeared to be the best sorted, ranging from poor to moderately well sorted.

The distribution of percent calcium carbonate in surficial sediments at soft bottom stations (41-99%) indicated a predominant carbonate facies at all sites across the shelf. Station 2, and to some extent Station 6, showed a reduced mean carbonate content (41-86%), indicating a greater abundance of insoluble quartz clastics. This increase in quartz clastics may reflect the proximity to the coast and/or sediment transport from the Caloosahatchee River and Charlotte Harbor.

Surficial Sediment Hydrocarbons

Results from the Year One and Year Two southwest Florida shelf surficial sediment hydrocarbon studies are consistent with each other and with other hydrocarbon studies in the area. Predominant hydrocarbons were characterized as marine biogenic, with some terrigenous input evident in the samples collected farthest offshore (100 to 200m water depths). The offshore terrigenous biogenic hydrocarbons probably reflect Loop Current transport of northern Gulf of Mexico waters along the southwest Florida shelfbreak. None of the Year Two samples exhibited petrogenic hydrocarbons and only Station 12 from Year One contained any indicators of petroleum-like hydrocarbons.

The results clearly indicate that surficial sediments within the southwest Florida shelf study areas contain only very low levels of primarily marine biogenic hydrocarbons. These results provide essential information for assessing the impact of future oil drilling, production, and transport operations within the region. Any significant hydrocarbon input should be readily apparent and easily detectable.

Surficial Sediment Trace Metals

Year One analyses for Barium, Cadmium, Copper, Iron, Nickel, Lead, Vanadium, and Zinc showed both low levels and uniform distributions across the southwest Florida shelf. Observed levels were directly related to sediment mineralogy, which showed carbonate levels in excess of 90% at 13 of 15 sampled stations. Except for copper and zinc, no significant correlations between trace metal concentrations and grain size were evident. Copper tended to be associated with medium clays and finer sediments; zinc, with very fine clay sediments.

Data obtained during the Year One investigation were compatible with previous data from the Florida shelf. Trace metal levels were somewhat lower than those reported for typical carbonate rocks and only about 5% of those reported for Mississippi River suspended matter. The generally low concentration levels of trace metals in the carbonate-rich sediments of the southwest Florida shelf are indicative of "pristine" conditions. Any significant trace metal input from oil and gas development activities would be readily detected should it occur.

6.0 LIVE BOTTOM BIOTA

Twenty live bottom stations (Figure 1-1) were characterized and studied in detail. At each station, approximately 200 35mm color photographs were taken during a TV/still camera tow within a 1000m-square area around the station center. Generally, 100 photographs were later analyzed to obtain percent cover estimates for all biota and for particular identifiable taxa, using quantitative slide analysis (QSA). Next, dredge and trawl samples were taken to obtain specimens of most epibiotal taxa. Three triangle dredges and one otter trawl sample were collected at each station; the trawls were intended to supplement dredge samples by capturing more fishes, certain crustaceans, and larger sponges that might not fit into the dredge opening. Epibiota were photographed on deck, rough sorted, and preserved for later laboratory identification.

Ecological Characterization of Individual Stations

An ecological characterization is provided for each live bottom sample station, as follows: The location and physical features of the station are briefly summarized and a table indicating the taxonomic richness and general composition of station biota is presented. This table (see Table 6-1 for example) lists the numbers of taxa collected by different sampling methods (TDS - triangle dredge, QSA - quantitative slide analysis, OTH - otter trawl - hard bottom) and identified to genus or species level, broken down by major taxonomic groups. This way, both the total taxa present at each station, and the contributions of the various sampling techniques, are easily seen. A second table lists specific taxa most frequently collected from the station (see Table 6-2 for example). Details of the epibiotal cover are next presented (see Table 6-3 for example) and discussed. Percent cover estimates are listed for total epibiota, and for individual major contributions (taxonomic groups or species), for each separate seasonal sampling cruise. The ecological characterization concludes with additional remarks highlighting any particularly distinctive features of the station's biology.

Table 6-1. Station 01, all cruises combined: Number of taxa identified to genus or species level captured by different live bottom sampling methods. Breakdown by major taxonomic groups.

TAXONOMIC GROUP	# TAXA (TDS)	# TAXA (QSA)	# ADDITIONAL TAXA	CUMULATIVE # TAXA	# TAXA (OTH)	# ADDITIONAL TAXA	CUMULATIVE # TAXA
CYANOPHYTA	2	0	0	2	0	0	2
CHLOROPHYCOPHYTA	23	6	0	23	9	1	24
PHAEOPHYCOPHYTA	15	3	0	15	7	1	16
RHODOPHYCOPHYTA	38	3	0	38	18	3	41
ANTHOPHYTA	2	0	0	2	2	0	2
PROTOZOA	0	0	0	0	0	0	0
PORIFERA	41	10	0	41	12	3	44
CNIDARIA	14	5	0	14	7	3	17
ANNELIDA	0	0	0	0	0	0	0
GASTROPODA	33	0	0	33	2	0	33
POLYPLACOPHORA	3	0	0	3	0	0	3
APLACOPHORA	0	0	0	0	0	0	0
BIVALVIA	23	0	0	23	7	0	23
SCAPHOPODA	2	0	0	2	0	0	2
CEPHALOPODA	2	0	0	2	0	0	2
ARTHROPODA-PYCNOGONIDA	1	0	0	1	1	0	1
ARTHROPODA-MANDIBULATA-CRUSTACEA	65	0	0	65	15	1	66
SIPUNCULA	0	0	0	0	0	0	0
PRIAPULIDA	0	0	0	0	0	0	0
PHORONIDA	0	0	0	0	0	0	0
ECTOPROCTA	17	0	0	17	8	2	19
BRACHIOPODA	0	0	0	0	0	0	0
ECHINODERMATA	24	2	0	24	10	1	25
HEMICHORDATA	1	0	0	1	1	0	1
CHORDATA-UROCHORDATA	22	2	0	22	12	0	22
CHORDATA-CEPHALOCHORDATA	0	0	0	0	0	0	0
CHORDATA-GNATHOSTOMATA	29	0	0	29	25	14	43
TOTAL	357	31	0	357	136	29	386

TDS = Triangle Dredge Samples; QSA = Quantitative Slide Analysis; OTH = Otter Trawl, Hard Bottom.

Table 6-2. Species collected in at least 9 of 12 dredge samples or 3 of 4 trawl samples from Station 1.

Group/Species	Number of Dredge or Trawl Samples Containing the Listed Species	
	Dredge	Trawl
ALGAE		
Laurencia intricata	11	3
Udotea conglutinata	9	2
U. cyathiformis	9	2
Gracilaria debilis	9	2
PORIFERA		
Cinachyra alloclada	12	4
Homaxinella waltonsmithi	9	2
CNIDARIA		
Siderastrea radians	11	0
Cladocora arbuscula	10	3
Solenastrea hyades	10	1
Phyllangia americana	9	1
CRUSTACEA		
Gonodactylus bredini	11	2
Podochela riisei	10	2
Macrocoeloma camptocerum	9	2
BRYOZOA		
Celleporaria magnifica	10	3
Stylopoma spongites	10	0
ECHINODERMATA		
Ophiolepis elegans	12	3
Arbacia punctulata	11	1
Lytechinus variegatus carolinus	10	3
Ophiothrix angulata	9	2
Luidia alternata	3	3
ASCIDIACEA		
Rhabdopleura compacta	10	2
FISHES		
Serraniculus pumilio	5	3
Hippocampus erectus	3	3
Synodus foetens	0	3
Diplectrum formosum	0	3

Table 6-3. Station 1: Percent cover estimates for all epibiota and for major contributors. Seasonal designations refer to the period when each cruise was conducted.

Season	Percent Cover	
	All Epibiota	Major Contributors*
Summer	26.8	9.8 Chlorophycophyta (0.9 Udotea sp.) 13.8 Rhodophycophyta (0.9 Cryptonemiales; 1.4 Gracilaria sp.) 1.9 Phaeophycophyta (1.7 Rosenvingea intricata
Fall	15.4	7.9 Chlorophycophyta (1.0 Udotea sp.) 6.1 Phaeophycophyta 0.7 Porifera
Winter	13.3	7.7 Phaeophycophyta (6.6 Sargassum sp.) 1.9 Cnidaria (1.1 Siderastrea sp., 0.7 Cladocora arbuscula) 2.0 Porifera 1.0 Chlorophycophyta
Spring	20.0	15.2 Phaeophycophyta 2.5 Porifera (1.3 Cinachyra spp.) 1.1 Cnidaria (0.9 Oculina sp.) 0.8 Chlorophycophyta

*The level of taxonomic identification varied for different groups. Percent cover estimates for all taxa within a major group were pooled; the contributions of particularly abundant species, genera, or other taxonomic groupings are shown in parentheses.

SHELFWIDE PATTERNS

Several approaches were used to evaluate shelfwide distribution patterns of the live bottom biota. Results from the initial television transect surveys, already presented in Section 2.0 (Figures 2-1 and 6-1A), were first reviewed. Next, the individual station characterizations, based primarily on quantitative slide analysis, were combined to produce a zonation scheme (Figure 6-1B), and thirdly, groups of stations sharing similar biotas were obtained from cluster analyses of the triangle dredge and otter trawl sample collections (Figure 6-2). Finally, the results of these different approaches were integrated and compared with previously published zonation schemes.

All approaches to delineation of station groupings identified a basic inshore-offshore zonation pattern consisting of a major group of stations at 20 to 70m depths and two or more groups of stations at 60 to 160m depths. Specific station groupings, however, differed depending on the sampling method. A large grouping of inner and middle shelf stations was evident from both photographic observations and sample collections. Television transect results suggest a grouping of Stations 1, 3, 7, 9, 15, 17, 21, and 27 as the Inner and Middle Shelf Live Bottom Assemblage II, as distinct from the Inner Shelf Live Bottom Assemblage comprising Stations 13 and 19. The latter two did not emerge as a distinct group in examination of QSA results, although Station 13 appeared unique in having high, patchy levels of gorgonian cover and a blue-green algal bloom during Summer; the uniqueness of Station 13 did not emerge in cluster analysis results, in part because the gorgonian species present there were not included (the truncation criteria limited analysis to relatively widely distributed taxa). Several gorgonians (e.g., Plexaurella spp., Eunicia spp., Muricea sp.) were generally restricted to Station 13, and Year III sampling has subsequently identified gorgonian-dominated assemblages at shallower depths on Transects B, C, and D.

Although QSA results suggest a general similarity of all of the inner and middle shelf stations listed above, ambiguities in the classification of Stations 10 and 11, as well as 9 and 27, were suggested by the results of otter trawl clustering. In addition, several mid-shelf stations exhibited similarities (presence of crustose perennial algae and occasional Agaricia

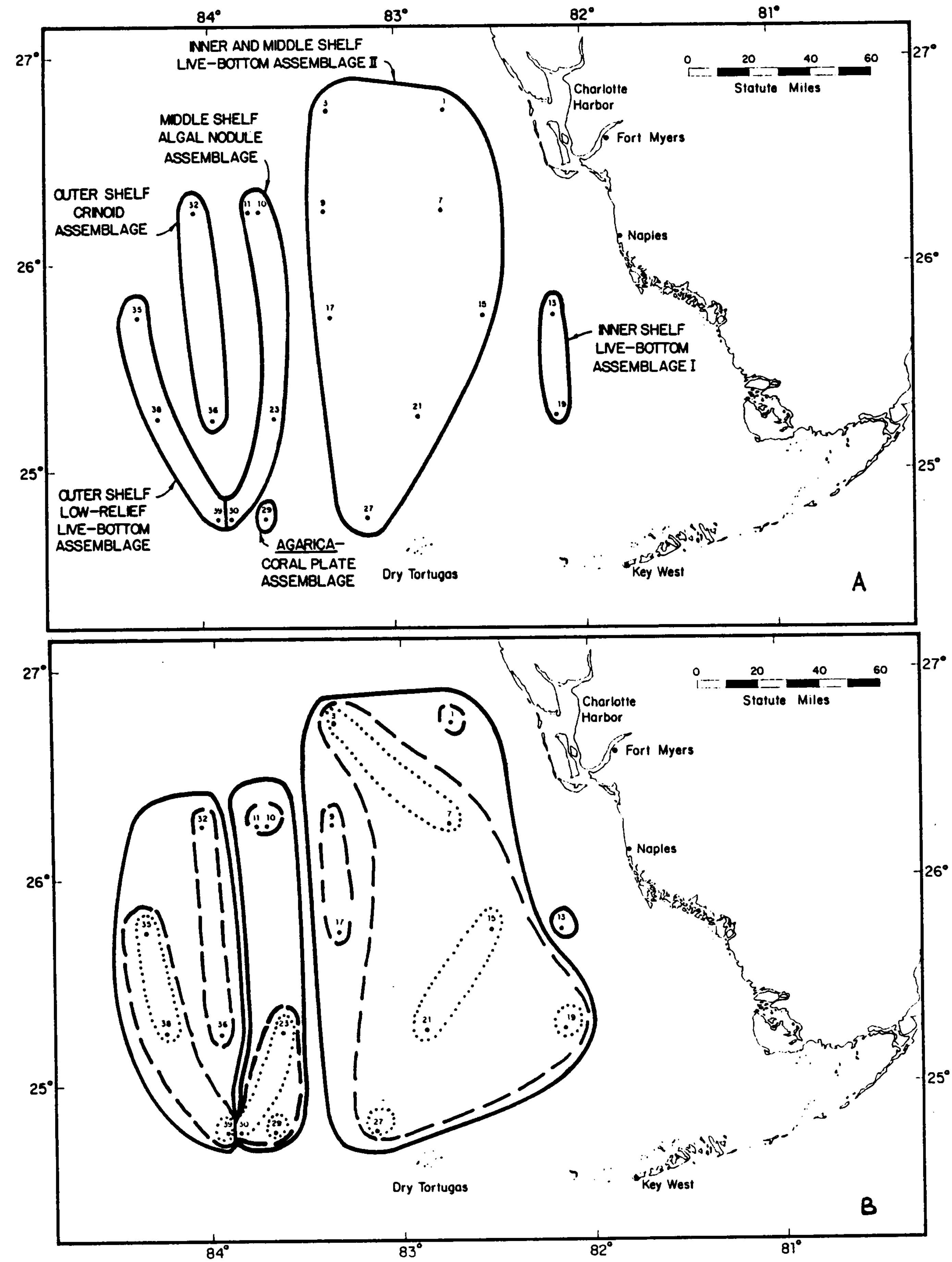


Figure 6-1. Live bottom station groupings based on: (A) television transect surveys, (B) examination of QSA data.

