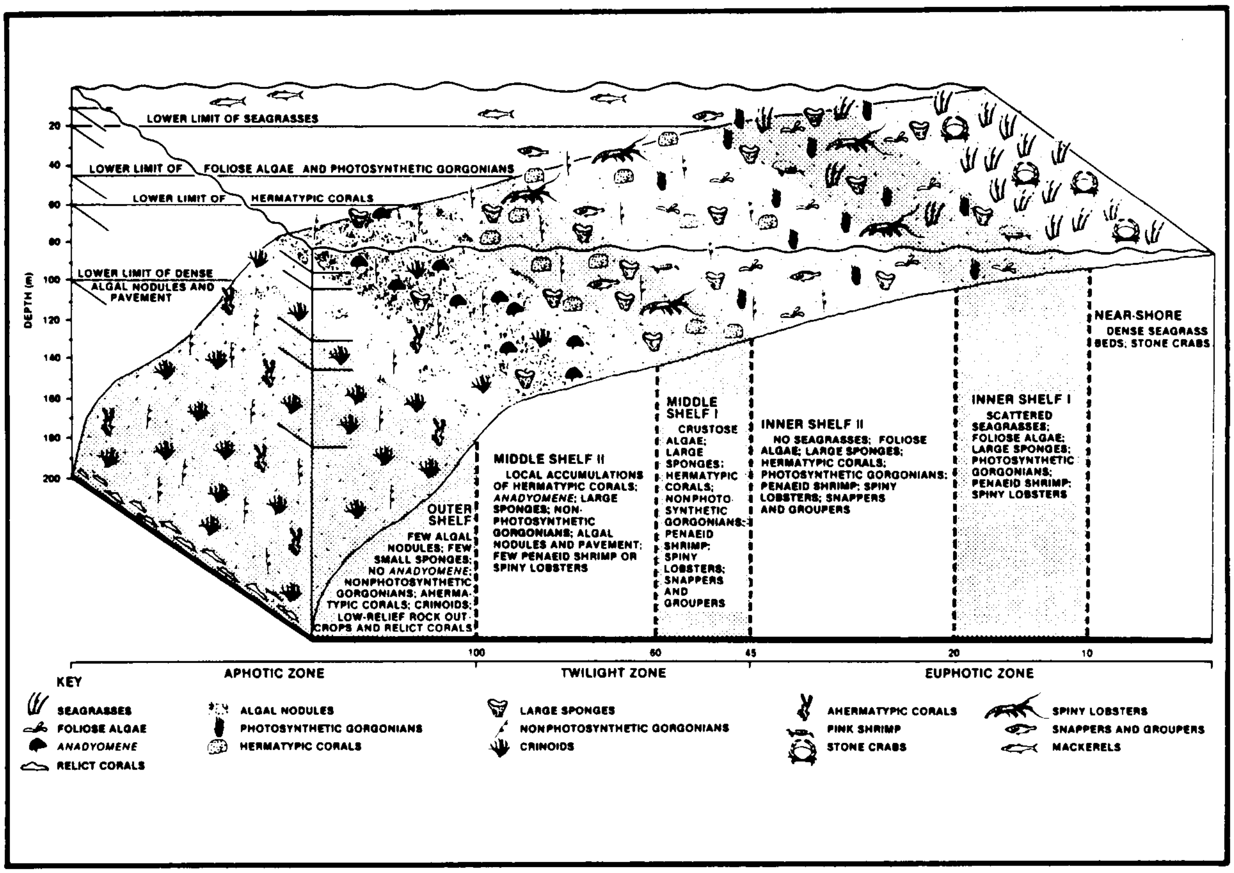
OCS Study
MMS 87-0023

Southwest Florida Shelf Ecosystems Study

Volume II: Data Synthesis Report



MMS U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

OCS Study
MMS 87-0023

Southwest Florida Shelf Ecosystems Study

Volume II: Data Synthesis Report

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1.0 INTRODUCTION

The Minerals Management Service (MMS) has four priority goals for outer continental shelf (OCS) leasing: (1) orderly oil and gas resource development to meet the nation's energy needs; (2) protection of the human, marine, and coastal environments; (3) receipt of fair market value; and (4) preservation of free enterprise competition. Informed management decision making is paramount in achieving these goals: the MMS OCS Environmental Studies Program is one of the instruments used by MMS to aid in the decision making process. The objectives of this 6-year program have been to obtain environmental data on the impacts of petroleum exploration and production activities on the OCS and provide relevant information to support management decisions concerning OCS leasing.

This report concludes the 6-year Southwest Florida Shelf Ecosystems Program of environmental studies. The objectives defined by MMS for this environmental studies program were as follows:

1. Determine the location and distribution of various benthic habitats and associated communities;
2. Determine the seasonal structure and density of selected live- and soft-bottom communities (live-bottom communities are operationally defined as those associated with either a hard substrate or a thin veneer of sediment over a hard substrate on which average density of attached macrofauna is greater than approximately one individual per square meter);
3. Compare community structure of live- and soft-bottom fauna and flora to determine the differences and similarities between them and their dependence on substrate type;
4. Determine and compare the hydrographic structure of the water column and bottom conditions at selected sites within the study area;

5. Determine and compare sedimentary character at selected sites within the study area and estimate sediment transport;
6. Relate differences in biological communities to hydrographic, sedimentary, and geographic variables; and
7. Provide essential information on the dynamics of selected live-bottom communities and determine the major factors which influence their development, maturation, stability, and seasonal variability.

The ultimate goal of this program was 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.

The following subsections provide a brief description of the study area and a brief history of the 6-year program. Subsequent sections of this report present Year 6 data collection and management methods (Section 2.0), study area characterization (Section 3.0), impact projections (Section 4.0), conclusions (Section 5.0), and references cited (Section 6.0).

1.1 STUDY AREA

The study area extends seaward from the west coast of Florida to the 200-m isobath and from 27°N latitude southward to the Florida Keys and Dry Tortugas (see Figure 1.1-1). The region includes Florida Bay, but not other estuarine areas. This area contains numerous live-bottom habitats and associated communities in a complex, patchy matrix. Live-bottom areas are often separated by wide expanses of sand- or mud-bottom areas.

STATION	YEAR 1	2	3	4	5
1	●	●			
2	●				
3	●	●			
4	●	●			
5	●	●			
6	●	●			
7	●	●			●
8	●				
9	●	●			
10	●				
11	●	●			
12	●	●			
13	●	●			
14	●	●			
15	●	●			
16	●	●			
17	●				
18	●				
19	●			●	
20	●	●			
21	●	●		●	●
22	●	●			
23	●	●		●	●
24	●	●			
25	●	●			
26	●				
27	●				
28	●	●			
29	●	●		●	●
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31		●			
32		●			
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34		●			
35		●			
36		●		●	●
37		●			
38		●			
39		●			
40			●		
41			●		
42			●		
43			●	●	
44			●	●	●
45			●	●	
46			●	●	
47			●	●	
48			●	●	
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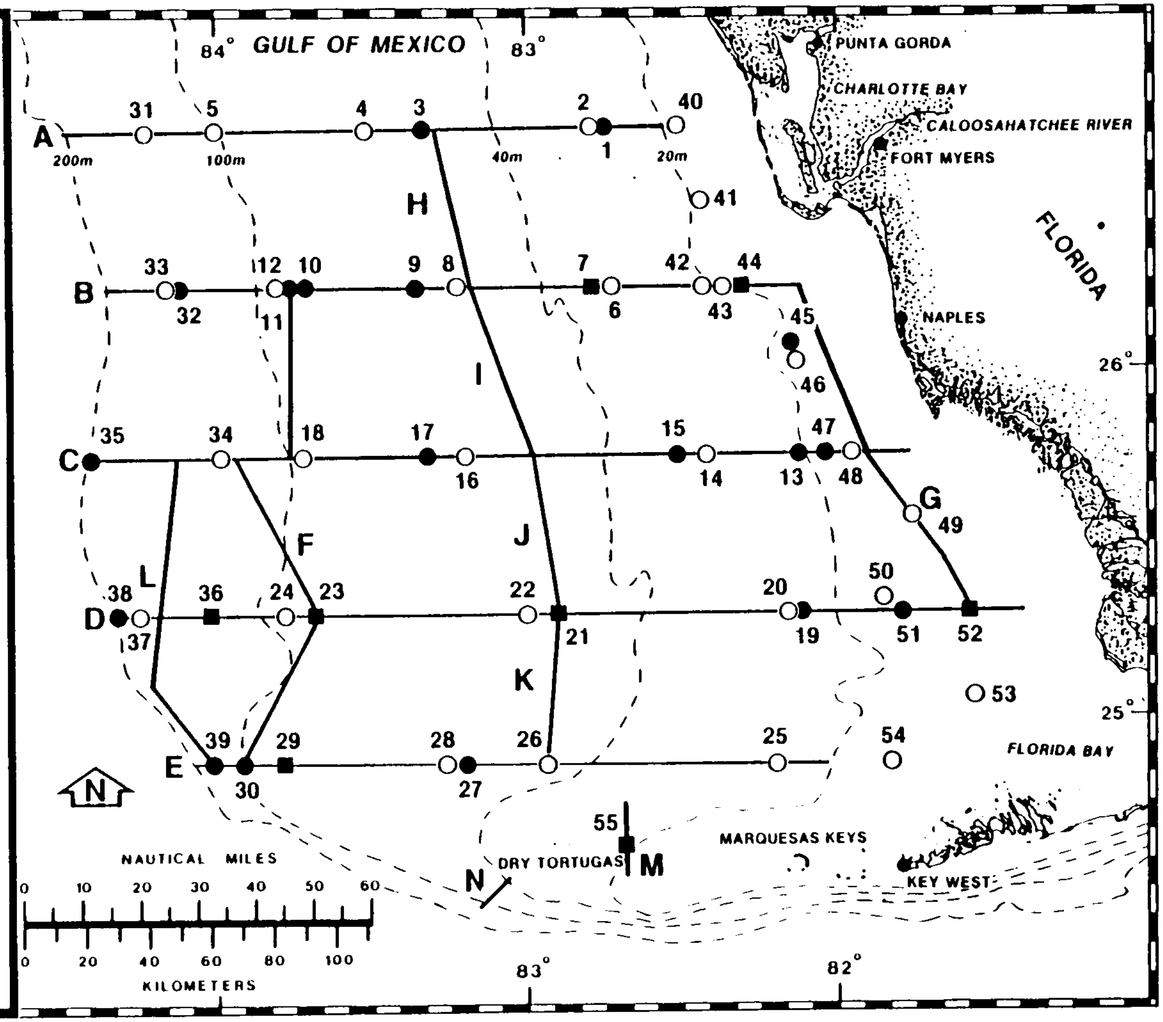


Figure 1.1-1 Southwest Florida Shelf Ecosystems Program study area with Years 1 through 5 geophysical and towed underwater television transects (A-N) and discrete stations (1-55) indicated. Inset indicates years during which stations were sampled; ○ = soft-bottom, ● = live-bottom, and ■ = intensively sampled station.