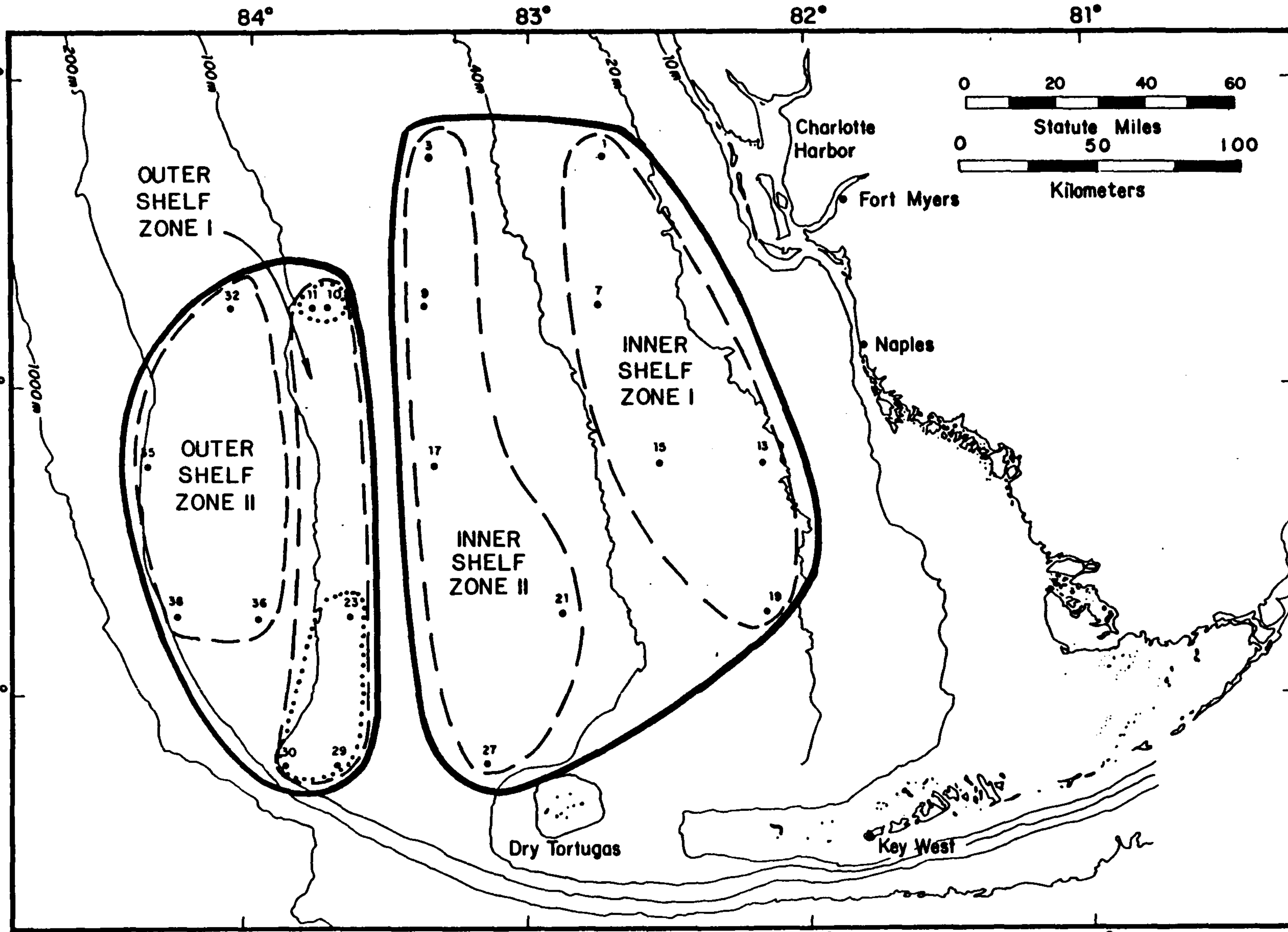


Figure 6-2 . General groupings of live bottom stations on the basis of cluster analysis of dredge and trawl data.

sp.) to coralline algal nodule stations, perhaps indicating that assemblages in the 50 to 60m depth range are ecotonal in character.

Cluster analysis of both triangle dredge and otter trawl data suggests depth-related sub-clustering within the large group of inner and middle shelf stations. Similar station groupings did not emerge in the remote visual assessments, probably because the particular taxa responsible for station groupings were often crustaceans, hard corals, or algae that did not contribute much to total cover values; in addition, the low taxonomic resolution of visual identifications of some groups tends to reduce the ability to distinguish shifts in species composition.

Analysis of television transect data suggests that a coralline algal nodule-based assemblage occurs at 62 to 108m depths primarily on Transects B, D, and E; Stations 10, 11, 23, and 30 were located in areas characterized by this assemblage. The substrate at these stations ranged from coralline algal nodules over sand (Station 10,11, and 23, with the latter having much higher nodule cover) to a coralline algal pavement (Station 30). A related assemblage, the Agaricia Coral Plate Assemblage, occurs at Station 29. QSA data suggest that all of these stations are generally similar, but that Station 29 is unique (Agaricia sp. coral plates; high cover values for Anadyomene menziesii) and Stations 10 and 11 are distinct from the others in lacking coverage by the deep water green alga Anadyomene menziesii and having lower overall cover values. Triangle dredge clustering generally confirmed the taxonomic similarity of Stations 10, 11, 23, 29, and 30 but suggested that Stations 10 and 11 are somewhat more similar to each other than to the others. Cruise-to-cruise variation in the clustering of dredge data from Stations 11, 23, 29, and 30 indicates a likely north-south gradient in taxonomic composition within this station grouping, and some of the otter trawl clustering results suggest an affinity of the northern stations (10 and 11) with Stations 9 and/or 3. Although television transect and QSA data indicate the uniqueness of Station 29 with its Agaricia-coral plate assemblage, neither triangle dredge nor otter trawl clustering was able to discriminate consistently between this station and Stations 23 and 30. This probably reflects the effects of truncating the data set by frequency of occurrence (Agaricia sp. occurred only occasionally in a few other samples), and the limitations of binary (presence/absence) data. In trawl and dredge clustering, taxa comprising a large proportion of total cover, biomass, or numbers carry the same weight in the analysis as relatively rare taxa.

Stations 32 and 36 were selected on the basis of television transect surveys as representative of the Outer Shelf Crinoid Assemblage; Stations 35 and 38 were selected as representative of the Outer Shelf Low-Relief Live Bottom Assemblage. Station 39 constituted a unique station with high relief and a high proportion of rock outcrops. QSA data confirm the general affinity of all five stations and the distinctiveness of Stations 35, 38, and 39, which exhibited seasonal (Summer) blooms of (unidentified) deepwater green algae. Neither triangle dredge nor otter trawl clustering delineated Stations 35 and 38 as separate from Stations 32 and 36 (no triangle dredge or otter trawl results were available for Station 39).

Despite the distinctiveness of the coralline algal nodule and Agaricia coral plate assemblages (Stations 10, 11, 23, 29, and 30) from deeper Stations 32, 35, 36, 38, and 39, these groups of stations appeared taxonomically similar in both triangle dredge and (to a lesser extent) otter trawl cluster analyses.

Differences in the shelfwide zonation patterns derived from the dredge and trawl collections, QSA data, and television transect surveys partly reflect differences in the weighting of information used. Cluster analysis of presence-absence data from dredges and trawls tends to emphasize a zoogeographic perspective. That is, the results reflect the overlapping distributional ranges of species that contribute to the species-pool available to constitute a community at any given site, without considering the relative abundance of the species.

Delineation of biotic assemblages by QSA, which is quantitative, and television observations, which are semi-quantitative or subjectively quantitative, involves a different perspective; assemblages are delineated on the basis of relative abundance and, to a lesser extent, overall taxonomic composition. That is, from the large pool of taxa capable of inhabiting a site, relatively few are observed to occupy a significant portion of total area, and consistent assemblages or combinations of abundant taxa can be formed. It is also likely that the occurrence of certain organisms tends to influence the number and kinds of associated organisms by providing habitats. For example, coralline algae colonizing primarily thick sand substrates at Stations 10, 11, 23, 29, and 30 provide a substrate (algal nodules or algal nodule pavement) for the establishment of other epibiota, and many of the crustaceans and ophiuroids found at several stations are commensal or otherwise dependent on sponges.

In addition to providing different perspectives on similarity and distinctiveness, the different types of data collected and the analytical approaches used each have individual limitations that influence their interpretation. Triangle dredge and otter trawl data are binary (for most taxa), and as such, are insensitive to relative abundance patterns (except insofar as abundance influences the likelihood of capture for a particular taxon); equal weighting of (numerous) rare and (relatively few) common species in a given catch tends to emphasize dissimilarities between stations or samples because rare taxa are the least likely to be adequately sampled. Truncation of the data set by an objective criterion such as overall frequency of occurrence (by station or replicate) tends to overemphasize similarity and underemphasize taxonomically distinctive stations (or small groups of stations). The major problem with both television transect surveys and QSA data is limited taxonomic resolution; many taxa are not identifiable to species from photographs, and analysis of data grouped into multispecific and multigeneric taxa overemphasizes similarities between samples or stations.

Comparison With Previous Zonation Schemes

Faunal zonation on the west Florida continental shelf has been discussed by Collard and D'Asaro (1973), Lyons and Collard (1974), Hopkins (1979), Lyons (1980), and Lyons and Camp (1982). None of their conclusions are based specifically on data collected only at hard bottom sites.

Data from the present study encompass a range of depths from 20 to 160m on the southwest Florida shelf. In general, the results of cluster analysis of dredge and trawl data are consistent with the zonation patterns of Lyons (1980). No data are available for depths corresponding to Lyons' Shoreward Zone (0 to 10m), although shallow stations have been sampled during Year III of the study. Our Inner Shelf Zones I and II correspond to Lyons' (1980) Shallow Shelf Zone and Middle Shelf Zone I, and provide corroboration for the existence of a faunal break at about 70m. Although our study included stations at 160m depths, no faunal break at or near 140m was evident, but it is still likely that a distinctive fauna is present nearer the shelf edge. Within our Outer Shelf Zone (70 to 160m), sub-zones were evident -- i.e., the 60 to 80m stations (Outer Shelf Zone I) vs. the 130 to 160m stations (Outer Shelf Zone II). This division reflects the occurrence of the coralline algal nodule (and Agaricia-coral plate at Station 29) substrate. Because this substrate type is most extensively developed in the southwest portion of the study area (Stations 23, 29, and 30) and is lacking on Transect A, it is not surprising that a similar biotic zone was not proposed for Lyons' (1980) Hourglass study area, which overlapped Transect A but extended northward.

Seasonality

The southwest Florida shelf is a seasonal environment, though the degree of seasonal environmental variation depends on depth, latitude, and proximity to the shelf edge. Live bottom communities have both seasonal and nonseasonal components, and the assessment of seasonality is influenced by the type of data available and by practical limitations on sampling adequacy. Our studies show that: 1) taxonomic richness varies seasonally among both algal and some non-algal taxa at most stations and the variation (at least for all taxa combined) is generally greater at shallow than mid-shelf or deep outer shelf stations; 2) overall taxonomic composition, as judged from biotal zonation patterns derived from cluster analysis of dredge and trawl data, varies little seasonally despite changes in taxonomic richness (although problems in sampling adequacy and the effects of truncation of the data set complicate the results); and 3) biotal cover varies seasonally, primarily reflecting seasonal abundance patterns of different algal groups.

DISCUSSION

This section of the main report (6.5) compares the results of our live bottom studies with those of other live bottom and reef habitats in the Gulf of Mexico and South Atlantic Bight. Incidental data collected on fish, shrimp, and the possible impacts of "red tides" are also presented. The discussion concludes with a methodology evaluation and review of future research needs. Some selected topics are briefly reviewed below.

Hard Bottom Habitats Overview -- The southwest Florida shelf provides a large area of scattered hard substrates (some emergent, but most covered by a thin veneer of sand) that allow the establishment of a tropical hard bottom biota in what must be regarded as a marginally suitable environment. The only high-relief features, a series of shelf-edge prominences which are probably the remnants of extensive calcareous algal reef development prior to sea level rise (Holmes, 1981), are now too deep to support active coral communities. Most major reef-building hermatypes are restricted to relatively shallow waters; conditions in shallow waters of the southwest Florida shelf are apparently unsuitable, whether due to occasional cold fronts, turbidity, sediment movement, etc., to allow the establishment of any extensive hermatypic coral populations on the inner shelf. The growth of coralline algae at mid-shelf depths (60 to 80m), which results in the production of algal nodules and a crustose algal pavement in the southwest portion of the study area, provides an extensive substrate for the development of deepwater hermatypic corals. The coral *Agaricia* sp., with its platelike growth form, is adapted to maximize light capture at these depths, and the sharp lower depth limit of its occurrence in the study area (about 80m as noted in television transect surveys) suggests light limitation. The coralline algal nodule and algal pavement/*Agaricia* assemblages represent the nearest to the development of an active reef habitat on the shelf. The remaining hard bottom areas scattered across the broad shelf, whether consisting of exposed or thinly covered hard bottom, are generally colonized by seasonal algae, sponges, and other filter feeders of mixed warm-temperature (Carolinean) and tropical (Caribbean) affinities. The tropical biota consists primarily of the hardier, more tolerant forms (including, for example, the hard corals *Siderastrea* sp. and *Solenastrea* sp).

Future Studies -- The continental shelf off southwest Florida remains a relatively unstudied habitat. The present study has provided a general descriptive characterization of live bottom communities and opens the way for a variety of possible research efforts that may serve to elucidate functional and causal relationships or develop refined capabilities to detect changes that could result from oil and gas drilling and production activities.

Some study needs are being addressed by ongoing aspects of the Southwest Florida Shelf Ecosystems Study series: Year Three efforts have focused on describing shallower live bottom communities and evaluating and comparing certain sampling techniques; Year Four and Five are addressing seasonality and benthic dynamics, including sediment movement and larval recruitment. Future work oriented toward producing a general understanding of the biology of live bottom communities, relationships to environmental variables, and the functional aspects of live bottom ecosystems should include efforts to:

1) Determine nutrient fluxes across the shelf;

2) Determine rates, sources, and nutritional characteristics of particulate organic matter to live bottom communities (e.g., Loop Current upwelling-induced phytoplankton blooms vs. terrigenous inputs); and

3) Quantify biomass and energy flow at particular locations;

4) Elucidate physiological characteristics and rate processes of particularly important groups -- e.g., sponges;

5) Identify trophic relationships, especially those involving commercially important fish or shellfish.

Specific applied research efforts should focus on the development of a monitoring capability for live bottom biota and on the persistence, resistance, and resilience of the biota in the face of natural and human-induced disturbance. Conducting research at depths that are not readily accessible to divers is problematic and will require innovative approaches such as the use of submersibles for observation and experimentation.

7.0 SOFT BOTTOM BIOTA

Nineteen soft bottom stations (Figure 1-1) were characterized and studied in detail. Samples of soft bottom biota were obtained by two methods: a modified Reineck box core sampler (19 x 30 x 40cm deep) and a Marinovich 7.6m semi-balloon otter trawl with a 3.8cm stretch mesh in the body of the net and 1.3cm mesh in the cod end. Generally, five box cores and one trawl sample were obtained per station on each sampling date. The box core samples were processed on board ship by elutriating the sediment in a sieving device through a 0.5mm mesh sieve. Box core and trawl specimens were then preserved for later laboratory identification.

Ecological Characterization of Individual Stations

An ecological characterization is provided for each individual soft bottom sample station, as follows: the location and physical features of the station are briefly summarized and a table indicating the taxonomic richness and general composition of station biota is presented. As before, this table (see Table 7-1 for example) lists the numbers of taxa collected by different sampling methods (BCI - Box Core Infauna, OTS - Otter Trawl, Soft Bottom) and identified to genus or species level, broken down by major taxonomic groups.

A second table (see Table 7-2 for example) summarizes faunal density estimates and equitability/diversity values from the replicate box core data collected at the station. A third table (see Table 7-3 for example) lists specific taxa that were among the five most abundant organisms collected in the box cores during one or more of the seasonal sampling cruises. The ecological characterization concludes with a brief descriptive summary of the macroepifauna recorded from the station.

Table 7-1. Soft bottom Station 04, all cruises combined: Number of taxa identified to genus or species level from box core (BCI) and otter trawl (OTS) samples. Breakdown by major taxonomic groups.

TAXONOMIC GROUP	# TAXA (BCI)	# TAXA (OTS)	# ADDITIONAL TAXA	CUMULATIVE # TAXA
CYANOPHYTA	0	0	0	0
CHLOROPHYCOPHYTA	0	3	3	3
PHAEOPHYCOPHYTA	0	1	1	1
RHODOPHYCOPHYTA	0	1	1	1
ANTHOPHYTA	0	0	0	0
PROTOZOA	0	0	0	0
PORIFERA	0	13	13	13
CNIDARIA	1	0	0	1
ANNELIDA	189	2	0	189
GASTROPODA	13	7	7	20
POLYPLACOPHORA	1	0	0	1
APLACOPHORA	3	0	0	3
BIVALVIA	44	3	3	47
SCAPHOPODA	5	0	0	5
CEPHALOPODA	0	9	9	9
ARTHROPODA-PYCNOGONIDA	0	0	0	0
ARTHROPODA-MANDIBULATA-CRUSTACEA	104	28	25	129
SIPUNCULA	1	0	0	1
PRIAPULIDA	1	0	0	1
PHORONIDA	0	0	0	0
ECTOPROCTA	1	0	0	1
BRACHIOPODA	1	0	0	1
ECHINODERMATA	4	10	10	14
HEMICHORDATA	0	0	0	0
CHORDATA-UROCHORDATA	1	2	2	3
CHORDATA-CEPHALOCHORDATA	1	0	0	1
CHORDATA-GNATHOSTOMATA	0	42	42	42
TOTAL	370	119	116	486

BCI = Box Core Infauna
OTS = Otter Trawl, Soft Bottom

Table 7-2. Faunal density estimates (number of organisms m^{-2}), diversity values (Shannon-Weaver Index), and equitability values (Pielou's J') for soft-bottom Station 4.

Parameter	Cruise				Mean	Range of Values Over All Stations[a]
	Fall	Spring	Summer	Winter		
Faunal Density	2,767	5,003	3,620	6,096	4,372	2,210 - 18,233
Diversity Index	1.77	1.85	1.82	1.68	1.78	1.13 - 1.97
Equitability	0.84	0.82	0.83	0.76	0.81	0.54 - 0.86

[a]Values for individual sampling cruises at all soft-bottom stations.

Table 7-3. Dominant taxa for Station 4, for each cruise, based on the five most abundant organisms identified to the genus or species level from box core samples. Values are ranks.

Taxon (Group)	Cruise			
	Fall	Spring	Summer	Winter
Synelmis albini (P)	1	1	1	2
Goniadides carolinae (P)	2	(+)	(-)	3
Selenaria sp. (B)	3	(+)	(+)	(+)
Lysippe cf. annectens (P)	4	(+)	(+)	(+)
Amaroucium sp. (U)	5	(-)	(-)	(-)
Sphaerosyllis sp. (P)	(+)	2	(+)	(+)
Fabricia sp. (P)	(+)	3	(+)	(+)
Ampharetidae genus B (P)	(-)	4	4	(+)
Paleanotus sp. A (P)	(+)	5	(+)	4
Glycera oxycephala (P)	(-)	(-)	2	(-)
Prionospio cristata (P)	(+)	(+)	3	(+)
Ischnochiton sp. (Pp)	(+)	(+)	5	(-)
Haploscoloplos sp. (P)	(-)	(-)	(-)	1
Pholoe minuta (P)	(+)	(+)	(-)	5

(P) = Polychaeta
(B) = Bryozoa
(U) = Urochordata
(Pp) = Polyplacophora
(+) = present but not among five most abundant
(-) = absent

SHELFWIDE PATTERNS

Box Core Infaunal Data -- A total of 1,378 taxa were collected in box core sampling, of which 1,227 (89%) were identified to genus or species. Over 50% of these taxa were polychaetes, with crustaceans, bivalves, and gastropods also contributing significant proportions of the total. Widely distributed taxa included the polychaetes *Synelmis albini* (Pilargidae), *Notomastus hemipodus* (Capitellidae), *Levinsenia gracilis* (Paraonidae), *Tharyx annulosus* (Cirratulidae), *Prinospio steenstrupi* (Spionidae), *Sthenelais boa* (Sigalionidae), and *Fabricia* sp. (Sabellidae), as well as the cephalocarid crustacean *Sarsiella* sp.

Figure 7-1 illustrates shelfwide variation in total taxa (identified to genus or species) collected in the box cores. Among stations that were sampled on all four cruises (which consequently had a higher number of taxa collected) taxonomic richness appeared highest at several mid-shelf stations (4, 16, 22 and 18). The number of taxa collected at the deep (>100m) offshore stations was generally low in comparison, even considering that they were sampled on only two of the four cruises. Taxonomic richness was also low at Stations 25 and 26, which are located in the southeast corner of the study area.

Shelfwide patterns of faunal abundance for all stations and cruises are summarized in Table 7-4. The highest average densities occurred at the deep Station 37 (although the average belies the large difference between results of the two sampling dates); densities were also high at Stations 6, 14, 20, and 22, all at relatively shallow depths. Two of the stations that supported the highest average faunal densities (Stations 6 and 37) also exhibited the highest degree of "seasonal" variation in faunal density. In contrast to the results for Station 37, most of the other relatively deep stations (5, 12, 31, 33, 24) supported low faunal densities. Remaining stations supported intermediate densities.

Cluster analysis results for box core data (Figure 7-2) indicate a strong separation of stations along the offshore-nearshore direction, with the outer stations (5, 12, 18, 24, 31, 22, 34, and 37; depth range 86 to 148m) most strongly separated from the rest. Within the larger group of remaining

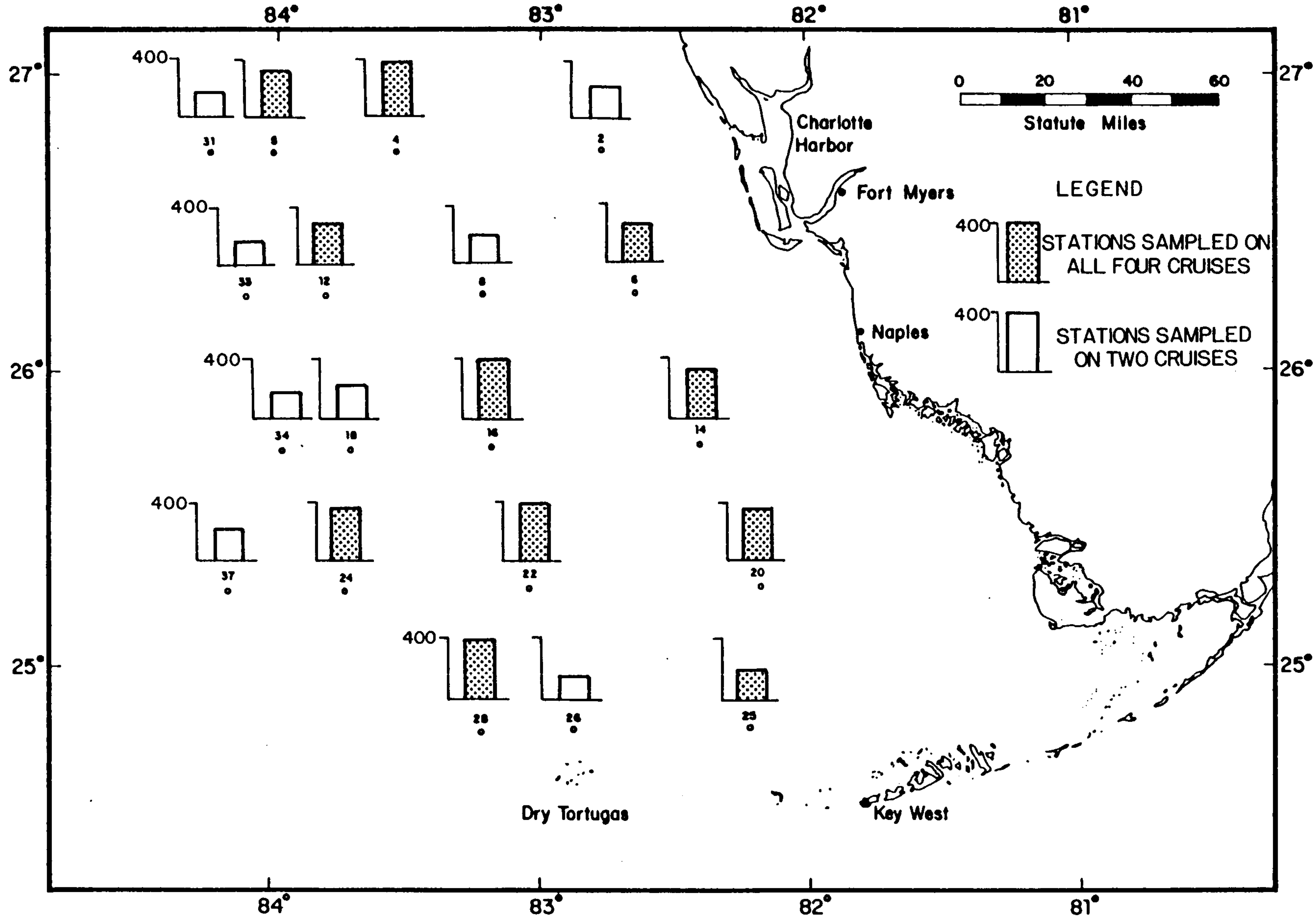


Figure 7-1. Shelfwide variation in the total of taxa (identified to genus or species) collected in box core samples at soft bottom stations.

Table 7-4. Faunal densities (number of organisms m^{-2}) for soft-bottom benthic stations, based on box core samples.

Station	Cruise				Mean	Station Rank
	Fall	Spring	Summer	Winter		
2	6696	9200	-	-	7948	7
4	2767	5003	3620	6096	4372	14
5	2227	3710	2680	3313	2983	19
6	9393	3940	14269	10187	9447	3
8	5040	5570	-	-	5305	12
12	3343	3833	2210	3737	3281	17
14	9436	8586	14156	13419	11399	2
16	4890	7756	6503	7453	6650	10
18	3817	4930	-	-	4373	13
20	6516	8246	8343	10566	8418	4
22	6770	9083	10652	6063	8142	5
24	3780	4170	7970	9083	6251	11
25	6203	9776	7496	4223	6925	9
26	5270	9553	-	-	7411	8
28	6676	6923	10283	8280	8040	6
31	-	-	3193	3410	3302	16
33	-	-	2943	3363	3153	18
34	-	-	3447	4633	4040	15
37	-	-	5053	18233	11643	1

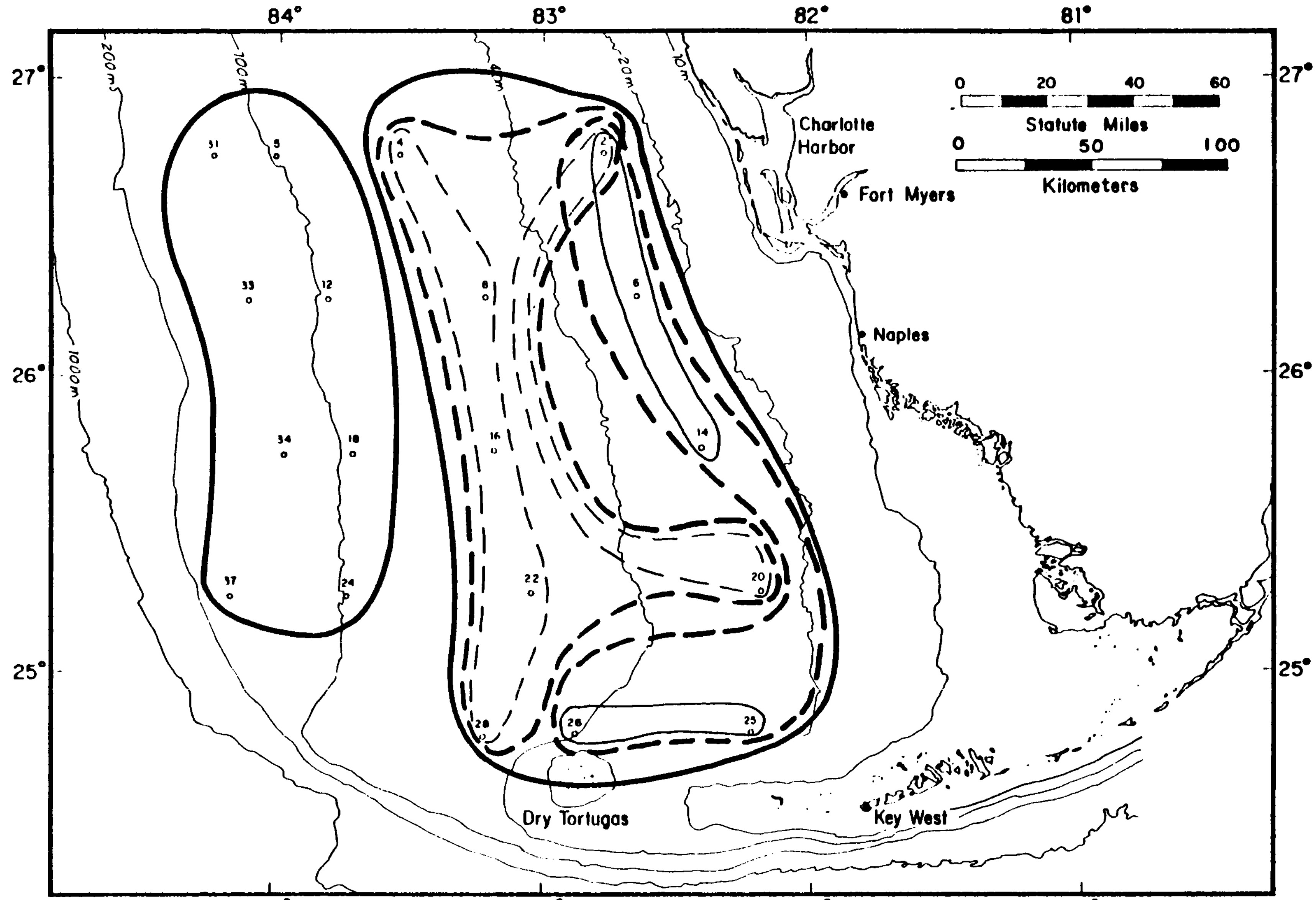


Figure 7-2. Station groupings based on cluster analysis of box core infaunal data, all cruises combined.

stations, further subclustering into an intermediate (including Stations 2, 4, 8, 16, 20, 22, and 28; depth range from 23 to 59m) and a nearshore zone (including Stations 2, 6, 14, 25, and 26; depth range from 25 to 38m) is evident. The latter two groupings are not strictly along bathymetric contours; Station 20 (23m depth) consistently grouped with stations in the 50 to 60m depth range, as did Station 2 (25m depth) for one cruise. The grouping of Stations 25 and 26 also clearly does not reflect a bathymetric grouping and is related to sediment composition. The overall pattern was consistent over seasons, but pronounced seasonality of community composition was evident at some stations.

Otter Trawl Macroepifaunal Data -- A total of 667 taxa were collected in otter trawls at soft bottom stations, of which 621 (93%) were identified to genus or species. About one third were fishes, with crustaceans, echinoderms, bivalves, gastropods, and sponges contributing significantly to the total. The dusky flounder, *Syacium papillosum*, was the most ubiquitously distributed species; other widely distributed species included the fringed filefish, *Monacanthus ciliatus*, the pancake batfish, *Halieutichthys aculeatus*, and the barbfish, *Scorpaena brasiliensis*. Among stations that were sampled on all four cruises, the number of taxa collected was highest at mid-shelf stations such as Stations 16, 22, and 28. Taxonomic richness was distinctly lower at inner shelf stations and also at the deep (>100m) offshore stations (even taking into consideration that they were only sampled twice).

Macroepifauna at each station were characterized by their affinities for soft bottom or live bottom habitats. Because trawl sampling at each station encompassed a much larger area of the station than did box core sampling, a variety of habitats could have been encountered and reflected in the composition of the biota collected. Based on the composition of trawl catches, Stations 5, 8, 16, 22, 26, and 28 could be characterized as encompassing areas of "moderate to thick" live bottom. Station 2, 6, 31, and 33 supported macroepifauna typical of sand or shell/sand habitats, whereas Stations 4, 12, 14, 18, 20, 24, 25, 34, and 37 supported macroepifaunal assemblages that suggest the presence of scattered live bottom. Between-cruise variations in these assessments were evident, but these were most pronounced at Stations 14, 18, and 26. All soft bottom stations supported -- at most -- a very sparse live bottom epibiota in comparison with that present at live bottom stations.

Cluster analysis results for the otter trawl data of all cruises combined are presented in Figure 7-3. As for the individual cruises, there were three major station clusters distinguishing nearshore, intermediate, and offshore zones. The offshore zone consisted of Stations 31, 33, 34, and 37. However, Summer Cruise data for Stations 5, 13, and 24 also clustered with these stations. The intermediate zone was composed of a number of subclusters, the two largest of these separated the zone into two groups of stations at different depths. The level of "seasonal" variability was higher than for the box core clustering; rarely did all seasonal samples for a particular station cluster closely, and two stations (Stations 5 and 12) exhibited enough seasonal variability to appear in more than one major cluster.

Epiflora -- The abundance and taxonomic composition of macroalgal assemblages were examined by two approaches: still camera photographs were examined for the presence of macroalgae at each station; and macroalgae were identified from otter trawl and box core samples.

Photographic analysis indicated twelve stations (of 15 total) exhibited algal presence for Year I, while 9 stations had detectable algae for Year II (due to the deletion of Stations 2, 8, and 18). For both years, the Caulerpa species complex was the most ubiquitous, occurring at 10 of 12 stations for Year I and 7 of 9 stations for Year II, and occurring in relatively large percentages of photographs. Halimeda discoidea and Udotea and Udotea-like species were also common in bottom photographs. The deep (>100m) Stations 31, 33, 34, and 37 were apparently at the limit of the photic zone, as no algae were seen in the photographs from either of the Year II cruises (although a few were collected in the trawls).