1.2 PROGRAM HISTORY

The 6-year Southwest Florida Shelf Ecosystems Program began in 1980 as an interdisciplinary study designed to meet the objectives previously stated. During Year 1 of the program, field sampling cruises were conducted during October-November 1980 and April-May 1981. Geophysical surveys (bathymetric, seismic, and side-scan sonar) were conducted along Transects A through E (see Figure 1.1-1) from approximately the 40-m to the 200-m isobath. Along these same transects, from water depths between 20 and 100 m, visual records were obtained using towed underwater television and 35-mm, still color photography.

Water column data [salinity, temperature, dissolved oxygen, transmissivity, light penetration, nutrients, chlorophyll, and Gelbstoff (yellow substance)] were collected at 30 cross-shelf stations (see Figure 1.1-1). Benthic data were obtained with underwater television, still photography, and trawls for all 30 stations; in addition, triangular dredges were used to collect benthic data at the 15 live-bottom stations. Infauna data, sediment grain size, carbonate content, hydrocarbons, and trace metals data were collected at the 15 soft-bottom stations.

During Year 2, cruises were conducted in July-August 1981 and January-February 1982. Additional geophysical information was collected along a new north-south transect (Transect F, Figure 1.1-1), at approximately 100-m water depth, that tied together several of the previously surveyed east-west transects (Transects A through E). Visual data, again including underwater television and still-camera photography, were extended along Transects A through E from 100- to 200-m water depths.

Twenty-one of the 30 original hydrographic and benthic biological stations occupied during Year 1 were resampled twice in Year 2. For this set of stations, hydrographic and biological data were now available on a seasonal basis. In addition, nine new hydrographic and benthic biological stations (see Figure 1.1-1) were established on Transects A through E, in water depths ranging from 100 to 200 m. Each of these stations was sampled during both cruises.

Under a Year 2 contract modification (which was essentially a separate third year of hydrographic studies), two seasonal hydrographic cruises (April and September 1982) were conducted to yield a hydrographic analysis of temperature, salinity, transmissivity, phytoplankton, chlorophyll, and nutrients. Primary productivity was measured during both cruises and correlated with nutrient and other physico-chemical data. A simultaneous overflight by the National Aeronautics and Space Administration (NASA) ocean color scanner during the April cruise was completed to investigate chlorophyll and primary productivity throughout the region during the spring bloom. Optical oceanographic measurements were also taken during the April cruise as ground truth for the color scanner.

The expanded Year 3 benthic program incorporated three cruises. Cruise I (October 1982) continued the bottom-mapping activities that were begun in Year 1. Bathymetry, side-scan sonar, subbottom profiling, underwater television, still photography, and hydrography studies were conducted along Transects B, C, and D (extended eastward to depths of 10 m) and on new north-south transects (Transects G, H, I, J, K, and L; Figure 1.1-1).

Cruise II was conducted in December 1982 and consisted of biological and hydrographic sampling. Ten new soft-bottom stations in the 10- to 20-m-depth range were sampled for infauna and sediment grain size and hydrocarbon content. Five additional live-bottom stations in the same depth range as the soft-bottom stations were surveyed using underwater television, still photography, dredges, trawls, sediment traps, and diver-deployed quadrat bottom sampling. In addition, hydrographic casts were made at the live-bottom stations. During Cruise III, conducted in June 1983, the same stations and parameters sampled during Cruise II were resampled to provide seasonal data.

In Year 4 of the program, five soft-bottom and five live-bottom stations (Figure 1.1-1) were sampled during Cruises I (December 1983) and III (May 1985); this essentially completed the seasonal baseline descriptive study of the inshore area initiated during Year 3 (Cruises II and III). Hydrographic measurements (salinity, temperature, dissolved oxygen, and transmissivity) were made at all 10 stations. Infauna and sediment samples were collected at the five soft-bottom stations; macroalgae, epifauna, and nekton surveys (using underwater television, still photography, trawling, and dredging) were conducted at the five live-bottom stations.

In addition, five live-bottom stations (see Figure 1.1-1) were selected for intensive study of physical and biological processes. These stations, each representing a separate epifaunal community type, were sampled during Cruises I, II (March 1984), III, and IV (August 1984). Sampling at these stations consisted of dredging, trawling, underwater television, still photography, sediments, and hydrography.

In addition, in situ instrumented arrays were installed at these stations to study biological and physical processes. Each array was equipped with a current meter that measured current velocity and temperature continuously; 3 sets of sediment traps at elevations of 0.5, 1.0, and 1.5 m above the bottom; and 10 sets of artificial substrate settling plates that were scheduled to be retrieved at 3-month intervals over 2 years. The arrays at two stations also were equipped with a wave and tide gage and a time-lapse camera to document sediment transport and biological recruitment. These arrays were serviced quarterly.

During Year 5, quarterly sampling cruises were conducted [Cruise V (December 1984), Cruise VI (March 1985), Cruise VII (June 1985), Cruise VIII (September 1985), and Cruise IX (December 1985)]. Intensive sampling of the five Year 4 live-bottom stations continued, and three other stations were added for intensive study (see Figure 1.1-1). Two of these stations had been surveyed in previous years; the third station, located between the Dry Tortugas and the Marquesas, was a new station established in Year 5. This station was chosen primarily because it was at a key location within the boundary of the shelf and would provide valuable information for subsequent modeling efforts. The other two stations were selected because they were farther north than the original five stations and provided information on latitudinal variation.

There was some modification to the sampling program during Year 5. Dredging was discontinued at the five original live-bottom stations and was conducted at only two of the three additional stations. The third station was sampled only with the instrumented array and CTD because sufficient epifaunal information was available for this and similar shallow stations. A second modification was the transfer of a wave and tide gage from a more offshore station to the station located between the Dry Tortugas and the Marquesas because this station was shallower and, therefore, would provide better wave measurements. In addition, tide data from this station would be more valuable in providing boundary conditions for subsequent modeling efforts. Also, seven of the eight arrays were equipped with time-lapse cameras; only the deepest station (125 m) was not equipped with a camera because it was too deep for the standard camera cases used for this program. Finally, during Year 5, two new transects were surveyed with underwater television and side-scan sonar. Transect M ran north-south between the Dry Tortugas and the Marquesas at an average water depth of 27 m; Transect N ran from the

Tortugas shoals southwest to a depth of 100 m (see Figure 1.1-1). These transects were added to supplement the habitat-mapping studies completed in previous years.

2.0 DATA COLLECTION MANAGEMENT AND METHODS AND MATERIALS

2.0 DATA COLLECTION MANAGEMENT AND METHODS AND MATERIALS

The procedures used during Years 1 through 5 are briefly outlined in Section 1.0 of this report. Detailed descriptions of all field and analytical methods for these years are contained in the annual reports prepared for each of these years. The methods used during Year 6 for collecting historical data and development of an automated information system are described in the following subsections. The development of an automated information system was essential for processing the large number of references collected during this study. The system can be thought of as a bibliography installed in a microcomputer that allows the user to search, append, correct, and print references.

2.1 DATA COLLECTION

The first step in data collection was to conduct a Program Initiation Workshop where the Principal Investigators, as well as representatives from MMS, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and the Florida Governor's Office, met to present and discuss possible valued ecosystem components (VECs) that would be examined during subsequent conceptual modeling efforts. The VECs chosen by the attendees of this meeting were used to direct the information collection effort. This ensured that the energy spent on the literature search and data review was focused on the ecosystem components of most concern on the southwest Florida shelf.

Next, spatial, temporal, and topical limits were determined to control information collection. The spatial or geographic limits were varied, depending on the topic. The geographic limits for meteorology or physical oceanography delineated an area larger than the study area previously described because of the scale of some of the processes. The geographic limits for biology or geology, however, were identical to the limits of the study area.

Temporal limits extended from the earliest available information to the present.

Topical limits were also set to keep the information system a manageable size. Limits used in this study were based on the guidelines established by Mahadevan et al. (1984) in the preparation of their bibliography. The limiting rule applied was that behavioral, morphological, or taxonomic studies of single species would be de-emphasized except when those species were either endangered or designated as VECs. Unlike Mahadevan et al. (1984), method descriptions were de-emphasized unless site specific. These topical limits precluded overloading the automated information system with data that, although important, were not germane to the overall goals of this program.

As the information collection effort continued, the necessity for certain special inclusions became evident. The geographic limits as set forth in the Request for Proposal, particularly the easternmost geographic limit (i.e., the west coast of Florida), required that marine, estuarine, or intertidal information for certain Florida counties be included. These counties included: Sarasota, Lee, Collier, Charlotte, Monroe (which includes the majority of the references on Florida Bay), and the gulf-side references for Dade.

Certain references were included because of their topical content regardless of the geographic limits. These special inclusions were: any discussions of hydrocarbons in the marine environment (water column, sediments, and biota), the effects of drilling or drilling fluids and cuttings, the effects of offshore oil and gas development, discussions regarding biological processes or communities and the physical processes that affect each, important pelagic fishes (e.g., billfishes), and reports presenting the results of similar studies.

Numerous databases, agencies, institutions, private companies, and individuals were investigated as potential sources of relevant information. The majority of the information was obtained from existing databases or literature, although telephone calls and visits to specific individuals or agencies were occasionally used to collect information.

As expected, the majority of the site-specific information was contained in the reports authored by Woodward Clyde Consultants, Continental Shelf Associates, Inc.; Environmental Science and Engineering, Inc.; and LGL Ecological Research Associates, Inc., for Years 1 through 5 of the Southwest Florida Shelf Ecosystems Program. In addition to these reports, other publications provided relevant information or lists of other publications that might be relevant.

The basis for this project's automated information system was the references contained in the Tuscaloosa Trend's bibliography (Barry A. Vittor & Associates, Inc., 1985) provided to Environmental Science and Engineering, Inc., by MMS on microcomputer diskettes. The 1,106 references contained on these diskettes were transferred into the automated information system; 657 were deleted because they were considered not relevant to the Southwest Florida Shelf Ecosystems Program.

In addition, 559 references from the Mote Marine Laboratory bibliography (Mahadevan et al., 1984) were added to the automated information system. These references were chosen either because they were topically or geographically relevant to this program. Many of the county-specific references were obtained from this bibliography.

The remainder of the information was obtained from libraries, computerized literature searches (e.g., Lockheed's DIALOG Information

Retrieval Service, which currently accesses more than 220 databases containing in excess of 110 million records), searches of existing agency databases, and visits to various agencies and institutions. A search of the various libraries produced nearly 200 additional references not included in the previously mentioned sources. The majority of these references included some of the most current information available.

Computer or manual searches of various existing agency databases were conducted. The agencies included:

1. National Oceanographic Data Center (NODC),
2. Assessment and Information Services Center (AISC),
3. National Climatic Data Center (NCDC),
4. National Geophysical Data Center (NGDC),
5. U.S. Geological Survey (USGS), and
6. National Marine Pollution Information System (NMPIS).

Visits to various agencies, institutions, and private companies or organizations were conducted to obtain information not available from the previously described sources. These agencies, institutions, and private companies or organizations included:

1. U.S. Fish and Wildlife Service (USFWS),
2. Minerals Management Service (MMS),
3. NOAA Atlantic Oceanographic and Meteorological Laboratories,
4. NOAA/NMFS Southeast Fisheries Center,
5. NOAA/National Environmental Satellite and Data Information Service (NESDIS),
6. U.S. National Park Service,
7. U.S. Geological Survey (USGS),
8. Florida Department of Natural Resources,
9. Florida Institute of Oceanography,
10. University of South Florida,
11. Florida Department of Environmental Regulation (FDER),

12. Florida Bureau of Archaeological Research,
13. Florida Marine Fisheries Commission,
14. Florida Sea Grant,
15. Florida State University,
16. University of Florida,
17. University of Miami, and
18. Mote Marine Laboratory.

The completed database compiled from all of the sources described previously contains in excess of 1,300 entries. This database is accessed through an automated information system which has the capability for updating, deleting, editing, sorting, and searching.

2.2 AUTOMATED INFORMATION SYSTEM

A microcomputer system was chosen for the automated information system because the hardware and software are less expensive than the hardware and software for a minicomputer or mainframe computer. Existing software was chosen rather than attempting to develop software specific to this project. After evaluating various database manipulative programs available, it was decided to use PCINFO. PCINFO was one of the few microcomputer data management systems capable of manipulating databases and records of the size required by this project. In addition, PCINFO was considered more user friendly. Although PCINFO meets the minimum requirements of this project, improvements could be made. The edit features are cumbersome using this, or any microcomputer, software. The problem results from the large size of the database (in excess of 6 megabytes) and the record size. These problems could be circumvented on a minicomputer or mainframe computer; however, this would have required expensive software and hardware. Therefore, the approach was considered the most cost-effective compromise. Although the system is somewhat cumbersome, it is reasonably inexpensive, and hardware in the form of drives and microcomputers is readily available.

2.3 DATA MANAGEMENT

Data management and submission of relevant data to NODC were integral parts of the information collection task. This subtask involved identification, evaluation, and procurement of data sets (provided that the data are available in computer-compatible format).

Data sets were identified from several sources including the articles already contained in the automated information system, the existing ROSCOP forms listed in Ralph Childers Associates (1984), and interviews conducted either in person or by telephone.

Based on the information obtained about a specific data set, the Data Manager, along with the Program Manager, decided the level of effort to be expended in submitting these data or a record of these data to NODC. In all instances, regardless of data format and quality, a ROSCOP form was submitted to NODC (unless a ROSCOP had already been submitted to NODC by the original investigator). A ROSCOP form identifies the study, geographical location, all data types and their status and disposition, and whom to query for more information on the data. Consequently, anyone searching the NODC system will learn that the data exist and will be told whom to contact to obtain the data or further information.

If the data were obtained in a computer-compatible form (i.e., tape, disk, or cards), the data were reformatted (i.e., put into appropriate form with required headers and descriptions) to NODC format. A data documentation form (DDF) was prepared. The DDF provides NODC and other users with required ancillary information that increases the utility of the data submitted. The information contained in a DDF includes: originator identification (project title, names, addresses, sampling time and location, and disposition); scientific content (data field, units, sampling methods, analytical methods, and data processing techniques);

data format (record types, file organization, and precise data format); record format; and instrument calibration (calibration dates, organization providing calibration services, and calibration schedule).

Prior to submitting any data, an NESDIS data submission agreement was prepared. This agreement is a letter drafted by the Data Manager specifying data types (e.g., Eulerian current data), NODC file types (e.g., File Type 015--Eulerian Currents), a statement agreeing to submit the data in NODC format (as specified by file type), an agreement to submit a test tape, and an agreement to submit a DDF with all data submitted to NODC. This draft letter was sent to NODC where the letter was reviewed, additional conditions were appended, the letter was signed by the NODC director, and returned for the Program Manager's signature. This letter established an agreement between Environmental Science and Engineering, Inc., and NODC for all subsequent data submissions. Following finalization of the data submission agreement, the data (in NODC format and accompanied by a DDF) were submitted to NODC.

3.0 CHARACTERIZATION OF STUDY AREA

3.0 CHARACTERIZATION OF STUDY AREA

3.1 PHYSIOGRAPHY

The southwest Florida continental shelf, as delimited by the 200-m isobath, is a broad (approximately 250 km), flat, limestone platform with relatively few areas of high relief (see Figure 3.1-1). The shelf slopes gently to the west. In most locations, low-lying, hard substrates either alternate with or are covered by a thin veneer of coarse sand. The southwest Florida shelf has been arbitrarily divided (according to Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a) into three depth zones: the inner shelf (from the shore to 40-m isobath), the middle shelf (from the 40-m isobath to the 100-m isobath), and the outer shelf (from the 100-m isobath to the 200-m isobath). The inner shelf seafloor gently slopes to the west at less than 0.3 m/km. Although much of the bottom is characterized as smooth, it is punctuated with numerous circular and elongated depressions as large as 2 km in diameter (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a). Florida Bay, formed by the juncture of the Florida Keys and the west coast of Florida, is a shallow (less than 3 m) mud bottom bay which is being encroached on by a mangrove shore (Boesch and Rabalais, 1985).

The middle shelf is approximately 100 km wide. Between the 40- and 75-m isobaths, the seafloor of the middle shelf slopes to the west at 0.3 to 0.7 m/km; the slope increases to 1.4 to 1.7 m/km between the 70- and 100-m isobaths. The middle shelf contains local zones of irregular (rough) seafloor topography, areas of locally steeper slopes, and depressions. Holmes (1981) reported a 10-km-wide zone of partially buried carbonate reef-like structures in water depths of 70 to 90 m. This zone corresponds to the areas of irregular seafloor topography.

The outer shelf extends from the 100-m isobath to the 200-m isobath (the western limit of the study area). The outer shelf varies in width from

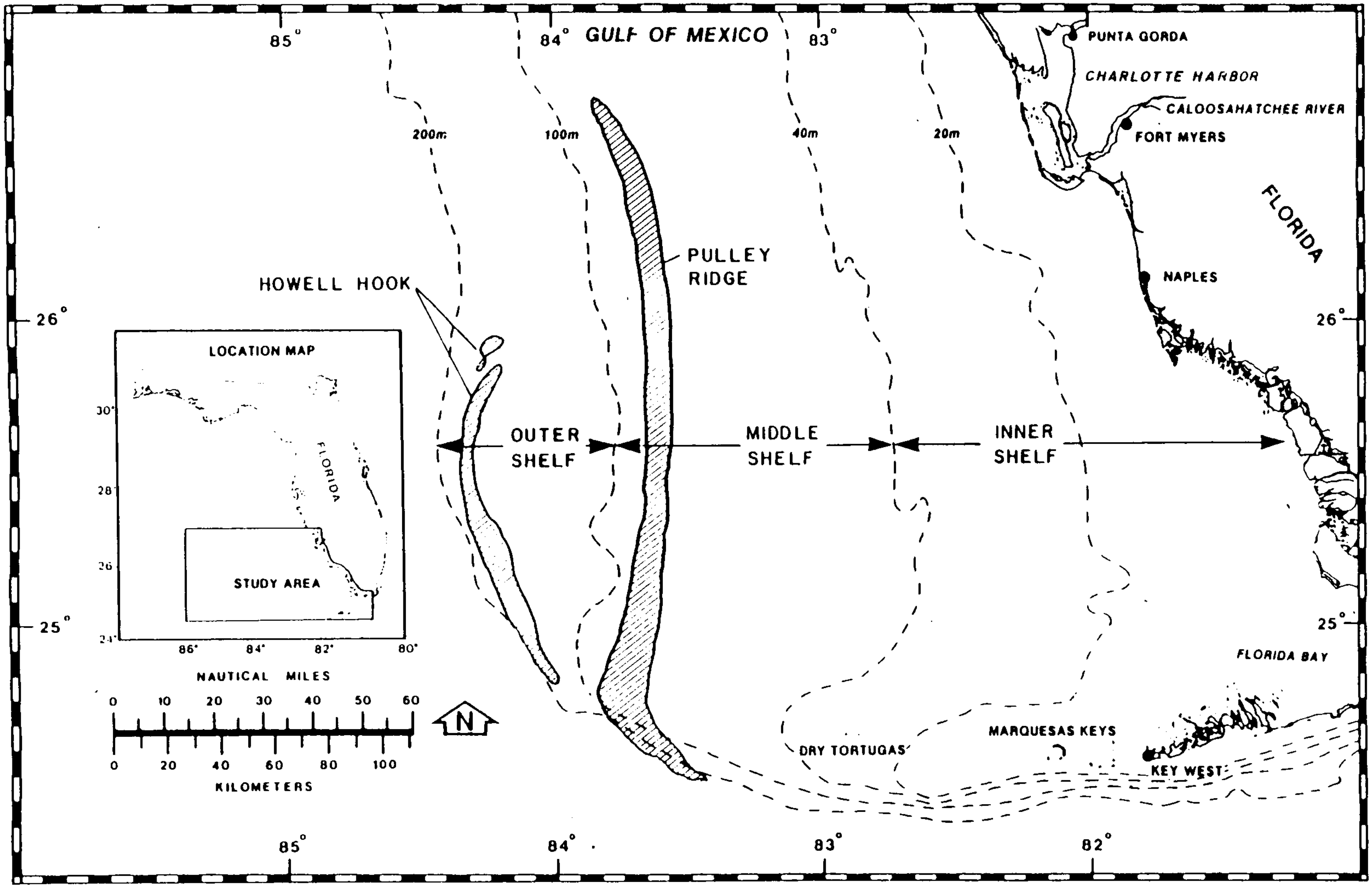


Figure 3.1-1 **Southwest Florida shelf physiography and depth zones.**

less than 10 km to approximately 65 km. The slope averages 3.5 m/km; maximum slope is 17 m/km. The outer shelf is broken by wave-cut terraces and seafloor depressions (similar to those found on the middle shelf). Holmes (1981) described a double-reef complex at the shelf break. The shallowest reef was described as a bioherm (biogenic reef or mound) and appears to be partially exposed through a thin sand veneer. This bioherm contains many exposed relict branching corals that extend 1 to 3 m above the bottom (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a).

3.2 METEOROLOGY

Previous authors have described the meteorological conditions on the southwest Florida shelf based on National Weather Service (NWS) weather stations and meteorological and marine observations collected by vessels in the area. With the installation of an instrumented NOAA Data Buoy Center buoy (NDBC Buoy No. 42003) at 26°N latitude and 86°W longitude in 1976 (approximately 160 km due west of the study area), the quantity of information available has increased. The following discussion is based on information presented by previous authors, NDBC buoy data, and data obtained from the Fort Myers (northeast portion of the study area) and Key West (southeast portion of study area) NWS stations. The NDBC buoy data characterize meteorological and sea conditions in the open gulf, Fort Myers characterizes onshore conditions, and Key West characterizes nearshore marine conditions.