The total number of macroalgal taxa collected in otter trawl and box core samples (summed over stations) varied from 7 (Spring Cruise) to 17 (Summer Cruise), with 11 taxa collected on each of the other two cruises. Some variation in catches of particular algae between cruises probably reflects problems with sampling methodology. Stations 16 and 28 exhibited the highest

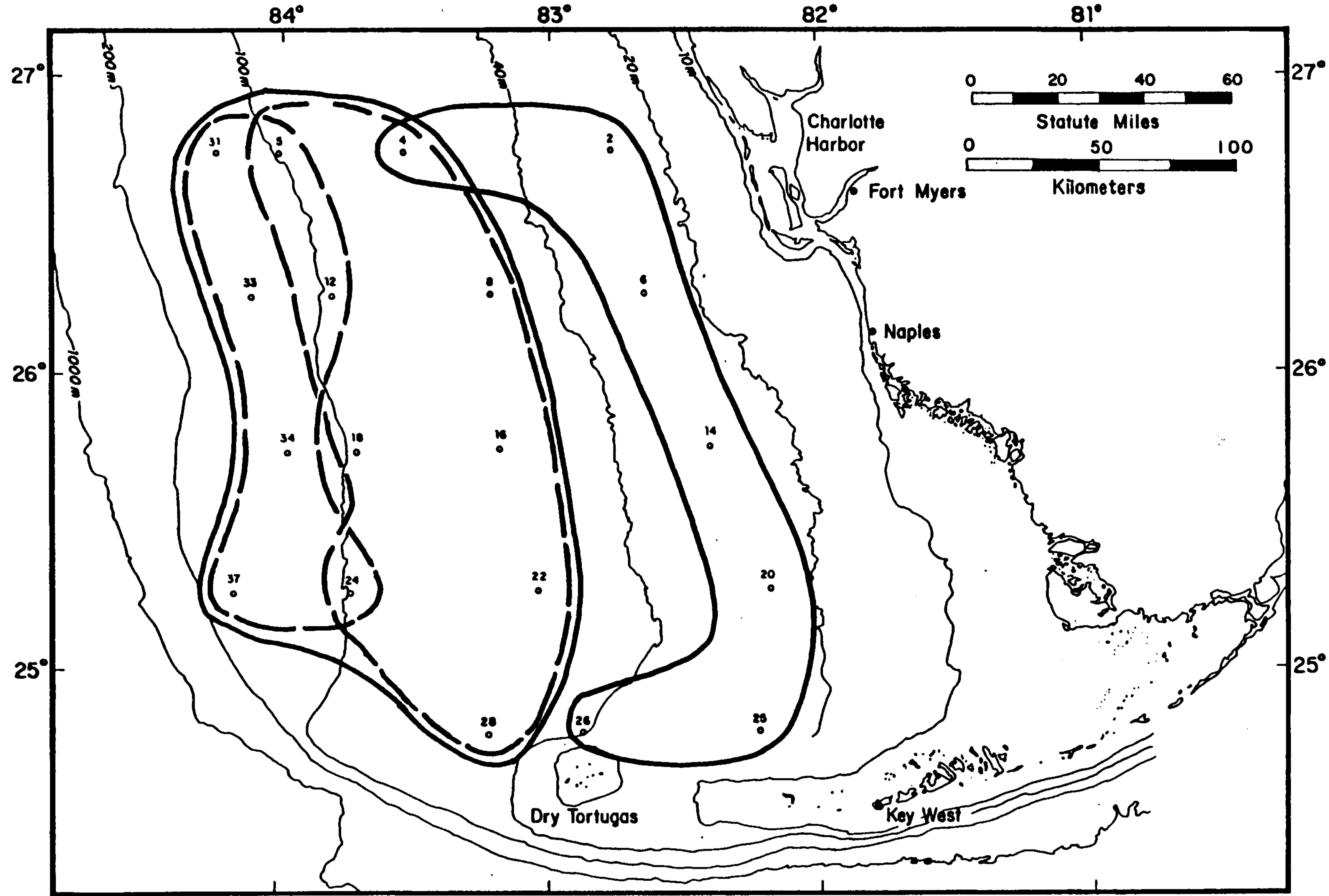


Figure 7-3. Simplified station grouping based on cluster analysis of otter trawl data, all cruises combined. (Some stations appear in more than one cluster due to seasonal changes in species composition.)

total number of algal taxa (12 over the two-year program); in addition, Stations 2, 4, and 16 supported a relatively high number of algal taxa on at least one cruise. In contrast, Stations 5 and 12 (both at 90m depth) and the deeper (>100m) outer shelf Stations 31, 33, 34, and 37 supported few algal taxa or none. The most ubiquitous macroalgae were *Caulerpa sertularioides*, the crustose green alga *Halimeda discoidea*, and the brown alga *Sargassum hystrix*; the latter was the only macroalga consistently collected at the deep, outer shelf stations. *Halimeda* was generally most commonly collected from mid-shelf (40 to 60m depths) stations (high percent cover at several live bottom stations in these depths was also noted).

DISCUSSION

Results of the two-year sampling effort at soft bottom stations on the southwest Florida shelf have produced a broad baseline description of macroinfaunal and macroepibiotal assemblages. The shelf is characterized by a rich, diverse infauna dominated by polychaetes and (to a lesser extent) peracarid crustaceans. The macroepibiota collected in trawls comprise a variety of demersal fishes and crustaceans having different substratum affinities, reflecting, in part, the distribution of scattered live bottom habitat across the otherwise sand-dominated shelf. Shelfwide patterns of infaunal abundance, species richness, diversity, equitability, assemblage composition, and macroepibiotal species richness and assemblage composition were described in the previous section. This section discusses some of these results in the context of other studies of continental shelf benthos and suggests possible environmental influences on soft bottom benthic communities.

Infauna -- The results of infaunal sampling are in general similar to those observed in other continental shelf environments in the Gulf of Mexico, South Atlantic Bight, and the Mid-Atlantic coast. Most shelf habitats are characterized by a diverse and relatively low-density assemblage of polychaetes and peracarid crustaceans (especially amphipods and cumaceans) that compares to less diverse but more abundant infaunal assemblages in nearshore and estuarine environments.

Many of the species, and nearly all of the genera, of common infaunal organisms collected in this study are found in a wide geographic range of shelf environments, though particular species may be associated with particular sediment types and/or bathymetric ranges on any given shelf. The wide geographic range of many infaunal species and genera -- in contrast to that of epibiota -- reflects, in part, the buffering effect of the sedimentary habitat against environmental variations (especially temperature) in the water column.

Faunal densities observed in this study were typical of those previously observed in continental shelf environments and lower than generally observed in estuarine areas. Similar densities of generally less than 10,000 individuals/m^2 have been determined in the South Atlantic Bight and the Mid-Atlantic continental shelf. With a few exceptions, infaunal density was low at the outer shelf stations, a result in accord with previous findings from the eastern Gulf of Mexico. Also, as in the MAFLA results, polychaetes contributed about 60% of the total abundance of infauna.

Species richness in the southwest Florida shelf area was extraordinarily high, about four times that previously reported for the eastern Gulf of Mexico.

Diversity and equitability values determined in this study are typical of continental shelf benthos. Nearshore areas, especially those that are organically enriched or polluted, frequently exhibit low diversity because of dominance by a few opportunistic species. Although seasonal and spatial variations in diversity and equitability were evident within our data, none of the stations were dominated by one or a few species.

Infaunal zonation patterns on the shelf appear to represent primarily bathymetric and sediment-type groupings. Comparison of our cluster analysis results with preliminary findings from reanalysis of MAFLA infaunal data suggests very similar depth range groupings of infauna, with many of the same "characteristic" species within particular station groups common to both data sets. The major difference is that MAFLA infaunal transects did not extend far enough south to traverse the Tortugas pink shrimp grounds where fine carbonate muds predominate.

Macroepibiota -- Macroepibiota collected in otter trawls in our study area comprised a variety of fishes, crustaceans, other motile invertebrates, and scattered sessile epibiota. Comparisons of species richness and catch with results of other studies are not warranted due to differences in sampling gear, degree of replication, and area covered, etc. Trawl/data from our study can be considered only semiquantitative at best, even with respect to species richness. In addition, the most comparable data, that obtained during the MAFLA surveys, are not currently in a form that is amenable to its use in extensive comparisons. Fish data from our trawls and from MAFLA collections have been re-analyzed and synthesized by Dr. Rezneat Darnell at Texas A&M University (J. Kleypas, Texas A&M University, personal communication).

Methodology Evaluation -- The report includes an extensive evaluation (Section 7.5.3) of our soft bottom sampling methodology. The adequacy of the box corer and otter trawl, sieve size, sample replication (species saturation) and sampling frequency, are all reviewed.

In regard to improving sampling methodology, we suggest that an attempt be made to delineate sediment "patch size" prior to collection of infaunal sampling. This would eliminate some of the within-station variability in composition and abundance of infauna we observed. A greater degree of sample replication should also be employed, especially if the objective is to delineate changes (seasonal or otherwise) in infaunal or macroepibiotal communities.

Future Studies -- Future studies of soft bottom benthos on the southwest Florida shelf should focus on dynamic aspects of the shelf ecosystem, and benthic processes. Important variables to be measured include:

1) The rate of POM deposition to the benthos in different areas of the shelf;

2) The composition (carbon and nitrogen content, etc.) of sedimenting POM;

3) Standing crop of benthic microalgae at different locations, and rates of benthic microalgal production (important for surface deposit feeders and microphagous herbivores);

4) Frequency and severity of sediment disturbance (e.g., by storms); and

5) Rates of recolonization of disturbed sediment by infaunal organisms.

8.0 THE SHELF ECOSYSTEM A SUMMARY SYNTHESIS

This section of the report integrates the live bottom and soft bottom biological distributions with physical environmental data collected from the shelf, and seeks to identify some of the driving mechanisms and controlling variables operating within the southwest Florida shelf ecosystem.

PHYSICAL ENVIRONMENT

Loop Current Influence

The hydrographic regime of the southwest Florida shelf has the potential for continual, significant influence by the Loop Current (Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983). Passage of the Loop Current adjacent to the continental slope produces geostrophic upwelling, while direct impingement can result in near-bottom shoreward flow. In addition, Loop Current filaments or frontal eddies (Figure 8-1) can move onto the shelf. All of these mechanisms produce upwelling of colder, deeper, nutrient-rich waters into shallower continental shelf depths where they significantly influence both water column and benthic primary production (Figure 8-2).

Regional Benthic Environmental Trends

When considering benthic communities developed across the southwest Florida shelf, it is useful to address water column parameters in an onshore-offshore zonal configuration. Bottom slopes increase offshore, near-bottom temperatures and salinities become more constant, and near-bottom dissolved oxygen values decline. Water clarity increases offshore, but because of increasing depth, less light reaches the sea floor. Offshore, the bottom is less disturbed by wave and storm action, experiences more frequent upwelling events, and higher levels of near-bottom dissolved nutrients.

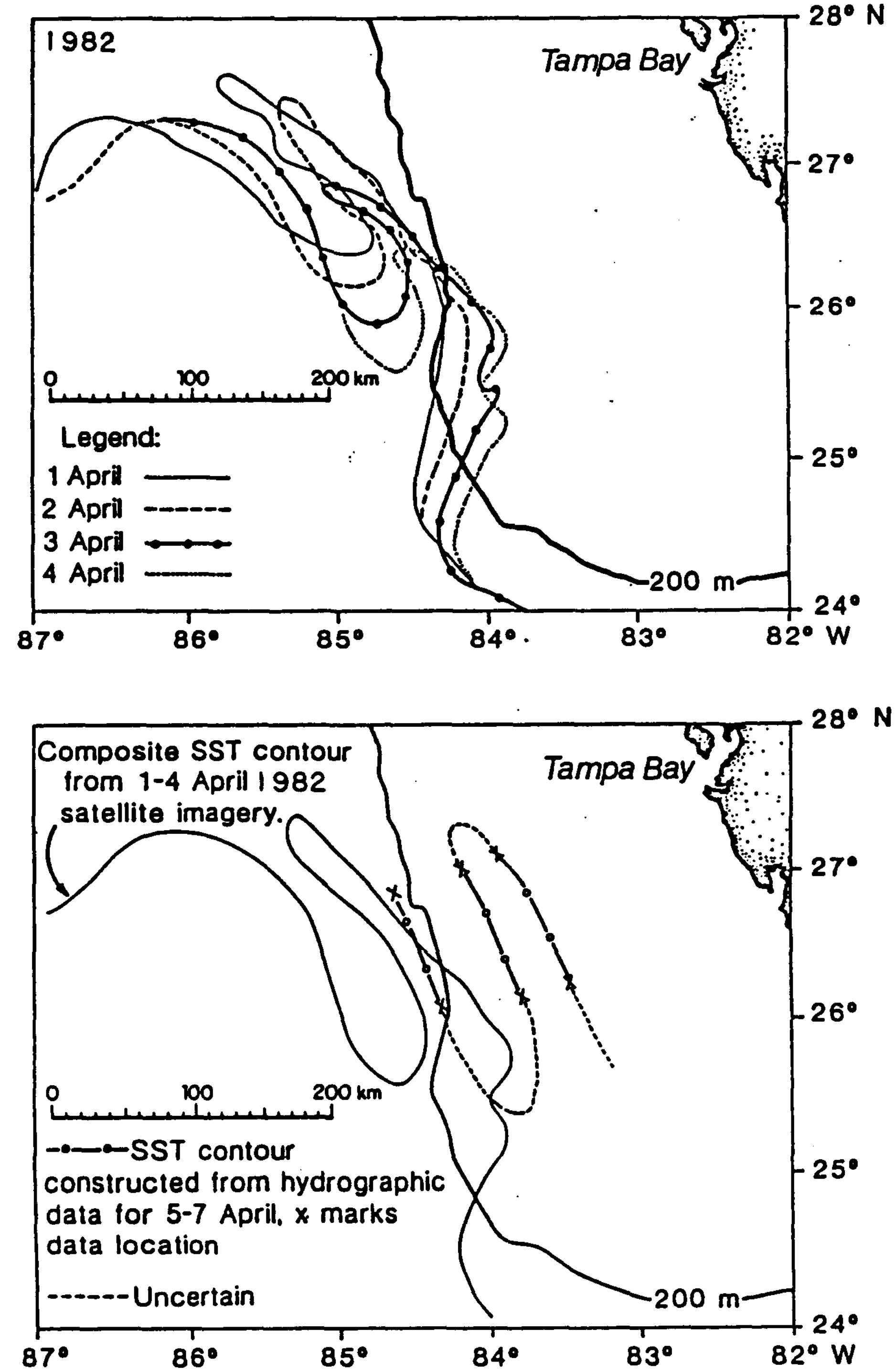


Figure 8-1. Time scale for impingement of Loop Current filament onto the shelf, April 1984 (after Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983).