3.2.1 AIR TEMPERATURE

Mean monthly temperatures range from 18°C (winter) to 29°C (summer) with the offshore and southern portions of the study area generally warmer (NCDC, 1983, 1986a, 1986b). The air temperatures over the open gulf exhibit narrower limits of variations on both a daily and seasonal basis (MMS, 1983). According to Jones et al. (1973), coastal extremes exhibit a larger range, particularly in the winter.

3.2.2 PRECIPITATION

The average annual precipitation values range from 97 cm at Key West to 136 cm at Fort Myers, with monthly mean values at these stations ranging from 4 to 16 cm and 3 to 23 cm, respectively. According to NCDC (1986a, b), the greatest precipitation occurs during different seasons at the two stations: at Fort Myers, 49% of the total annual precipitation occurs during the summer months (June, July, and August); at Key West, 43% of the total annual precipitation occurs during the fall months (September, October, and November). The greatest amount of precipitation recorded in 24 h (59 cm or 43% of the total average annual rainfall) occurred at Key West in November 1980 (NCDC, 1986b).

3.2.3 VISIBILITY AND CLOUD COVER

According to NCDC (1986a, b), the number of days visibility decreases to less than 400 m (defined as a heavy fog) decreases from 21 days at Fort Myers to 1 day at Key West. The cloud cover occurrence at Fort Myers and Key West is approximately 100 clear days, 100 totally overcast days, and 165 partly cloudy days.

3.2.4 BAROMETRIC PRESSURE

Mean monthly barometric pressures historically range from 1014 to 1019 millibars (mb), with the higher pressures occurring in the winter (NCDC, 1983, 1986a, 1986b). According to Jones _et al_. (1973), less than 10% of the pressure observations depart from the monthly mean by as much as 5 mb in the summer or by as much as 10 mb in the winter. Individual barometric pressure values can range from 959 to 1035 mb as a result of hurricanes, anticyclones, and extratropical cyclones.

3.2.5 WIND

Warzeski (1976) divided climatic conditions in south Florida into three energy levels or intensities: (1) prevailing mild southeast and east winds, (2) winter cold fronts, and (3)tropical storms and hurricanes. Winds recorded at the coastal stations (NCDC, 1986a, b) are from the east to northeast in late fall and early winter and from the southwest to east-southeast the remainder of the year. The mean monthly windspeeds range from 3.0 to 5.6 m/s, with the lowest windspeeds occurring during the summer. The mean annual windspeed at Key West is 5.0 m/s (nearly 30% greater than Fort Myers).

The mean annual windspeed of 5.6 m/s measured at the NDBC buoy was higher than the coastal stations; the mean monthly windspeed ranged from 3.9 to 7.1 m/s, and the highest windspeed recorded at the buoy since its deployment in 1976 was 34 m/s. During the summer, windspeeds exceed 8.7 m/s (Beaufort force 5) less than 5% of the time, and 30% of the time, the speeds are less than 3.1 m/s (Beaufort force 2). In winter, the windspeeds exceed 3.1 m/s 87% of the time and 8.7 m/s 23% of the time. The winds offshore are from the north to northeast in late fall and early winter and switch to the east for the remainder of the year (NCDC, 1983).

3.2.6 SEVERE STORMS

South Florida is impacted more often by tropical storms and hurricanes than any other equal-sized area of the United States (Gentry, 1974). The annual probability of a tropical cyclone striking the southwest Florida shelf exceeds 20%, the probability of hurricanes is 10%, and the probability of great hurricanes (winds in excess of 55 m/s or 125 mi/h) is 2 to 3%. Great hurricanes have crossed the study area on several occasions during the last century, the most notable being the Labor Day hurricane of 1935; winds were estimated between 90 and 110 m/s (Schomer and Drew, 1982). Jones et al. (1973) reported that storm surges as high as 4.5 m have been observed on the southwest Florida coastline. In addition to storm surges, hurricanes and tropical storms can produce surface waves in excess of 10 m and rains that exceed 50 cm in 24 h and can induce upwelling that can cool the surface waters of portions of the Gulf of Mexico for weeks. Leipper (1967) reported that Hurricane Hilda (1964) caused upwelling that produced large, persistent lenses of water that were 5°C cooler than the surrounding water.

In addition to tropical storms and hurricanes, extratropical cyclones (i.e., cyclonic storms originating in the middle and high latitudes) can impact the southwest Florida shelf. The winter migratory fronts that impact Florida are frequently the result of these extratropical cyclones. The winds associated with these storms can be as high as 15 to 25 m/s (MMS, 1983). According to Jones et al. (1973), extratropical cyclones are four to five times more common north of 28.5°N latitude (above Tampa), and, in general, these storms are more frequent in the winter.

3.3 PHYSICAL OCEANOGRAPHY

Previous investigators have described the physical oceanography (waves, tides, currents and circulation, and hydrography) of the eastern Gulf of Mexico. During the last 5 years, MMS-sponsored studies have been conducted to describe specifically the physical oceanography of the southwest Florida shelf. The following discussions are based on these data and the data collected by previous investigators. The locations of the various stations discussed in the following subsections are presented in Figure 3.3-1.

3.3.1 SURFACE WAVES

The wave regime described in this section is based primarily on Jones et al. (1973), wave data obtained from the NDBC Buoy No. 42003 (1976 to 1985), and wave data collected during 1985 at two southwest Florida shelf stations by Environmental Science and Engineering, Inc., and LGL Ecological Research Associates, Inc. One of the stations (Station 55) was located in 27 m of water between the Marquesas and the Dry Tortugas; the other (Station 52) was located 48 km from land at approximately 25°18'N latitude and 81°40'W longitude in 13 m of water.

According to Jones et al. (1973), the predominant wave direction tends to be from the east and northeast from September through February and from the east and southeast from March through August. Waves from the west

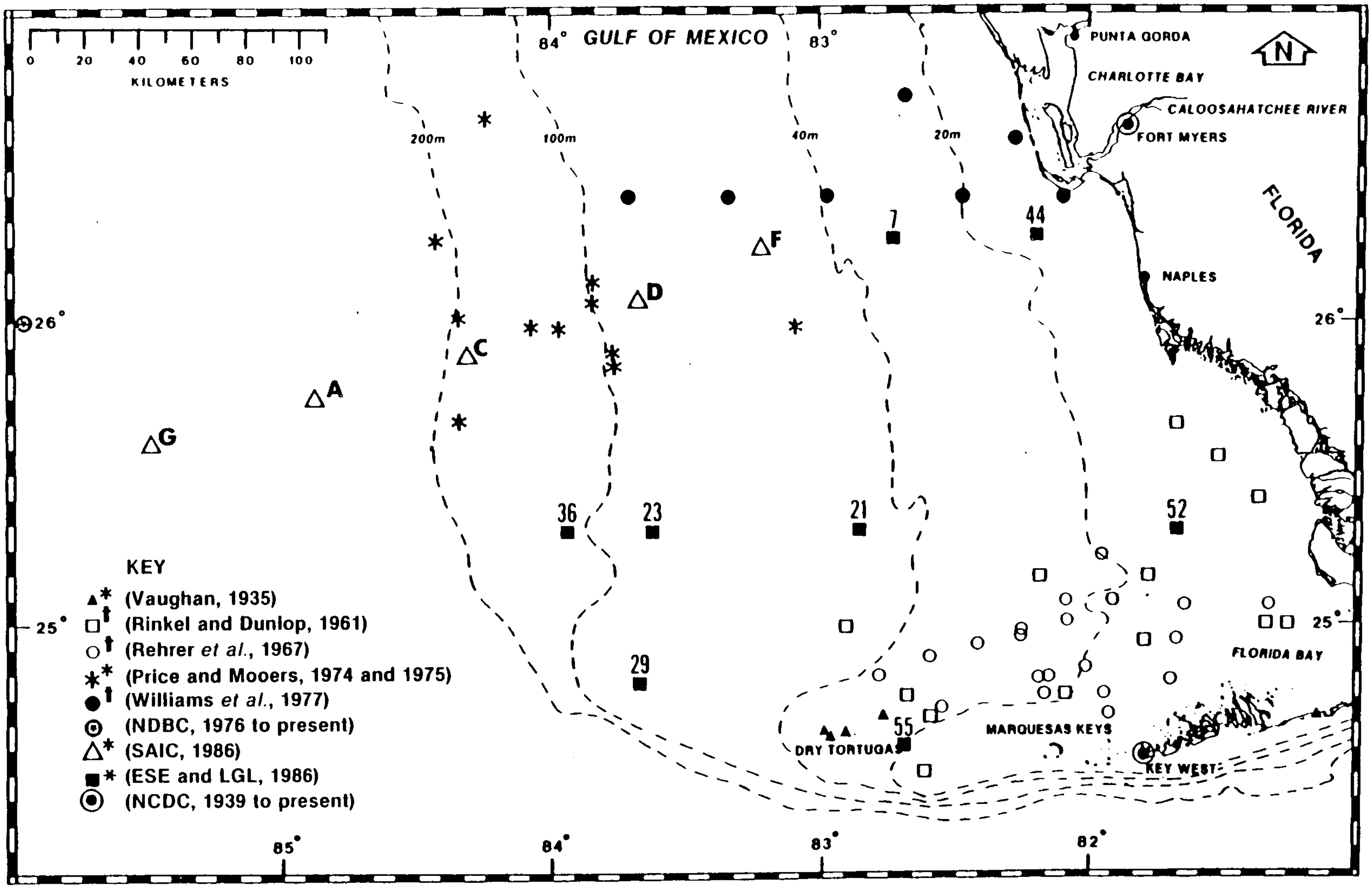


Figure 3.3-1 Station locations (historical and Southwest Florida Shelf Ecosystems Study) for the collection of dynamic physical oceanographic (waves, tides, and currents) and meteorological data (∗ denotes Eulerian current data and † denotes Lagrangian current data).

and northwest, especially in the fall and winter, tend to have greater heights than those from other directions as a result of virtually unlimited fetch and more energetic winds.

The mean monthly significant wave height measured by the NDBC buoy ranged from 0.7 to 1.5 m, with the highest values occurring between November and March. During the winter, 53% of the wave heights are greater than 1.5 m; during the spring, summer, and fall, wave heights exceed 1.5 m 40%, 12%, and 32% of the time, respectively. Wave heights greater than 2.5 m occur less than 9% of the time except in winter, when the waves exceed 2.5 m 16% of the time. The largest significant wave height recorded by the buoy between 1976 and 1985 was 10.7 m (Danek and Lewbel, 1986). This occurred on November 20, 1985, during Tropical Storm Kate.