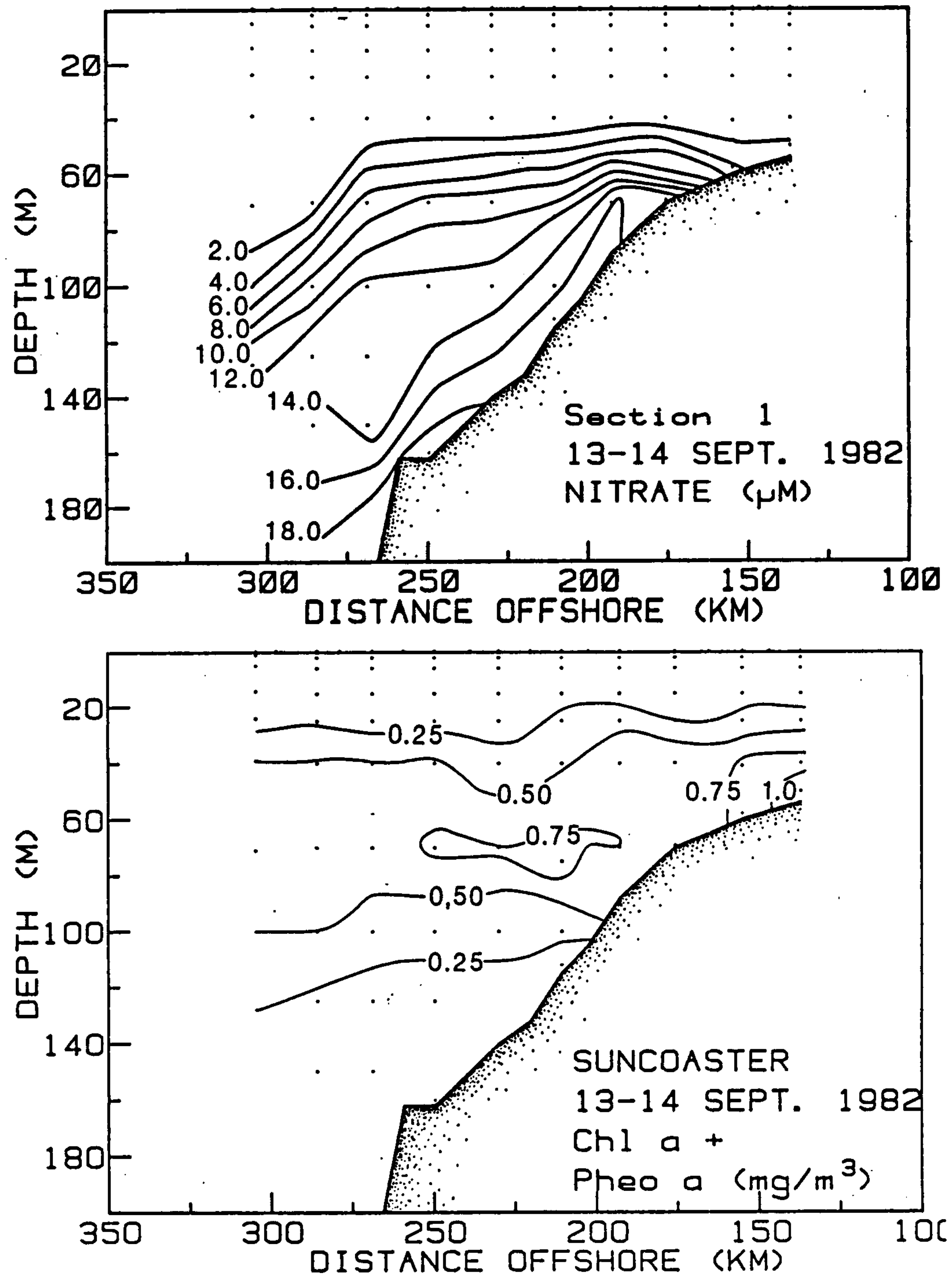


Figure 8-2 . Summer Cruise, 1982, Transect 1: nitrate (µM) and chlorophyll a + pheopigment a (mg/m^3) sections (after Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983). These illustrate shelf edge upwelling.

Shelf Structure and Sediments

The southwest Florida shelf consists of a broad carbonate platform overlain by varying thicknesses of late Tertiary-Quaternary sediments. Shallow nearshore sediments are quartz sands, which give way to calcareous sands within the present study area. The distribution of emergent and thinly-covered hard bottom is patchy and reflects in part the position of previous shorelines and ancient shallow reefs. On the inner shelf (<40m depths), the veneer of overlying sands is relatively thin and patch reefs, outcrops, and thinly-covered hard bottom are relatively common. Beyond about 40m depths, the wedge of unconsolidated sediments increases in thickness due in part to the impounding effect of a shallow, buried mid-shelf "reef complex" at about 70 to 90m depths. The surface expression of this ridge is most pronounced on the southernmost transect (Transect E), where Station 29 (which supports the *Agaricia* coral plate assemblage) is located on a distinct topographic elevation. The progressive increase in the proportion of "sand" substrate (vs. "thin sand over hard bottom") on Transects C, D, and E reflects a greater thickness and greater inshore penetration of the wedge of unconsolidated sediments in the southern part of the study area and a corresponding lack of live bottom (especially on Transect E). The increased thickness of the sand veneer at mid-shelf depths is also reflected in a relative lack of live bottom there; all four of the stations in 50- to 60m depths were located in very small patches, and live-bottom assemblages at 60- to 80m depths are associated with coralline algal nodules (or pavement) over a thick sand base. At greater depths, shell rubble provides a substrate for some live-bottom epibiota such as stalked crinoids (e.g., at Station 38). The major high-relief emergent hard bottom consists of a series of shelf-edge pinnacles that are probably drowned remnants of ancient calcareous algal reefs. In addition to the emergent hard bottom, the shelf is characterized by several different types of bedforms (e.g., sand waves) that are indicative of different levels and frequencies of disturbance by storms.

LIVE BOTTOM COMMUNITIES

Weighted Discriminant Analyses

The purpose of the weighted discriminant analyses (WDA) was to determine which environmental variable(s) best explained the station groupings derived during cluster analysis (Section 6.0). Environmental variables included station depth, near-bottom nitrite + nitrate, phosphate, silicate, salinity, temperature, and transmissivity. Separate WDA were run for each season (cruise), and for all seasons combined, on both the triangle dredge and otter trawl live bottom sample sets. Only the "all seasons" analyses yielded consistent results, as follows:

Live Bottom Triangle Dredge Data -- Of the variables included in the analysis, depth was best able to discriminate station groupings derived from triangle dredge cluster analysis. There was some evidence to suggest that near-bottom nutrient levels (nitrate + nitrite; phosphate) can also be used to discriminate stations groupings. The best separation was clearly between Group 1 and all other groups (Figure 8-3); Group 1 stations were at much greater depths than any other stations and were exposed to higher nutrient levels and lower temperatures than other stations. Depth per se cannot be invoked as a causative agent in the development of the biological assemblages of the shelf; rather, it is a correlate of several potentially influential environmental variables included in this analysis, such as nitrate and nitrite, phosphate, and temperature. In addition, it is likely to be correlated with several other variables (e.g., light levels, temperature range, substratum, etc.) that were not included in this analysis. In the absence of long-term average measurements of such variables (in contrast to the point measurements in this study), depth discriminates the assemblages effectively because it is a correlate of time-averaged environmental conditions.

Live Bottom Otter Trawl Data -- The results of the weighted discriminant analysis using otter trawl data indicate that depth and nitrate + nitrite levels are the variables best able to discriminate among station groupings. Depth per se was not as useful a discriminator as in triangle dredge-based analyses because otter trawl clustering placed some stations in different

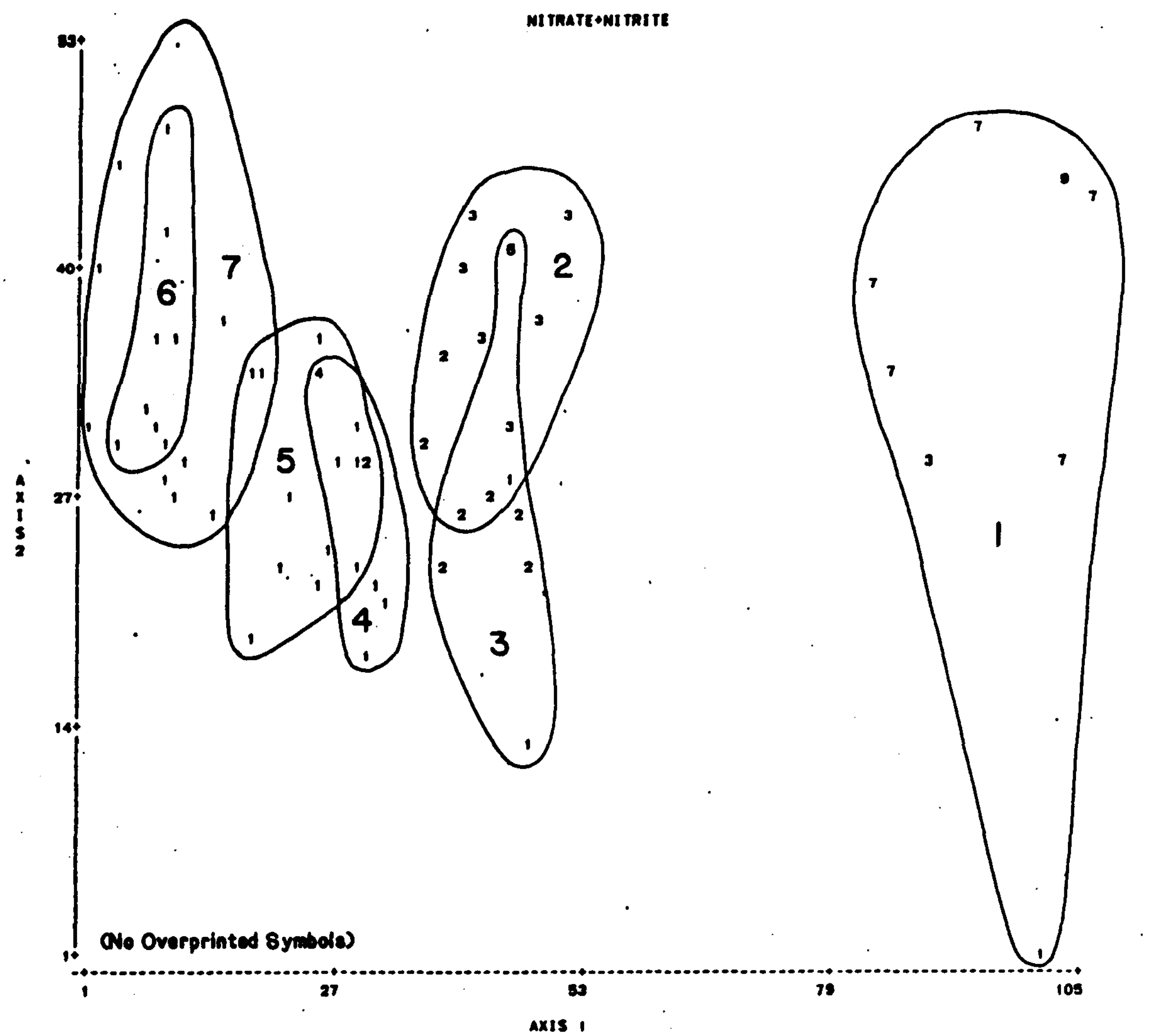


Figure 8-3 . Weighted discriminant analysis, triangle dredge data. Ordinal NITRATE + NITRITE values for each station/season plotted on the first two discriminant axes. Higher values indicate higher nitrate+nitrite concentrations.

groups depending on season. Of these seasonal groupings, only one could be associated with a specific environmental difference -- reduced salinity. However, the meaningfulness of this association is doubtful because the salinity was still 36.00 o/oo, only slightly lower than typical salinity values at the other outer shelf stations. Nutrient levels were not as successful in this analysis as in the corresponding triangle dredge analysis in separating station groups, with the exception of the deep, outer shelf stations which were subject to higher nutrient levels.

Live Bottom Communities and Environmental Variables

The following paragraphs summarize qualitative relationships observed between environmental variables and zonation patterns of the hard bottom biota.

Temperature -- The inferred effects of temperature on live bottom assemblages of the southwest Florida shelf include: (1) restriction of tropical-tolerant species to depths shallower than about 90m; (2) probable episodic mortalities of tropical and or sub-tropical tolerant species at shallow locations due to occasional severe winter cold fronts; and (3) regulation of seasonal algal abundance, especially at inner shelf locations.

Light -- The major influences of light levels on biological assemblages of the shelf are mediated by algae, including the symbiotic zooxanthellae harbored by hermatypic corals. Decreasing light levels with depth establish a lower limit for hermatypic coral development and probably determine (in part) the shelf-wide abundance patterns of benthic algae. Both algae and hermatypic corals can provide emergent structure that in turn provides microhabitats for a variety of associated cryptic fauna.

Although the level of 1% light penetration (65 to 70m on the southwest Florida shelf) is commonly taken as the lower boundary of the euphotic zone, some algal production obviously occurs at greater depths. In our study, unidentified "green algae" were noted on outcrops at deep (150 to 160m) shelf-edge stations where light levels should be quite low.

Salinity and Dissolved Oxygen -- Near-bottom salinities were consistently oceanic at all stations and are therefore not likely to be important controlling variables for live bottom biota. As expected in a generally oligotrophic shelf environment with no major riverine particulate inputs, dissolved oxygen levels were generally high and also not likely to exert a limiting influence on epibiotal assemblages present.

Particulate Organic Matter Inputs -- Non-living particulate organic matter (POM) is likely to represent a significant primary or supplemental food source for suspension-feeding epibiota such as sponges and ascidians, and deposited organic material can also serve as primary food for the abundance of associated motile invertebrates such as deposit-feeding crustaceans.

When the shelf as a whole is considered, significant differences in POM input are likely, and these should be a significant influence on the productivity and composition of benthic assemblages on the shelf. Deposition of phytoplankton production and resuspension of bottom sediments (including in situ benthic microalgal production) are likely to be the major POM inputs to the benthos, and Loop Current intrusions are likely to provide the largest pulses of POM deposition. The relative importance of various POM sources and the magnitude of POM deposition in relation to benthic respiratory demand could be assessed in future work using sediment traps and in situ respirometry.

Dissolved Nutrient Levels -- Most of the shelf benthic environment is exposed to consistently low nitrate and phosphate levels, but the near-bottom environment of the outer shelf is exposed to much higher nitrate and phosphate concentrations characteristic of deeper upwelled Loop Current water (Figure 8-2). This would be of little consequence if the penetration of the nutrient-rich layer were restricted to depths beyond the lower light limits of benthic algae. On the outer shelf, nutrient enrichment is apparently responsible for the observed subsurface chlorophyll maxima in the water column (e.g., Transect C, Winter and Spring Cruises). In the benthic environment the nutrient-enrichment effect extends inshore to about 55m depths, where several middle shelf stations (e.g., 11, 23, 29, and 30) exhibited order-of-magnitude higher near-bottom nutrient levels than shallower stations. It is within the 60 to 80m depth range, which is within the photic zone and within the range of the nutrient-rich bottom layer, where the coralline algal nodule (or pavement) substrate predominates, other crustose red algae are abundant, and (at southern stations) the leafy green alga Anadyomene menziesii occurs at high densities.

Substratum and Sediment Movement -- Sessile epibiota require a firm substrate for attachment. In the case of many corals and sponges, this means emergent hard bottom; for some epibiota (e.g., the crinoids at outer shelf stations), surface rubble or debris may suffice. The need for a stable sediment-free surface is probably most critical for larvae, and this may prevent the establishement of live bottom biota on sand-covered hard substrates. In the benthic environment of the southwest Florida shelf, most epibiota occur on hard substratum that is covered by a thin veneer of sand. Bare substratum must occasionally be generated (e.g., by shifting sediments), and the frequency and duration of periods of exposure of bare patches should be critical variables in determining rates of colonization by sessile epibiota.

Biotic Variables -- In addition to different tolerance ranges to physical environmental variables exhibited by different organisms, biological capabilities and biotic interactions could play important roles in determining the shelfwide distribution of live bottom epibiota. Important biological considerations include: (1) dispersal and colonization abilities; (2) trophic and/or habitat associations; (3) competition; and (4) predation. because the biota of the southwest Florida shelf is relatively unstudied (aside from taxonomy), the importance of specific processes and interactions in determining observed spatial and temporal patterns is largely speculative at this time.

SOFT BOTTOM COMMUNITIES

Weighted Discriminant Analyses

Weighted Discriminant Analyses (WDA) were run on the soft bottom box core infaunal data and soft bottom macroepifaunal otter trawl data. Principal Components Analysis was used to help select some 14 environmental variables (similar to those used for live bottom analysis, plus five sediment-related factors) used for the WDA.

Soft Bottom Box Core Infaunal Data -- Weighted discriminant analysis of box core infaunal data shows that depth and grain size (Figure 8-4) are the environmental parameters that, in combination, best distinguish among the station groupings derived from cluster analysis. Although a general depth-related zonation pattern is evident, the pattern is complicated at nearshore stations by variations in sedimentary parameters. Stations 25 and 26 in the inner portion of Transect E are located in an area of silt-sized carbonate sediments and support a distinctive infaunal assemblage. Nearshore stations (2, 6, 14, and 20) are all in comparable water depths but are characterized by different sedimentary parameters; coarse sand predominated at Stations 2 (Fall Cruise) and 20, whereas mean grain size was lower and fine sand content higher at Stations 2 (Spring Cruise), 6, and 14. The difference in the clustering of Station 2 between cruises (i.e., with station 20 in the Fall Cruise and with stations 6 and 14 on the Spring Cruise) appears to reflect sampling of different sediment patches on the two cruises.

Soft Bottom Macroepifaunal Otter Trawl Data -- The weighted discriminant analysis of otter trawl data from soft bottom stations provided little insight into possible controlling variables in comparison to the similar analysis of box core infaunal data. The results are more comparable to those of the live bottom otter trawl analysis, although for the soft bottom trawls, nutrient variables did not emerge as good discriminators. Although the groupings derived from cluster analysis can be broadly characterized as depth-related, "seasonal" difference in the collections at some stations resulted in cluster groupings that could not be "explained" by depth gradients. The other environmental variables included in the analysis provided little or no additional insight into possible factors controlling community composition at these stations. As noted in connection with live bottom otter trawl results, part of the apparent seasonal variability in trawl collections is probably attributable to sampling inadequacy.

Soft Bottom Communities and Environmental Variables

The weighted discriminant analysis identified depth and sediment grain size variables as environmental features that differed among station groupings emerging from cluster analysis box core data. In the soft-bottom trawl data, only depth discriminated the station groupings. As discussed previously,

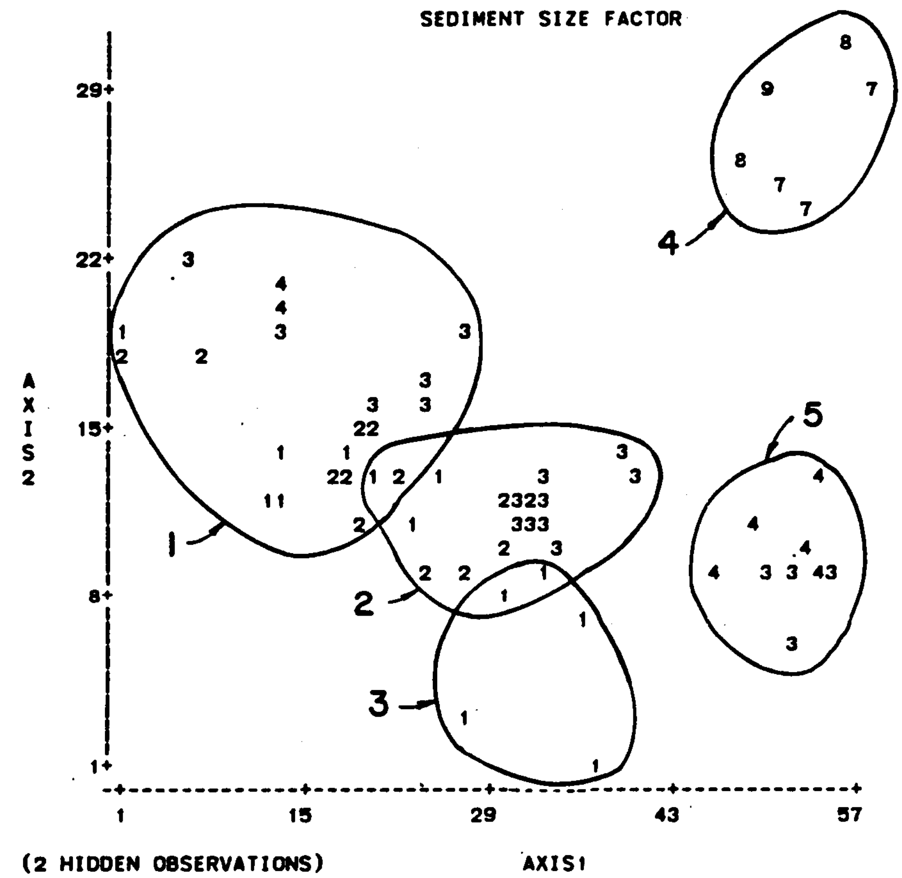


Figure 8-4 . Weighted discriminant analysis, box core infaunal data, Ordinal values of the SEDIMENT SIZE FACTOR for each station/season point plotted on the first two discriminant axes. Higher values indicate finer sediments.

depth per se has little explanatory value; its importance in the discriminant analysis is presumed to reflect depth-related trends in environmental variables such as temperature, light, nutrients, substratum, etc.

Temperature -- Most of the species collected in trawls were fishes. Shelfwide distribution patterns are considered reflections of the minimum temperature tolerance of the particular fish species: for tropicals, no growth at 18°C and mortality at 16 to 18°C; for subtropicals, no growth at 15°C and mortality at 15°C. Consistent temperatures of 18°C or more are most likely to predominate at mid-shelf depths in our study area while upwelling of deep Loop Current water onto the outer shelf results in cooler temperature anomalies.

Substratum -- Although not evident in the discriminant analysis of trawl data, substratum characteristics are also important determinants of community composition of fishes and epibenthic crustaceans. Distinctive assemblages are generally associated with major substrate types in the Gulf. Although the shelf is in general characterized by coarse carbonate sands, finer sediments predominate in certain areas, particularly at the inshore end of Transects E (Stations 25 and 26) and B (near Station 6). Stations 25 and 26 are located in the area of the Tortugas pink shrimp grounds, and Station 6 is in the area of the Sanibel grounds (Station 14 is just south of the latter).

Sediment Grain Size -- The emergence of grain size related parameters as important determinants of infaunal assemblage composition is in accord with results of other benthic studies of continental shelf habitats and with the know importance of sediment parameters for infauna. Sediment serves as both habitat and food source for many of these organisms, and substrate affinities can reflect effects of grain size variables on tube-building activities, motility, and feeding type.

Primary Production and Particulate Matter Input -- Other environmental factors that are likely to influence the abundance and community composition of infauna include the shelfwide variation in POM inputs and in situ micro- and macro-algal production. The magnitude of benthic production in different benthic environments is probably related to differences in ambient POM deposition rates, which should vary as functions of water depth and primary production in the overlying water column. The generally low infaunal standing crop of the southwest Florida shelf is a consequence of the oligotrophic quality of the overlying waters, as has been suggested for Gulf of Mexico deep-sea benthos. Because there is no major riverine influence on the area, interaction of the Loop Current with the shelf system is probably the major forcing function of water column primary productivity (Woodward-Clyde Consultants and Skidaway Institute of Oceanography, 1983).

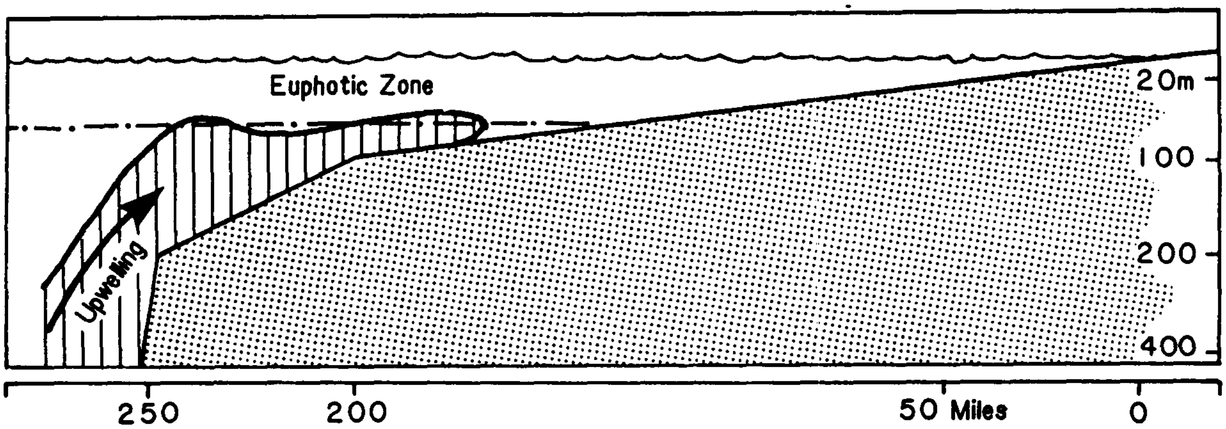
SUMMARY & CONCLUSIONS

Shelfwide and seasonal patterns in the composition of live and soft bottom assemblages and the abundance of the component biota presumably reflect the influence of a suite of environmental variables on the recruitment, survival, growth, and reproduction of benthic organisms. The relationships between environmental variables and the distribution of biotic assemblages (derived from cluster analysis) were investigated using weighted discriminant analysis. Environmental variables available for the discriminant analysis of data from live bottom stations included station depth and hydrographic variables (temperature, salinity, dissolved oxygen, transmissivity, and inorganic nutrients). Several sediment grain size variables were also available for inclusion in the soft bottom discriminant analysis. In both analyses, station depth emerged as a major discriminating "variable"; the usefulness of depth as a discriminator is believed to reflect depth-related trends in environmental variables such as temperature, light, nutrients, substratum quality, and POM inputs. Even though several of these depth-correlated variables were included in the discriminant analyses, depth per se was a better discriminator, probably because it integrates environmental conditions over time. Depth as a correlate of time-averaged environmental conditions has more explanatory value than do "point" measurements of those environmental variables.

Substratum and inorganic nutrient variables provided additional insight into station groupings in the discriminant analyses. Sediment grain size variables emerged as significant discriminators of soft bottom station groupings, reflecting the recognized importance of sediment characteristics as determinants of its suitability as a habitat and food source for deposit-feeding infauna. Inorganic nutrient (nitrate, phosphate) levels emerged as potential influences on the distribution of live bottom assemblages, though the causal mechanism for such influences is not known; several direct or indirect pathways of influence are possible.

Two peculiarities of the physical environment of the southwest Florida shelf have important influences on the distribution of assemblages and the abundance of biota. The first is the Loop Current, which passes southward along the shelf edge and generates geostrophic upwelling of cold, nutrient-rich water onto the outer shelf. Enhanced water column productivity due to nutrient enrichment is well-documented and could provide substantial POM inputs to outer and middle shelf benthos; these POM inputs are potential food sources for surface deposit-feeding infauna and suspension-feeding sessile epibiota. The second peculiarity is the existence of a north-trending subsurface reef complex in 70 to 90m depths, which is most prominent on the southernmost Transect E, where the *Agaricia* coral-plate assemblage occurs. Farther north along the mid-shelf buried reef complex, live bottom is increasingly sparse due to the submergence of the feature beneath the increasingly thick veneer of unconsolidated sediments.

A graphic summary of across-shelf environmental trends, some speculative ecological relationships, and a hypothetical schematic food-web for the southwest Florida shelf, are presented in Figures 8-5 and 8-6. In addition, models portraying the roles of substrate type and sediment movement as determinants of benthic community types developed across the inner, middle, and outer regions of the southwest Florida shelf, are presented in Figures 8-7, 8-8, and 8-9, respectively. Note that substrate "transitions" reflect both spatial differences in distribution of substrate types and temporal changes due to sediment movement and/or algal nodule formation.



REGIONAL TRENDS

← Increasing Bottom Slope ——

← More Constant Near-bottom Temperature /Salinity ——

← Decreasing Near-bottom Dissolved Oxygen ——

← Less Light Reaches Sea Floor ——

← Increasing Water Clarity ——

← Bottom Less Disturbed by Storms ——

← Increasingly Frequent Upwelling Events ——

← Increasing Near-bottom Dissolved Nutrients ——

SPECULATIONS

OFFSHORE	ONSHORE
Primary Production Pulses	Low Primary Production
Increased POM/DOM from Subsurface Plankton	Minimal POM/DOM from Land Runoff
Less Disturbed Bottom, Thicker Sand Veneer, Self-edge Attachment Sites	Unstable Shifting Sand Veneer
Available Substrate & Depth (Light) Limited	Bottom Disturbance & Food Limited

Figure 8-5 . Southwest Florida shelf ecosystem, a summary of regional trends and some speculations.

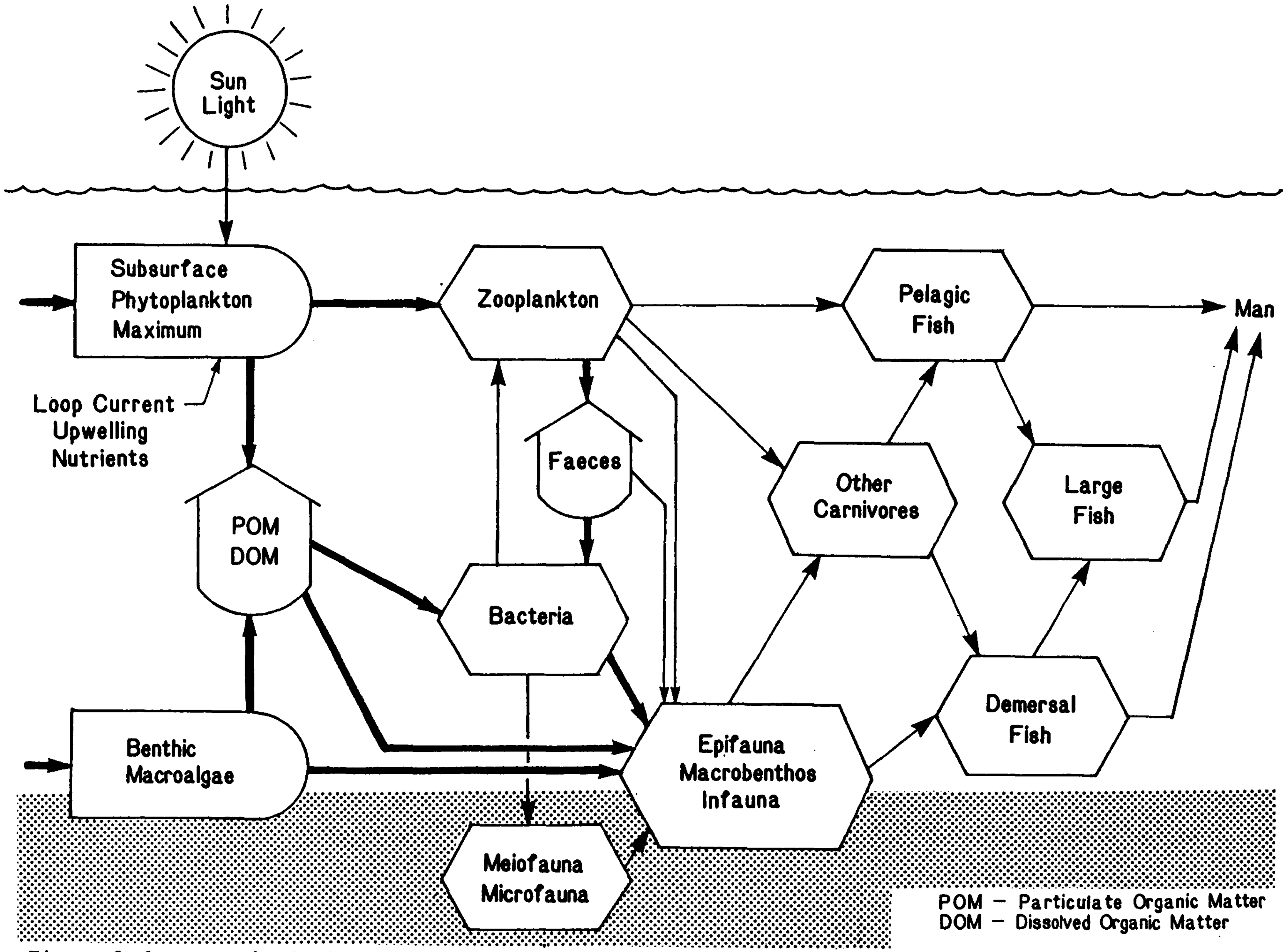


Figure 8-6. Hypothetical schematic food web for the southwest Florida shelf ecosystem, emphasizing the roles of the subsurface phytoplankton maximum, benthic macroalgae and macrobenthos (developed after Mann, 1982).