The waves measured offshore were generally larger than those measured nearshore because of the virtually unlimited fetch at the offshore station (buoy). The nearshore stations were somewhat in the lee of the land with east and northeast winds. At Station 52, located 48 km offshore in 13 m of water, wave heights greater than 1.5 m occurred less than 5% of the time and only during the winter and summer. The highest significant wave height measured at Station 52 was 2.2 m. Station 55, located in 27 m of water between the Dry Tortugas and the Marquesas, was less sheltered; consequently, wave heights were higher. The highest significant wave height measured at Station 55 was 4.7 m, which occurred during November. Significant wave height during the spring and summer months exceeded 1.5 m on an average of 2% of the time (never exceeding 5%). During the winter and fall, significant wave height exceeded 1.5 m approximately 5% of the time (with a maximum of 11% during November). The mean daily significant wave height exceeded 2.4 m 3% of the time during November; this was the only month 2.4 m was exceeded.

Overall, the summer months were the calmest; significant wave height did not exceed 1.5 m by more than 5% of the time nearshore and by no more than 12% offshore. The winter months had the highest percentage of waves above 1.5 m, but the largest waves were measured in the fall because of hurricanes and tropical storms.

During 1985, Danek and Lewbel (1986) estimated wave orbital velocities from data collected at the NDBC buoy and Stations 52 and 55. The results indicated that virtually no surface wave energy penetrated to a depth of 125 m. At 74 m, wave orbital velocities greater than 10 cm/s (based on NDBC buoy data) occurred less than 0.05% of the time; at 64 m, less than 0.1%; and at 47 m, less than 0.3%. Wave orbital velocities exceeded 10 cm/s 5% of the time at Station 55 (27 m) and 10% of the time at Station 52 (13 m). Consequently, the wave energy at stations less than 15 m can readily penetrate to the bottom and, therefore, is important in contributing to sediment resuspension. Wave energy is less important at deeper stations and probably contributes only to sediment resuspension during extreme weather conditions (e.g., hurricanes). It is unlikely that surface wave energy ever penetrates to the bottom at depths greater than 125 m (Danek and Lewbel, 1986).

3.3.2 TIDES

The tides of the Gulf of Mexico are weakly developed, and their observed range usually does not exceed 0.7 m (Durham and Reid, 1967). The tidal regime for the southwest Florida shelf has been described by Eleuterius (1974) as mixed [i.e., having both diurnal (daily) and semidiurnal (twice daily) tidal components].

The Station 52 and 55 wave gages, discussed previously, also functioned as tide gages. The tidal records from these gages indicate that the tides are mixed, with both a semidiurnal and diurnal component. The tidal range was approximately 1.5 m during spring tides and 0.7 m during neap tides. The tidal ranges at Station 55 were approximately one-half those observed at Station 52. Harmonic analysis of the tidal records indicated that the tides were more mixed at Station 55; at Station 52, the tides were predominantly semidiurnal. Power spectra analysis results indicated that there is more energy at the semidiurnal frequency at Station 52 than at the diurnal frequency, and there is more energy at Station 52 than at Station 55. The semidiurnal energy at Station 55 is comparable to the diurnal energy, indicating the area is a mixed tide region. The spectra for both stations indicated no major concentrations of energy in periods greater than 26 h (e.g., energy resulting from meteorological forces). The differences between the two stations are demonstrated in Figure 3.3-2.

The passage of major storms resulted in a variation in water level of less than 0.5 m at both stations; however, the variation was greater at Station 52. The results from all storms exhibited the characteristic decrease in water level as the storm approaches followed by an increase in water level.

3.3.3 CIRCULATION AND CURRENTS

Background

Discussion of the currents and circulation of the southwest Florida shelf must begin with a description of the Loop Current. The Loop Current per se rarely intrudes landward of the 100-m isobath; however, phenomena associated with the Loop Current (e.g., warm filaments) frequently intrude into the study area. These intrusions complicate any description of residual currents on the shelf and their seasonal variability. Numerous authors have described the Loop Current and its associated phenomena; summaries of these studies are provided in Cooper (1982) and Science Applications International Corporation (1986).

According to Cooper (1982), the Loop Current dominates the circulation of the eastern Gulf of Mexico and clearly affects the southwest Florida shelf. The Loop Current enters the Gulf of Mexico in the Yucatan Channel with velocities on the order of 100 cm/s (Chew, 1974), then swings north and east in a wide loop before exiting the Gulf of Mexico via the Florida

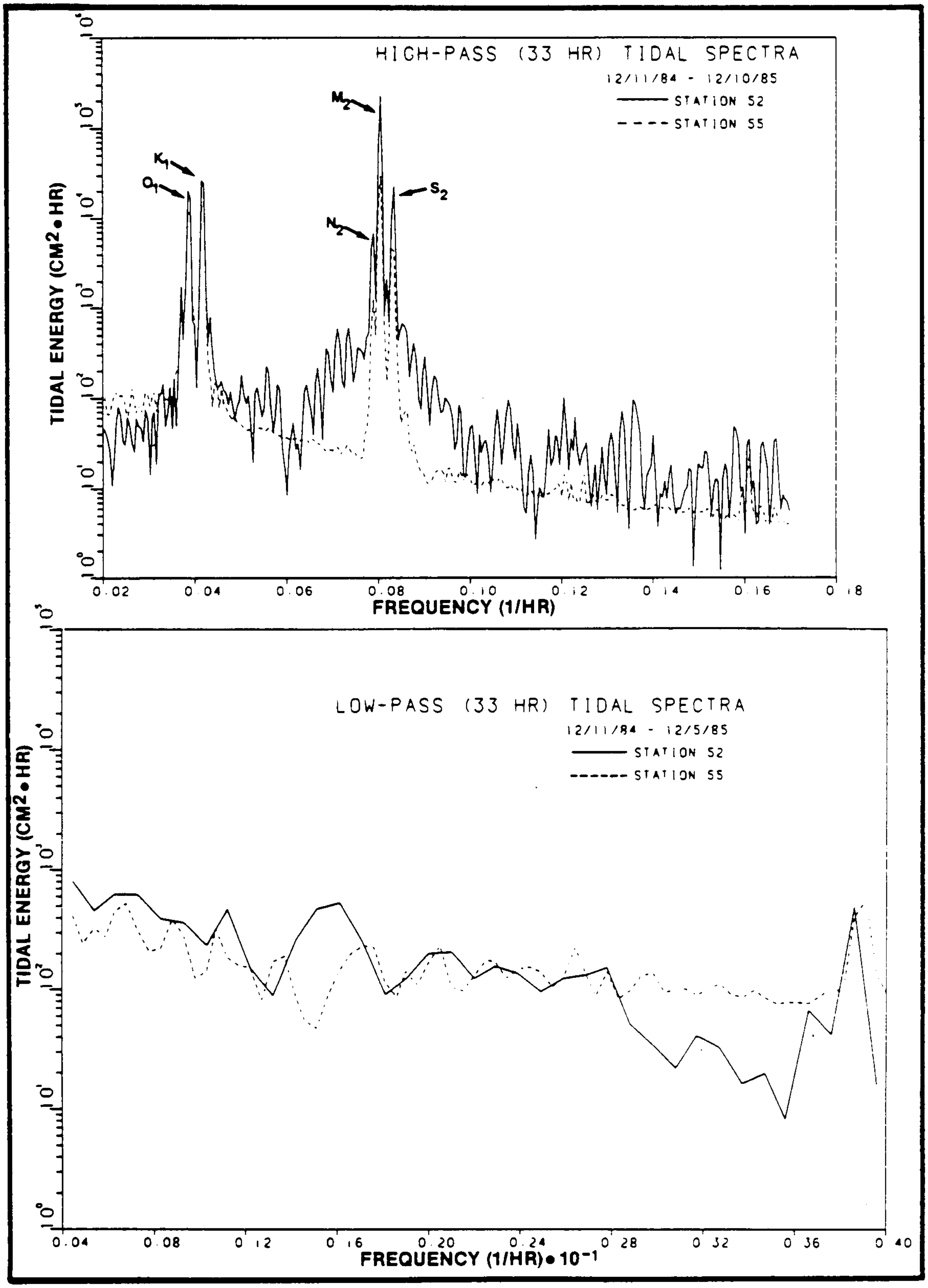


Figure 3.3-2 **Power spectra estimates of water level records (high-pass and low-pass filtered data) for stations 52 and 55.**

Straits (as the Florida current) to become the Gulf Stream (see Figure 3.3-3).

The Loop Current's boundaries fluctuate considerably; Leipper (1970), Maul (1977), and Behringer et al. (1977) have suggested an annual cycle with the Loop Current intruding in the spring (and possibly winter) and then receding in the fall. Behringer et al. (1977) further suggested that the maximum penetration of the Loop Current occurred in the early summer. Nevertheless, these investigators reported considerable variability in this annual cycle. Behringer et al. (1977) found that there could be as much as 8 to 17 months between periods of intrusion.

According to Cooper (1982), the annual cycle of the Loop Current has been challenged by Molinari (1978), who stated that the data upon which the annual cycle was based were biased by temporal sampling distribution. He cited maximum penetration during the winters (not summers) of 1966, 1969, 1973, and 1974 as evidence against the annual cycle. Vukovich et al. (1979) confirmed Molinari's observation of deep northward penetrations of the Loop Current during the winter for the same period. Nevertheless, Vukovich et al. (1979) reported that the precise position of the Loop Current could be obscured by warm gyres, which were not completely separated from the Loop Current and, therefore, had warm water from the Yucatan Strait flowing around it. These appeared as an extended warm zone which could be interpreted as the Loop Current. The majority of recent observations of the Loop Current were made using satellite thermal imagery. According to Vukovich (Science Applications International Corporation, 1986), usable infrared images of the Gulf of Mexico can be obtained from satellites for approximately 6 to 9 months of the year (i.e., in late fall, winter, and spring). In summer and early fall, lack of thermal contrast and high water vapor content near the sea surface mask the frontal features normally used to delineate the Loop Current. It is evident that much is unknown about the behavior of the Loop Current. Current MMS programs are continuing to investigate the Loop