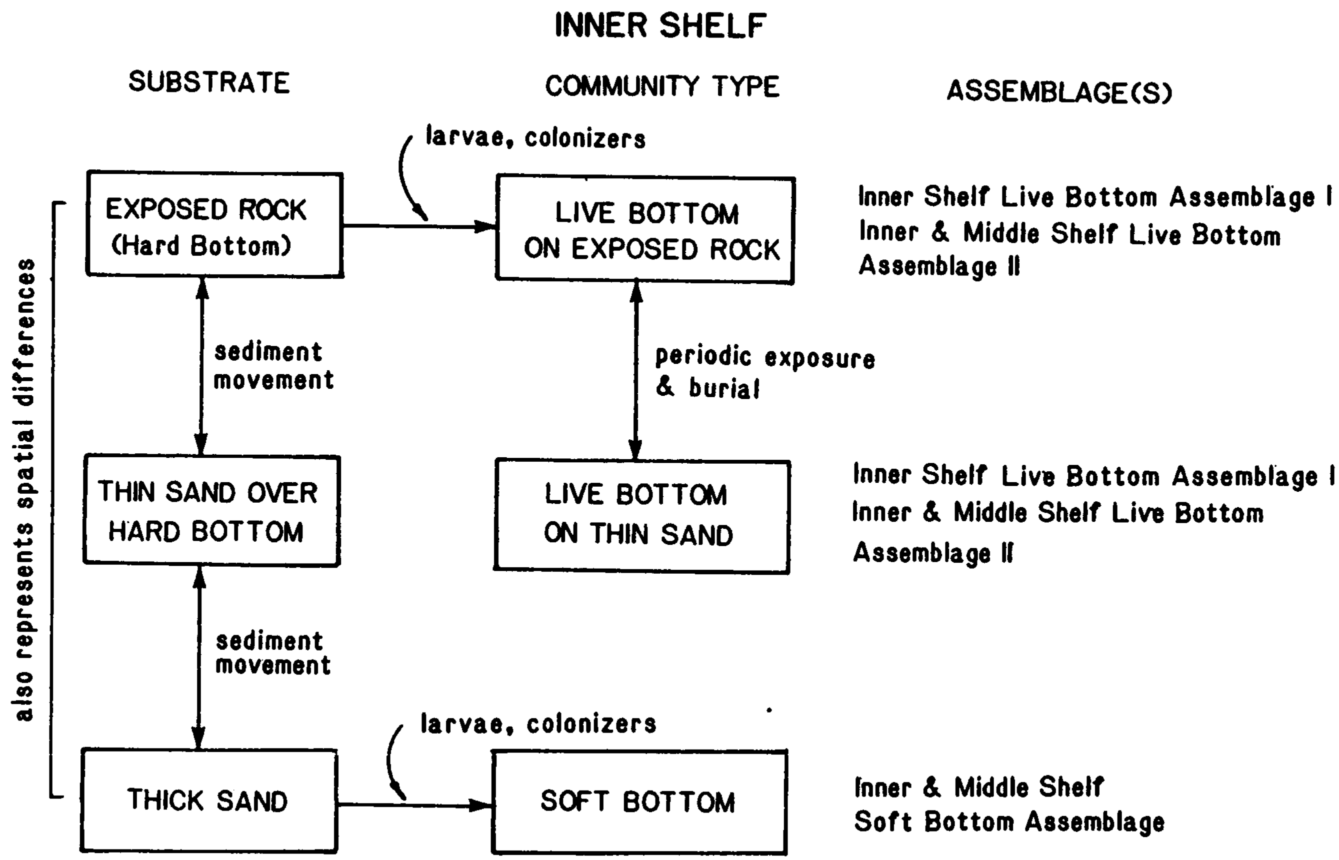


Figure 8-7. Southwest Florida inner shelf: hypothetical relationships among substrates, community types, and specific benthic species assemblages. See text for additional explanation.

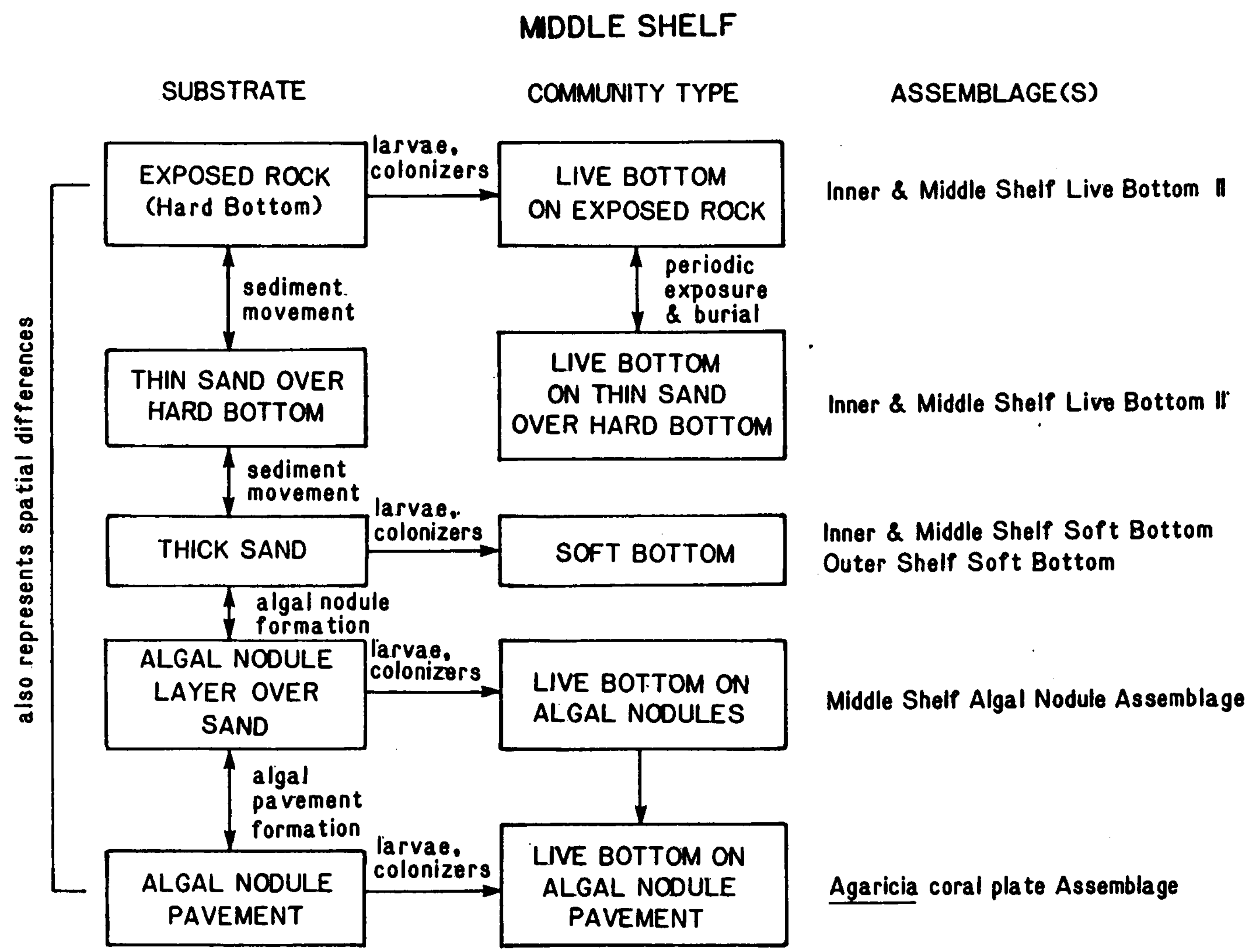


Figure 8-8. Southwest Florida middle shelf: hypothetical relationships among substrates, community types, and specific benthic species assemblages. See text for additional explanation.

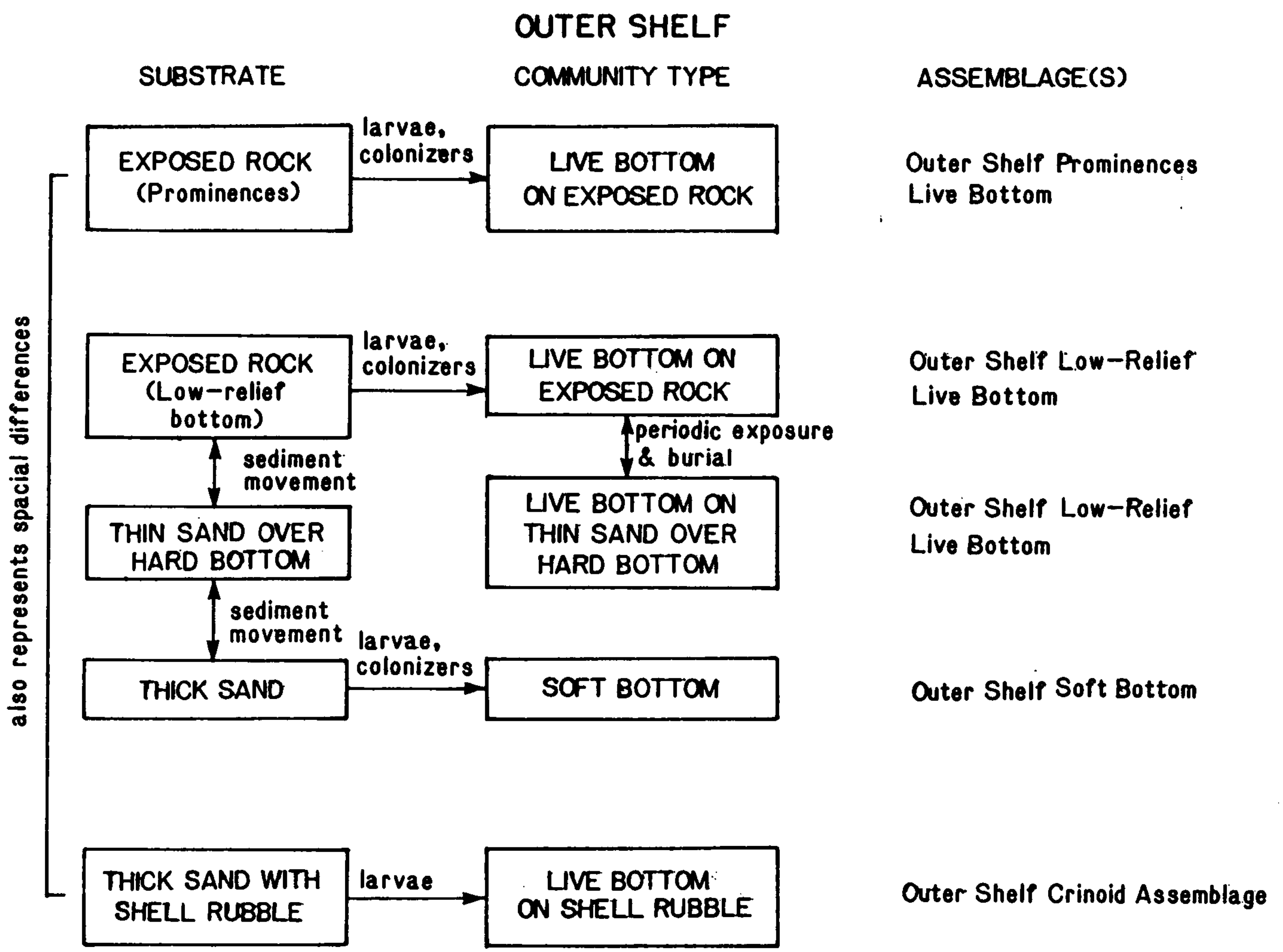


Figure 8-9. Southwest Florida outer shelf: hypothetical relationships among substrates, community types and specific benthic species assemblages. See text for additional explanation.

9.0 POTENTIAL OCS DEVELOPMENT IMPACTS

Southwest Florida shelf leases and the study transects are shown in Figure 9-1. The MMS has presented a number of scenarios for offshore oil and gas development and identified special concerns:

- Disruption or damage to sensitive biological communities in the vicinity of offshore drilling and pipeline operations; potential for oil spills and dispersant impacts on benthos;
- Harm to the endangered Florida manatee (and other endangered species);
- Destruction of sensitive coastal nesting habitats of birds and potential damage to individuals in the event of a spill; and
- Impacts on offshore marine commercial and recreational fishing.

This section of the report outlines the types of activities and potential impacts usually associated with the exploration, development, and production phases of OCS oil and gas development (Figure 2).

Information on the potential for oil spills on the southwest Florida shelf, and their potential trajectories and land-falls, should they occur, are available from four sources:

- Empirical studies of circulation using surface drift bottles and Woodhead surface drifters
- Empirical distributional studies of crude oil residues -- pelagic tar/tar balls
- Theoretical oil spill risk analysis and oil spill trajectory analysis performed by the U.S. Geological Survey
- On-going MMS Eastern Gulf of Mexico physical oceanography study programs.

Potential ecological consequences of drilling mud and cuttings impacts, oil spill impacts, dredging impacts (associated with offshore pipelines and nearshore/onshore development), and onshore development impacts, are all

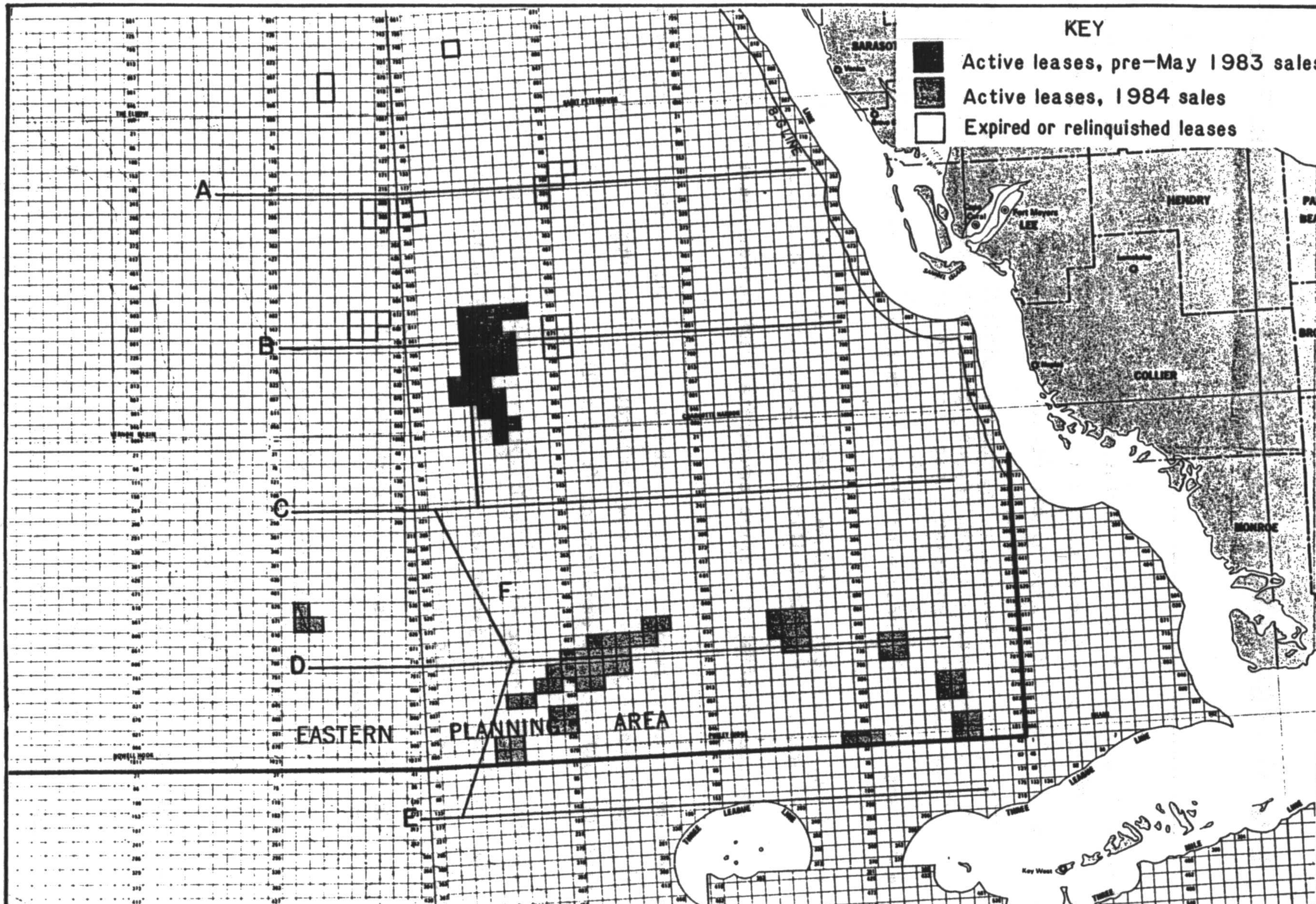


Figure 9-1. Southwest Florida shelf OCS oil and gas lease tracts and Year One and Two study transects (A-F ; after MMS, 1984).