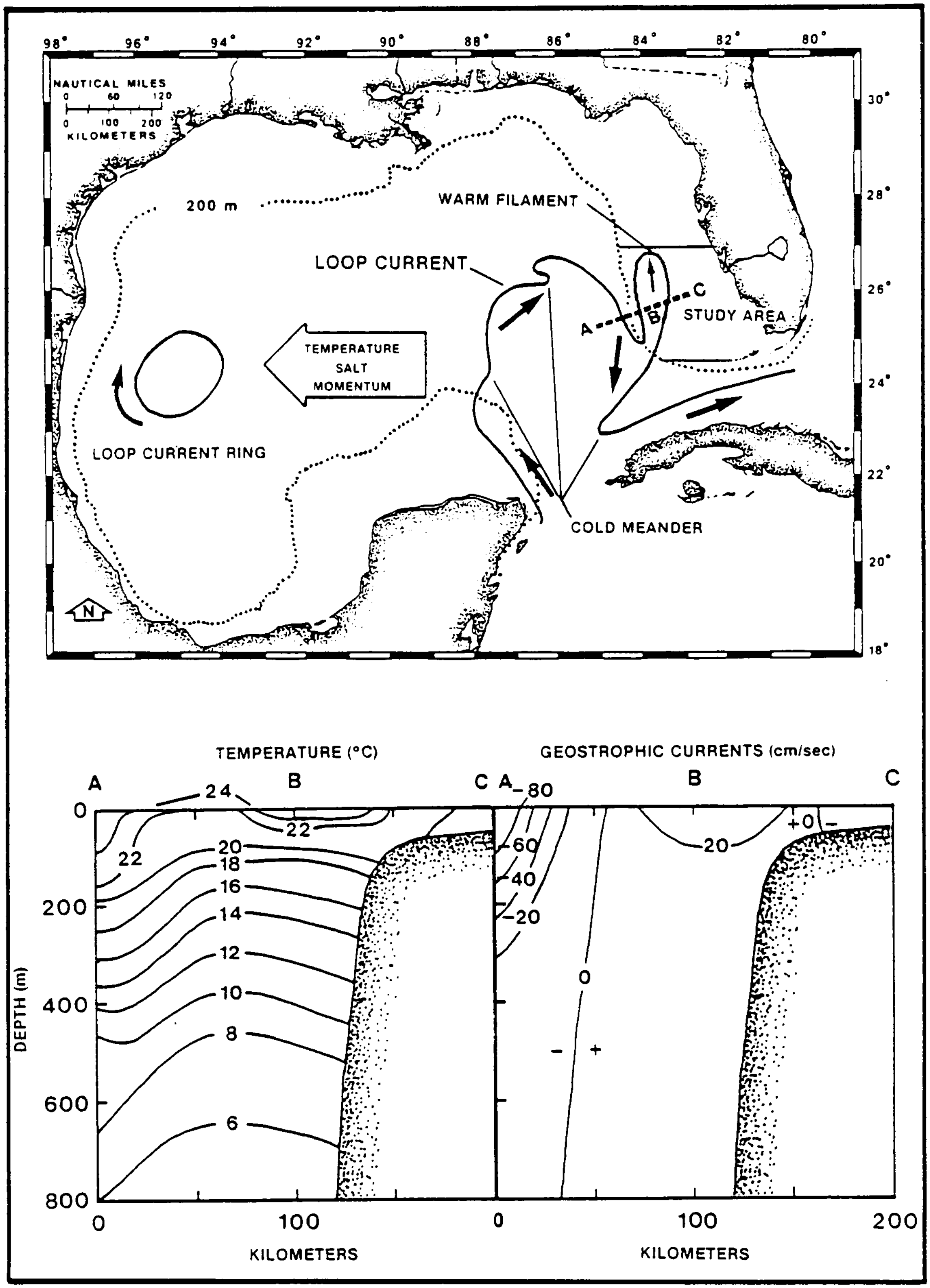


Figure 3.3-3 Schematic representation of Loop Current features and dynamic processes (top) and a cross section through a warm filament (bottom) showing distribution of temperature (note upwelling between Stations A and B) and current velocity (– denotes southward and + denotes northward).

Current and associated phenomena (e.g., rings or eddies, cold perturbations, etc.).

According to Vukovich and Maul (1985), a frequently observed phenomenon along the Loop Current boundary is the presence of cold-core perturbations which affect the circulation in the eastern Gulf of Mexico. These perturbations have many characteristics including: alternating cold and warm filament-like structures, cold intrusions, and cold meanders (see Figure 3.3-3). Generally, these perturbations are more pronounced on the northern and eastern boundaries of the Loop Current. These perturbations have, on the average, an along-flow scale length of 190 km and a cross-flow scale length of approximately 130 km; the speed of these perturbations ranges from 6 to 24 km/day, and the life cycle of these disturbances ranges from 16 to 120 days. Upwelling (see Figure 3.3-3) is frequently associated with these perturbations; upwelling is an important mechanism for importing nutrients onto the southwest Florida shelf.

Current Speed and Direction Distribution

Plots of near-bottom current speed and direction at a relatively shallow shelf station (Station 52--13 m) and deeper shelf station (Station 7--32 m) illustrate the gradual change in tides from semidiurnal to diurnal and from rectilinear in the east-west direction to more elliptical with increasing depth (see Figure 3.3-4). The predominance of the semidiurnal tides at Station 52 is reflected in current speed peaks of approximately 30 cm/s, which occur approximately every 6 h during the flood and ebb tides. The bimodal distribution of current direction (east and west) indicates nearly rectilinear motion in shallow water. The data also show the spring and neap tides with maximum and minimum speed ranges occurring at a 2-week interval. The progressive vector diagram for Station 52 indicates that although the maximum speeds were in the east-west direction, the net transport was to the southeast toward Florida Bay.

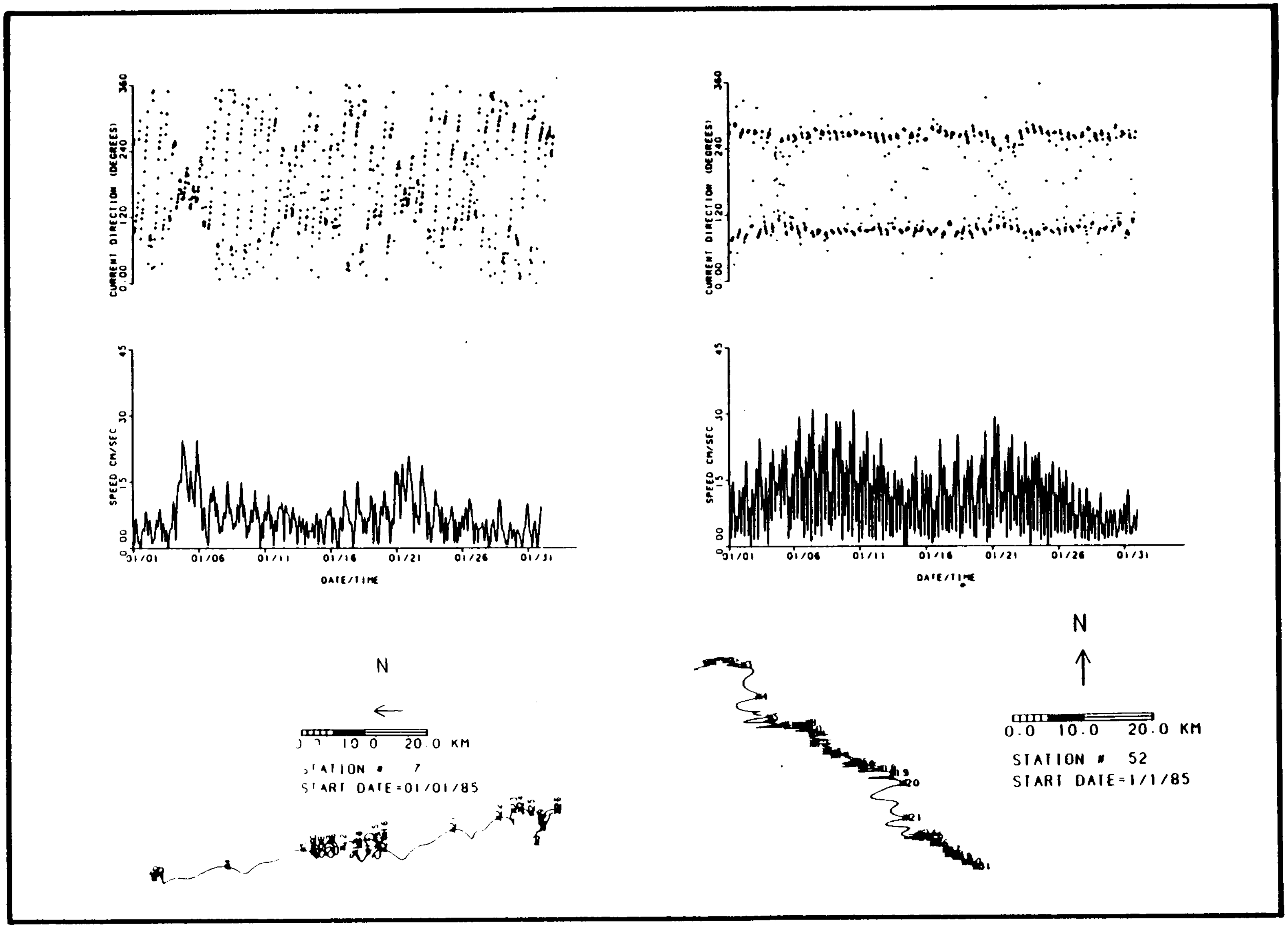


Figure 3.3-4 **Example of the change in current velocity characteristics from elliptical to rectilinear motion and diurnal to semidiurnal periodicity as depth decreases from 32m (Station 7) to 13m (Station 52).**

This finding was consistent for the 2 years of data examined for this station.

At Station 7, the tidal peaks in the speed record are apparent, but the speed does not drop to near zero at slack tide as it did in shallower water. The maximum speeds also are less and generally reached approximately 15 cm/s at flood tide and ebb tide. The direction varies more uniformly between 0 and 360° because of the tidal elliptical trajectories. Net transport, as indicated by the progressive vector diagram (see Figure 3.3-4), was more variable with time, but generally set to the south.

Near-bottom average current speeds across the shelf ranged 5 to 11 cm/s. Generally, the average current speed was highest nearshore (as the result of tides and wind), decreased 2 to 3 cm/s midshelf, and increased 1 to 2 cm/s (from the midshelf value) on the outer shelf region (primarily the result of Loop Current phenomena). The percentage of the time near-bottom current speeds exceeded 20 cm/s (the speed at which sediment transport is possible) followed this same basic trend with values as high as 14% nearshore, the lowest values (less than 2%) occurring midshelf, and values of nearly 5% on the outer shelf. The highest average current speeds were observed in the winter and spring; however, the maximum differences were only 2 to 3 cm/s.

<u>Energy Spectra</u>

Power spectra analysis was conducted to examine energy frequency concentration and to identify how the water current energy changes across the southwest Florida shelf. The 2- and 3-dimensional energy spectra from this analysis resulted in the following observations:

1. The tides dominate the currents on the shelf with two distinct peaks [one at the semidiurnal and another at the diurnal frequency (the latter could be resolved into two additional

peaks; one at the diurnal tide frequency and the other at the local inertial frequency)];

2. Energy at the semidiurnal frequency decreased with distance offshore;
3. Energy at the diurnal and inertial frequencies (nearly identical at this latitude) increased with distance offshore;
4. In deeper water, the tidal component appeared as speed fluctuations superimposed on larger (lower frequency) residual currents;
5. In shallow water, where tidal currents dominated, the current speed frequently dropped to zero at slack tide;
6. In shallow water, current motion was nearly rectilinear in the east-west direction;
7. In deeper water, current motion was more elliptical;
8. Low-frequency energy in the north-south component was greater than the east-west component in deep water as a result of strong net flows parallel to the depth contours;
9. Power spectra for the summer and winter currents were generally similar;
10. The seasonal energy distribution differences that did occur were probably the result of summer thermocline development (enhancing inertial currents) and winter winds that favored higher average current speeds at the lower frequencies; and
11. Intrusions related to the Loop Current frequently contributed to the low-frequency energy in the north-south component, particularly at the offshore stations.

The winter and summer 3-dimensional energy spectra for the east-west component presented in Figure 3.3-5 demonstrate many of these observations.

Net Transport

Net transport, calculated using progressive vector diagrams, exhibited considerable variability temporally and geographically. Nevertheless,

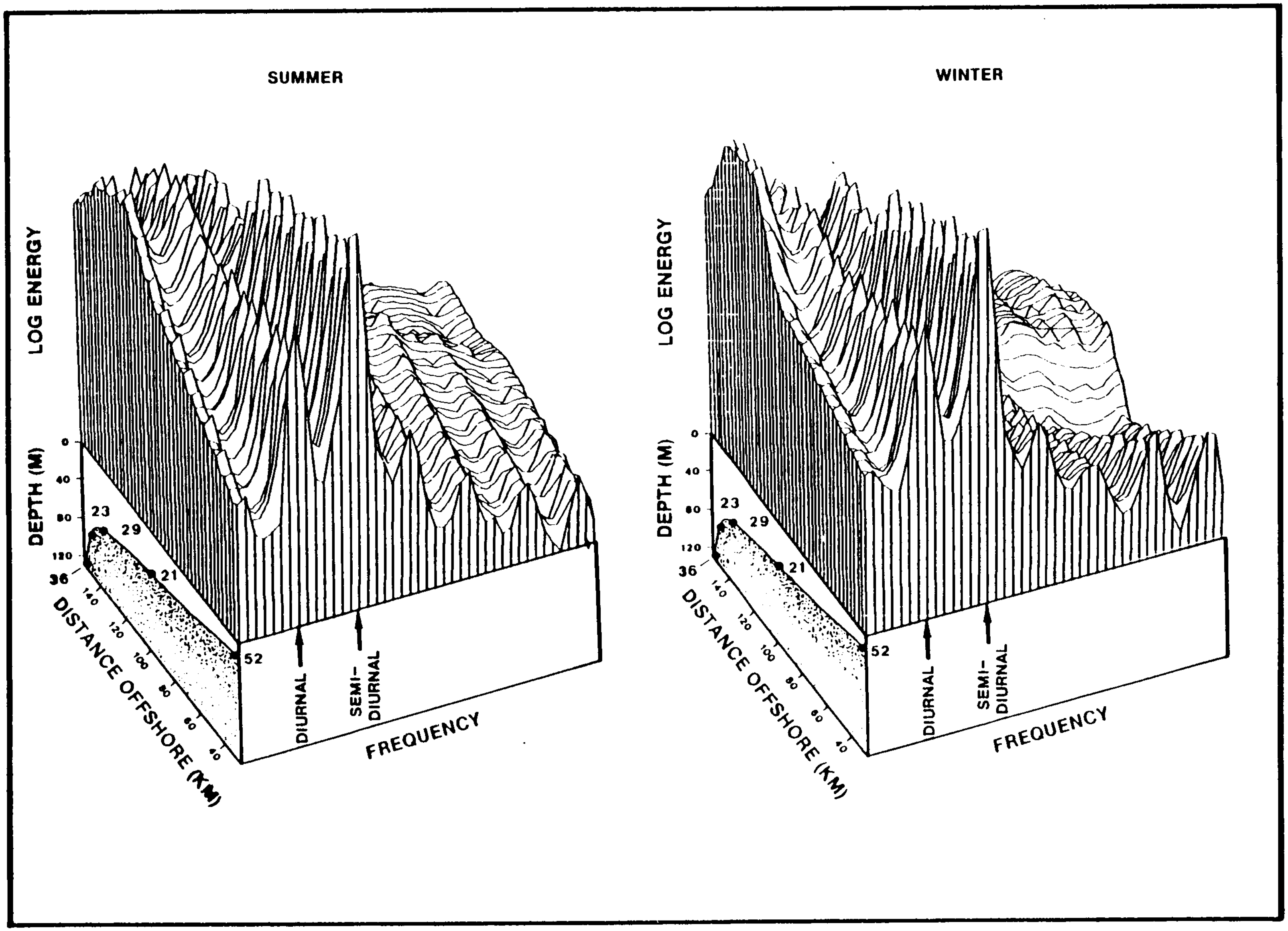


Figure 3.3-5 Three-dimensional summer (1984) and winter (1983-84) energy spectra, east-west component depicting cross-shelf variation in energy distribution.

during all seasons, near-bottom currents at Station 52 (13 m, see Figure 3.3-1), although dominated by east-west tidal currents, had a consistent net current to the southeast toward Florida Bay at less than 2 cm/s. The near-bottom currents at Station 55 (27 m, located between the Dry Tortugas and the Marquesas) also exhibited a consistent flow to the south except for a small net current to the northeast during the winter. The outer stations (e.g., Stations 23 and 36) were somewhat consistent and exhibited net near-bottom currents typically to the south, probably as a result of the Loop Current. The midshelf net near-bottom currents (Stations 21 and 29) and those measured at the northern stations (Stations 7 and 44) were more variable, possibly as a result of the previously described Loop Current boundary perturbations.

The seasonal near-bottom net currents measured by Environmental Science and Engineering, Inc., and LGL Ecological Research Associates, Inc., (Danek and Lewbel, 1986) combined with the data collected by Science Applications International Corporation (1986), as well as historical data, were used to prepare a map of annual residual currents on the southwest Florida shelf (Figure 3.3-6). This current representation is valid only for those times when the Loop Current or its associated phenomena are not intruding into the study area. These intrusions, as well as other short-term phenomena, are discussed in subsequent sections.

Event Analysis

Important short-term phenomena on the southwest Florida shelf include Loop Current intrusions or boundary perturbations, the passage of hurricanes or tropical storms, and the passage of winter cold fronts. The intrusion of a warm filament (see Figure 3.3-3) typically results in a 2 to 4°C increase in temperature, an increase in average current speed by as much as a factor of 2, and a change to unidirectional distribution for current direction (see Figure 3.3-7). These events typically last for approximately 5 to 10 days. These intrusions can extend across nearly the entire shelf, although they rarely intrude beyond the 20-m isobath.

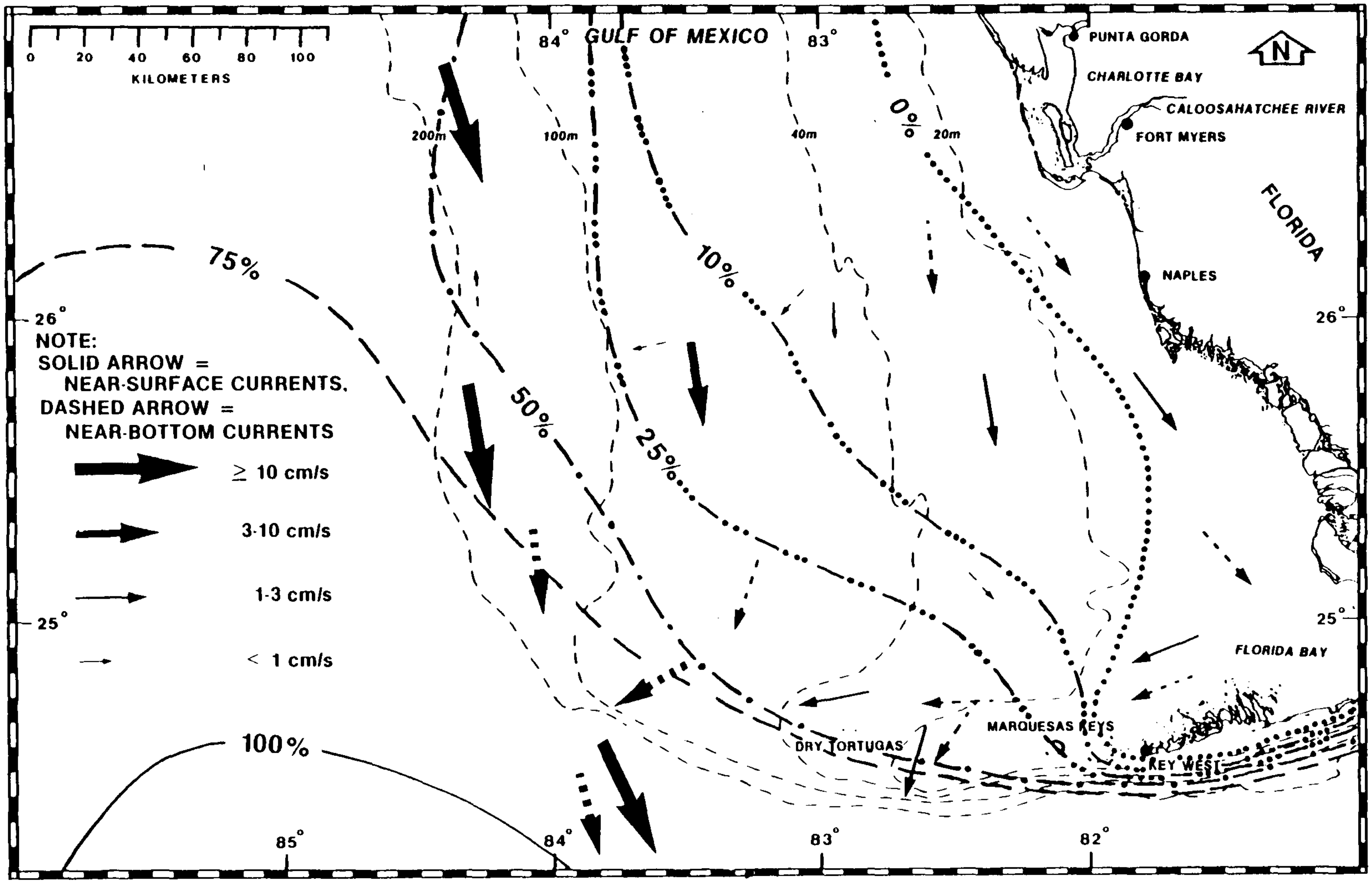


Figure 3.3-6 Estimated annual residual current pattern based upon Eulerian current data collected by ESE and LGL (1986) and SAIC (1986) as well as historical Lagrangian current data. Also shown is the probability of Loop Current maximum boundary phenomena incursion (April, according to Vukovich *et al.*, 1979).