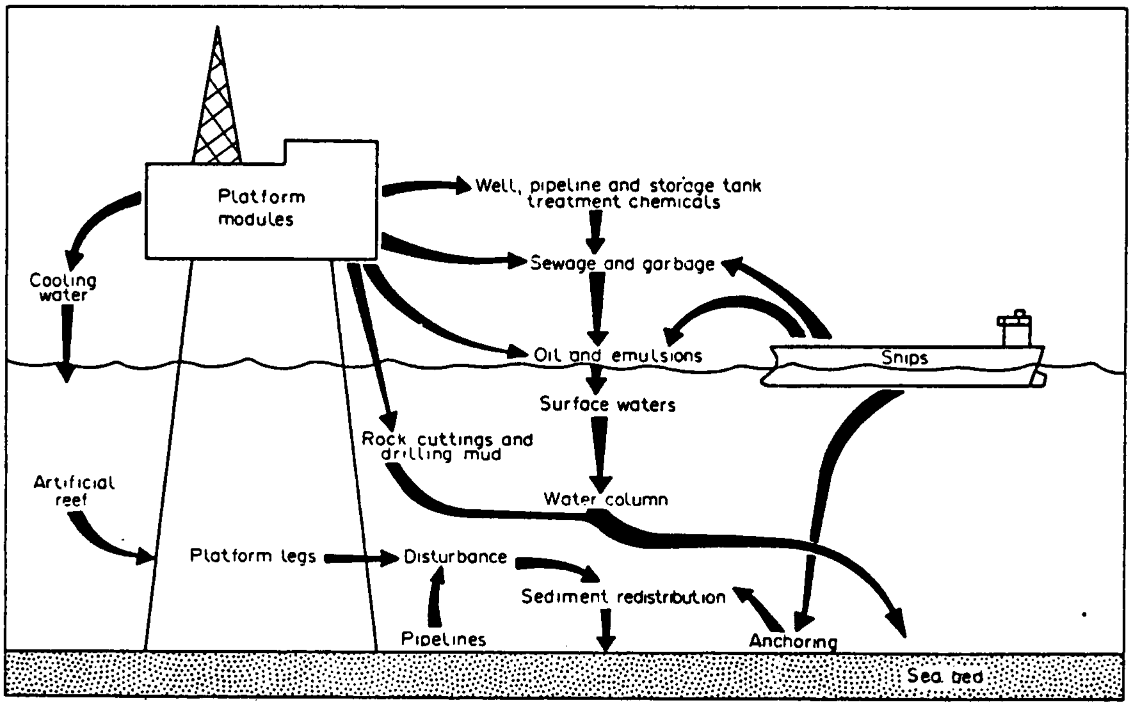


Figure 9-2. Potential pathways for various biological effects of oil and gas development (Dicks, 1982). Additional pathways include atmospheric imputs from flare stacks and fires, release of produced waters, and export through "reef" species food chains.

outlined in the report. Special regional concerns include: biologically sensitive coastal areas, marine mammals (including the manatee), marine turtles, coastal and marine birds, commercial fisheries, recreational fisheries, and the role of offshore rigs as artificial reefs.

SAMPLE STATION SPECIFIC IMPACTS

This concluding portion of Section 9.0 briefly outlines the types of OCS development-related impacts that would be of greatest potential significance and concern at each of the 39 individual sampling stations examined during this study. A summary listing of potential OCS development-related impacts, compiled from the discussions presented above, is provided in Table 9-1. General substrate characteristics at each sampling station are reviewed in Volume 2, Section 5.0. Live bottom and soft bottom species assemblages present at each site are described in Volume 3, Sections 6.0 and 7.0, respectively. These data, combined with the development activities presented in Table 9-1, have been used to examine those specific impacts most likely to be of concern at individual sampling stations.

A summary of potential impacts for each live bottom sample station is presented in Table 9-2, and for each soft bottom station in Table 9-3. Six separate impact criteria are considered for each individual station summary. Four criteria represent general categories of OCS development-related concerns drawn together from Table 9-1. These concerns reflect an individual sampling station's likely susceptibility to: (1) bottom disturbance; (2) burial/sedimentation; (3) added hard substrate; and (4) toxic pollutants, respectively. In addition, each station's relative habitat "value," and potential recovery rate following possible disturbance, are considered. Further explanation of the terms used in the station impact summaries is presented below.

Relative Habitat Value

As a group, all live bottom stations are regarded as significantly more susceptible to development impacts than soft bottom stations. The "relative habitat value" criterion is therefore based on the distinctiveness and abundance of any live bottom assemblage present at each sample station -- the

Table 9-1. Summary of potential impacts associated with southwest Florida shelf OCS exploration and development activities.

Activity/Source	Potential Impacts
(1) Anchoring Drill Rigs & Boats	Bottom disturbance Breakup of algal pavement Smothering benthos Increased turbidity & Reduced photosynthesis
(2) Rig-associated Boat Traffic	Increased potential for local air & water pollution & possible collisions with sea turtles & manatees
(3) Discharge Sewage, Garbage, Deck Drainage	Local water pollution
(4) Discharge Cooling Waters	Locally increased ambient water temp.
(5) Discharge Drill Cuttings	Smothering benthos Increase in hard substrate for epifaunal attachment Release of mud additives, heavy metals, hydrocarbons
(6) Discharge Drilling Muds	Burial of hard substrate Smothering of benthos Increased turbidity & reduced photosynthesis Clogging respiratory/feeding structures Release of mud additives, heavy metals, hydrocarbons
(7) Discharge Produced Waters	Discharge of brine, oil and grease, trace metal residues Local changes ambient ion ratios
(8) Oil Spills from Rigs, Tankers & Pipelines	Shoreline impacts Oil coating on birds & turtles; asphyxiation Acute & chronic toxic effects Shading, reduced photosynthesis, potential toxicity due to dispersants
(9) Emplaced Drilling Structures	Artificial reef effects -- attachment surfaces, increased shelter, food supply Increased fishing opportunities
(10) Pipeline Installation	Dredging, bottom disturbance Smothering of benthos Increased turbidity & Reduced photosynthesis Resuspension of polluted sediments
(11) Onshore Development	Loss of coastal habitat Dredging impacts Water, energy requirements Increased potential for pollution Increased urbanization

Table 9-2. Impact Summary Table for Live Bottom Sampling Stations.

Station	Relative Habitat "Value"	Likely Susceptibility to: Bottom Disturbance	Likely Susceptibility to: Burial/ Sedimentation	Likely Susceptibility to: Added Hard Substrate	Likely Susceptibility to: Toxic Pollutants	Relative Recovery Rate
1	C	Moderate	Moderate	Moderate	Yes	Slow
3	D	Moderate	Moderate	Moderate	Yes	Slow
7	C	Moderate	Moderate	Moderate	Yes	Slow
9	D	Moderate	Moderate	Moderate	Yes	Slow
10	C	High	Moderate	Moderate	Yes	Slow
11	C	High	Moderate	Moderate	Yes	Slow
13	B	Moderate	Moderate	Moderate	Yes	Slow
15	B	Moderate	Moderate	Moderate	Yes	Slow
17	D	Moderate	Moderate	Moderate	Yes	Slow
19	C	Moderate	Moderate	Moderate	Yes	Slow
21	B	Moderate	Moderate	Moderate	Yes	Slow
23	B	High	Moderate	Moderate	Yes	Slow
27	D	Moderate	Moderate	Moderate	Yes	Slow
29	A	High	High	Moderate	Yes	Very Slow
30	A	High	High	Moderate	Yes	Very Slow
32	D	Moderate	Moderate	Moderate	Yes	Slow
35	C	High	Moderate	Moderate	Yes	Moderate
36	C	Moderate	Moderate	Moderate	Yes	Slow
38	C	Moderate	Moderate	Moderate	Yes	Slow
39	C	High	Low	Low	Yes	Slow

See text for explanation of terms.

Table 9-3. Impact Summary Table for Soft Bottom Sampling Stations.

Station	Relative Habitat "Value"	Likely Susceptibility to: Bottom Disturbance	Burial/ Sedimentation	Added Hard Substrate	Toxic Pollutants	Relative Recovery Rate
2	F	Low	Moderate	High	Yes	Rapid
4	F	Low	Moderate	High	Yes	Rapid
5	F	Low	Moderate	High	Yes	Rapid
6	F	Low	Moderate	High	Yes	Rapid
8	E	Low	Moderate	High	Yes	Rapid
12	F	Low	Moderate	High	Yes	Rapid
14	F	Low	Moderate	High	Yes	Rapid
16	E	Low	Moderate	High	Yes	Rapid
18	F	Low	Moderate	High	Yes	Rapid
20	F	Low	Moderate	High	Yes	Rapid
22	E	Low	Moderate	High	Yes	Rapid
24	F	Low	Moderate	High	Yes	Rapid
25	F	Low	Moderate	High	Yes	Rapid
26	F	Low	Moderate	High	Yes	Rapid
28	E	Low	Moderate	High	Yes	Rapid
31	F	Low	Moderate	High	Yes	Rapid
33	F	Low	Moderate	High	Yes	Rapid
34	F	Low	Moderate	High	Yes	Rapid
37	F	Low	Moderate	High	Yes	Rapid

See text for explanation of terms.

species richness and apparent abundance of epibiota, and the spatial extent of the live bottom patch. Live bottom Stations 29 and 30, with the Agaricia coral plate assemblage, are considered to be unique, rich, live bottom areas and are ranked highest (Rank A). The soft bottom stations are considered the least distinctive and support relatively sparse epibiota (Rank F); however, soft bottom Stations 8, 16, 22, and 28 exhibited species-rich trawl collections that included many typical live bottom species, so these four stations are assigned a slightly higher value (Rank E). Of the remaining live bottom stations, Stations 13, 15, 21, and 23 are considered to be the most important in terms of percent cover and species richness (Rank B).

Susceptibility to Impacts

The four general categories listed here represent a summary of the various impacts presented in Table 9-1. Further explanations of each susceptibility category are outlined below.

Bottom Disturbance

For example, anchor and rig emplacement and removal. This is presumed to have the greatest potential for impact where epibiota occur on exposed rock (e.g., at Station 39) or a surface layer of algal nodules (Stations 10, 11, and 23), algal nodule pavement (Stations 29 and 30), or shell rubble (Station 35). The rest of the live bottom stations would be affected, but less severely, and soft bottom stations even less so.

Burial/Sedimentation

For example, release of drilling muds and cuttings. This would be most damaging at Stations 19 and 30, where the agariciid corals are sensitive to sedimentation. There would be little effect at Station 39 because of the steep slope and likely strong currents at shelf edge. Other live bottom stations could be impacted to various degrees, but are classified here as moderate. The soft bottom stations are also considered to be susceptible, not so much because of burial but because of possible changes in sediment texture, an important determinant of infaunal community composition. Fine drilling mud particles would be an atypical substrate over much of the shelf, except perhaps at Stations 25 and 26, where carbonate muds predominate. Cuttings particles can range up to several centimeters in size and these too would be atypical almost anywhere on the shelf.

Effect of Added Hard Substrate

For example, anchors, platform legs, cuttings piles, etc. The impact would be greatest where there is currently no emergent hard bottom (for prominent epibiota) -- that is, at the soft bottom stations. There would be significant effects at all live bottom stations, though the impact would be least where there is already considerable relief, such as at Station 39.

Effects of Toxic Pollutants

For example, components of drilling muds, spilled oil, or other wastes. We have no information to suggest differential sensitivity of live and soft bottom biota. Presumably, significant impacts could result at any station if the exposure level were high enough.

Relative Recovery Rate

This is very speculative at this time and is intended to be used in a comparative sense only. Most infaunal species have short generation times and high growth rates in comparison with large, sessile epibiota (e.g., sponges, hard corals) typical of live bottom areas. Moreover, most of the shelf is covered by sand bottom, whereas the distribution of live bottom is patchy; therefore, the availability of suitable larvae and colonists for a defaunated soft bottom area is likely to be greater than for a live bottom area. We speculate that the formation of the algal nodule pavement and the large *Agaricia* coral plates could take longer than would regrowth of other epibiota such as sponges and gorgonians. Finally, recovery of crinoids attached to shell rubble at Station 35 may be somewhat more rapid than recovery of sessile epibiota attached to rock outcrops of thin sand over hard substrate. The shell rubble should be readily and frequently moved under natural conditions by strong near bottom currents; this suggests the crinoids may be quick to recolonize such areas after a disturbance.

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During the first year of the program, we experienced several unavoidable logistical and laboratory delays; the biological sampling program yielded double the volume of material and almost twice the number of species projected from previous studies. Year Two analyses were also slowed by this increased volume of data, as well as by closure of our San Diego, Environmental Systems Division office. Woodward-Clyde Consultants thus particularly appreciates the continuing support, advice and encouragement received from Minerals Management Service staff: Contract Officers, Carroll Day and Frances Sullivan; New Orlean's COR Officers, Robert Avent and Murray Brown; and Washington, D.C. Technical Officers, Mark Grussendorf, Tom Ahlfeld, and Jim Lane.

This Final Report was prepared jointly by Woodward-Clyde Consultants and Keith B. Macdonald & Associates, Inc. (San Diego, California) working closely with staff inputs and draft report sections provided by the various subcontractors cited above. Contract terms require that for public information purposes, principal contributors to the study be identified, their educational backgrounds noted, and their roles within the program specified. This information is set out below. Woodward-Clyde Consultants and Keith B. Macdonald & Assoc., Inc. gratefully acknowledge the unique personal contribution of each of these individuals to the overall success of the study.

Woodward-Clyde Consultants -- Prime Contractor

Keith B. Macdonald, Ph.D. (University of California - Scripps Institution of Oceanography, Marine Ecology/Geology, 1967) -- Program Manager. Program inception through December 1983. In June 1984, Keith B. Macdonald & Associates, Inc., subcontracted to WCC to complete the Year Two Final Report. Text and graphics editor all sections; contributions to analysis and intepretation.

Robert E. Bonin, M.S. (Texas A&M University, Biological Oceanography, 1977) -- Assistant Program Manager. Shipboard quality assurance; editorial contributions to Sections 2.0, 3.0, and 5.0.

Hong Chin, Ph.D. (New York University, Oceanography, 1971) -- Physical and chemical oceanography; editorial contributions to Section 4.0.

Jan D. Rietman, Ph.D. (Stanford University, Geophysics, 1966) -- Principal Investigator, Geophysical Investigations.

Drs. Gordon A. Robilliard and Ted Winfield each assisted Woodward-Clyde Consultants with Program Management functions following closure of the San Diego office.

Final text figures were drafted by Cynthia Heyman of Woodward-Clyde Consultants; the Final Report text was prepared by Word Processor Specialist Robert H. Collins of Tonga WordPro, Inc., San Diego, California.

Continental Shelf Associates, Inc. -- Prime Subcontractor

David A. Gettleson, Ph.D. (Texas A&M University, Biological Oceanography, 1976) -- Principal Investigator, Live Bottom Biology.

Neal W. Phillips, Ph.D. (University of Georgia, Athens, Ecology, 1983) -- Principal author of Section 6.0; major contributions to sections 7.0 and 8.0.

Keith D. Spring, M.S. (Florida Institute of Technology, Biological Oceanography, 1981) -- Laboratory Supervisor; contributions to Sections 5.0, 6.0, and 7.0.

Frederick B. Ayer II, B.S. (New College, Marine Biology, 1974) -- Field Operations Manager.

Mote Marine Laboratory -- Subcontractor

Selvakumaran Mahadevan, Ph.D. (Florida State University, Biological Oceanography, 1977) -- Principal Investigator, Soft Bottom Biology. Contributions to Section 7.0

James K. Culter, M.A. (University of South Florida, Zoology, 1979) -- Infaunal studies ; principal authorship of Section 7.0.

University of South Florida - Subcontractor

Kenneth D. Haddad, M.S. (University of South Florida, Marine Science, 1980), acting as an independent consultant, formerly with USF, presently relocated at Bureau of Marine Research -- Principal Investigator, Water Column Data Analysis; principal authorship of Section 4.0; contributions to Section 8.0.

EcoAnalysis, Inc. Ojai, CA. -- Data Analysis Subcontractor

David E. Guggenheim, M.A. (University of Pennsylvania, Philadelphia, Regional Science, 1980) -- Senior Data Analyst. All phases of data analysis, contributions to interpretation.

Robert W. Smith, Ph.D. (University of Southern California, Biology, 1976) -- Contributions to analytical approach and methodology.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.