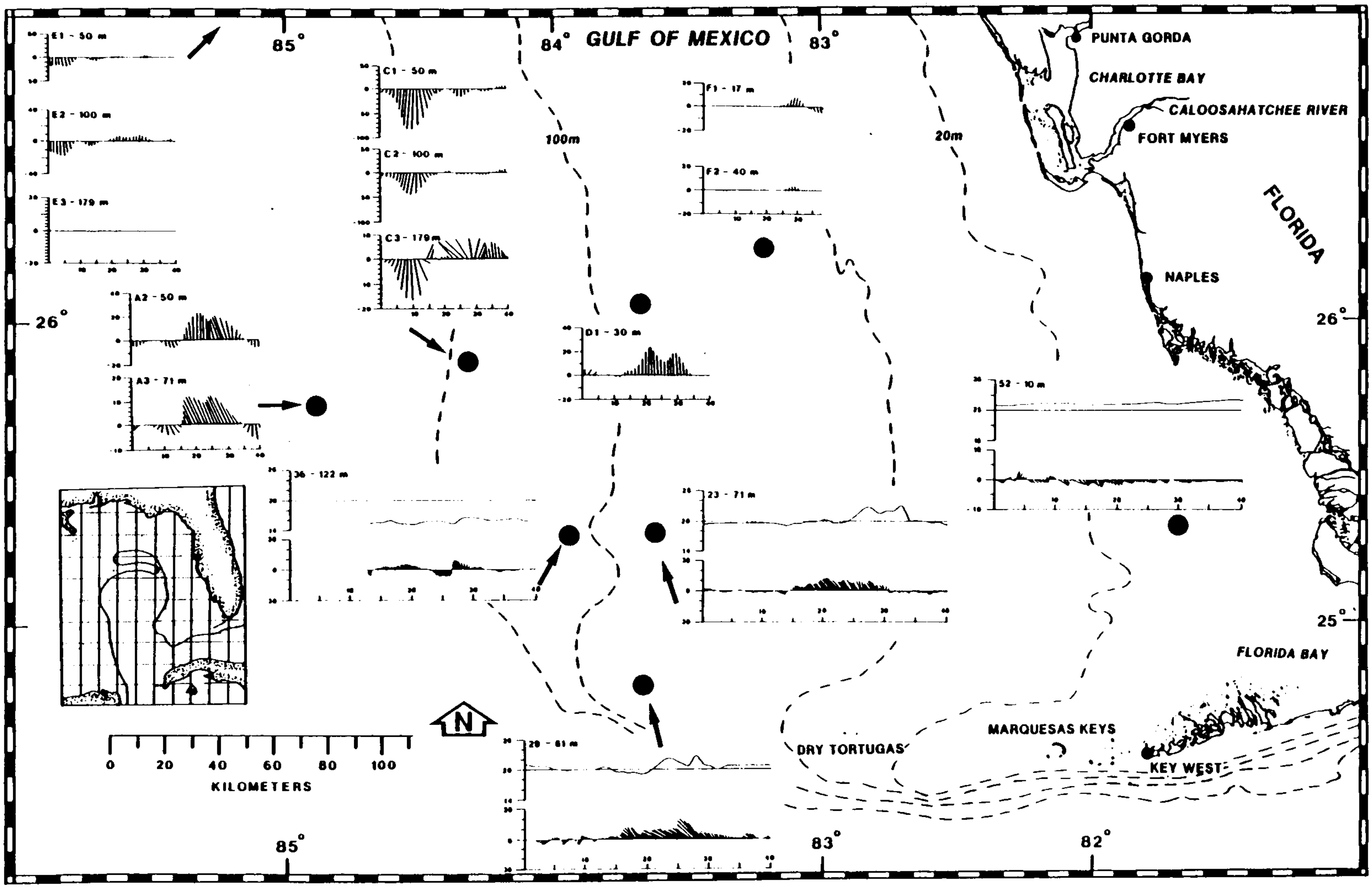


Figure 3.3-7 The effects of Loop Current intrusions and boundary perturbations on current velocity (cm/s) and temperature (°C). This particular intrusion, presented as mean monthly plot of the Loop Current boundary (inset), occurred in May 1984.

The passage of a hurricane or tropical storm with its associated high winds can result in over a five-fold increase in average current speeds for a period of 2 or 3 days. Currents and near-bottom temperatures were measured during the passage of Tropical Storm Bob during July 1985. This was a relatively weak storm which strengthened from a tropical depression to a tropical storm as it moved eastward across the project area. The maximum winds developed during this storm were estimated at 21 m/s (40 knots). The strong winds caused a marked deceleration and brief reversal of surface currents near the shelf break (Figure 3.3-8). Bottom currents showed relatively rapid response to the surface wind stresses between water depths of 50 m and the shoreline. Maximum near- bottom currents increased from 5 to 35 cm/s in the coastal boundary layer at a water depth of 10 m.

Near-bottom temperature records from current meters located at the 10- and 29-m depths show sudden changes of more than 3°C, indicating that the shelf water masses were significantly disturbed. The direction of the bottom temperature changes is different at these two locations. This suggests the storm may have caused downwelling, pronounced setup and setdown in the coastal area, rapid drainage of coastal estuaries, or combinations of these processes.

The passage of winter cold fronts has two major effects on the area. These disturbances are commonly associated with strong winds that cause high waves and relatively strong currents. The cold air masses can result in rapid cooling of surface waters and have resulted in temperature drops of up to 8°C in the shallow depths of Florida Bay.

3.3.4 HYDROGRAPHY

Most of the historical hydrographic data collected in the eastern Gulf of Mexico were obtained from locations seaward of the Southwest Florida Shelf Ecosystems Program study area or from nearshore or estuarine

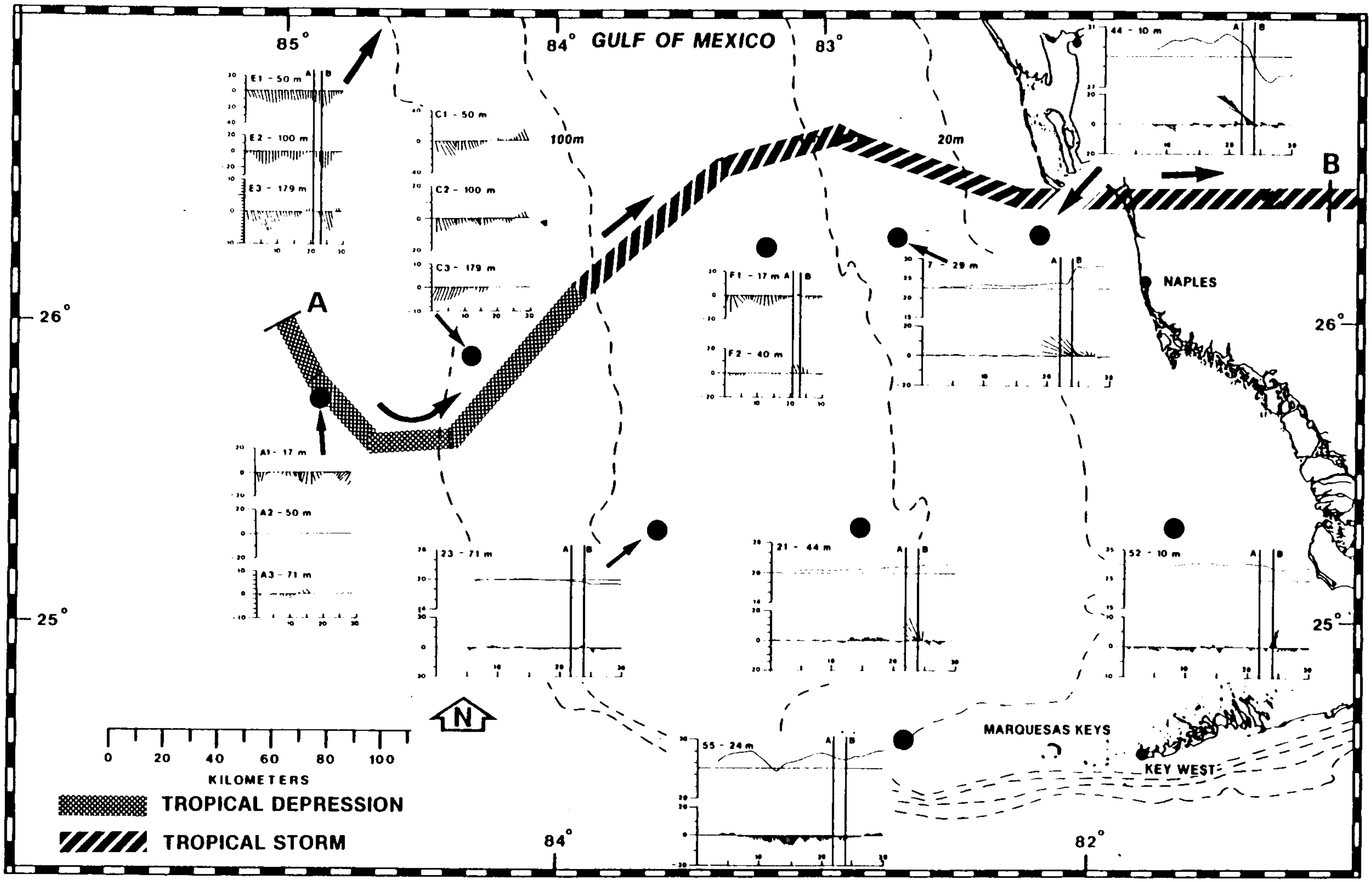


Figure 3.3-8 The effect of the passage of Tropical Storm Bob on current velocity and temperature during July 1985.

locations such as Florida Bay. The most complete source for recent hydrographic data obtained from the study area is the Southwest Florida Shelf Ecosystems Program Year 2 Modification (Woodward Clyde Consultants, and Skidaway Institute of Oceanography, 1983). Near-bottom and limited water column data were obtained during Years 4 and 5 of the Southwest Florida Shelf Ecosystems Program (Danek and Lewbel, 1986), and hydrographic data (particularly temperature data) were obtained for the most western extreme of the study area by Science Applications International Corporation (1986). In addition to these sources, several other papers provided important data not obtained from the previously mentioned sources. These included Jones et al. (1973), Schomer and Drew (1982), Boesch and Rabalais (1985), plus numerous other publications on more specific topics. All of these data were used to provide a hydrographic characterization of the study area.

Temperature

The nearshore environment (bottom depths less than 10 m) of the southwest Florida shelf exhibits the greatest temperature variability both seasonally and daily (following the diurnal pattern of air temperatures). According to Schomer and Drew (1982), Florida Bay water temperatures normally range from a winter low of 15°C to a summer high in excess of 30°C. In the shallow waters of Florida Bay, temperatures as high as 38°C (Schomer and Drew, 1982) and as low as 9°C (Walker, 1981) have been recorded. Schomer and Drew (1982) also observed that in the shallow waters of the Florida Keys, temperature changes as great as 8°C can occur within 24 h. Temperatures in the Florida Keys can drop as low as 10°C with the passage of cold fronts.

The remainder of the southwest Florida shelf (extending from the 10-m isobath to the 200-m isobath) exhibits some annual temperature variability, but generally of a lesser magnitude than the nearshore temperatures (see Figure 3.3-9). Surface water temperatures ranged from 20°C during the winter to 30°C during the summer. The variability in

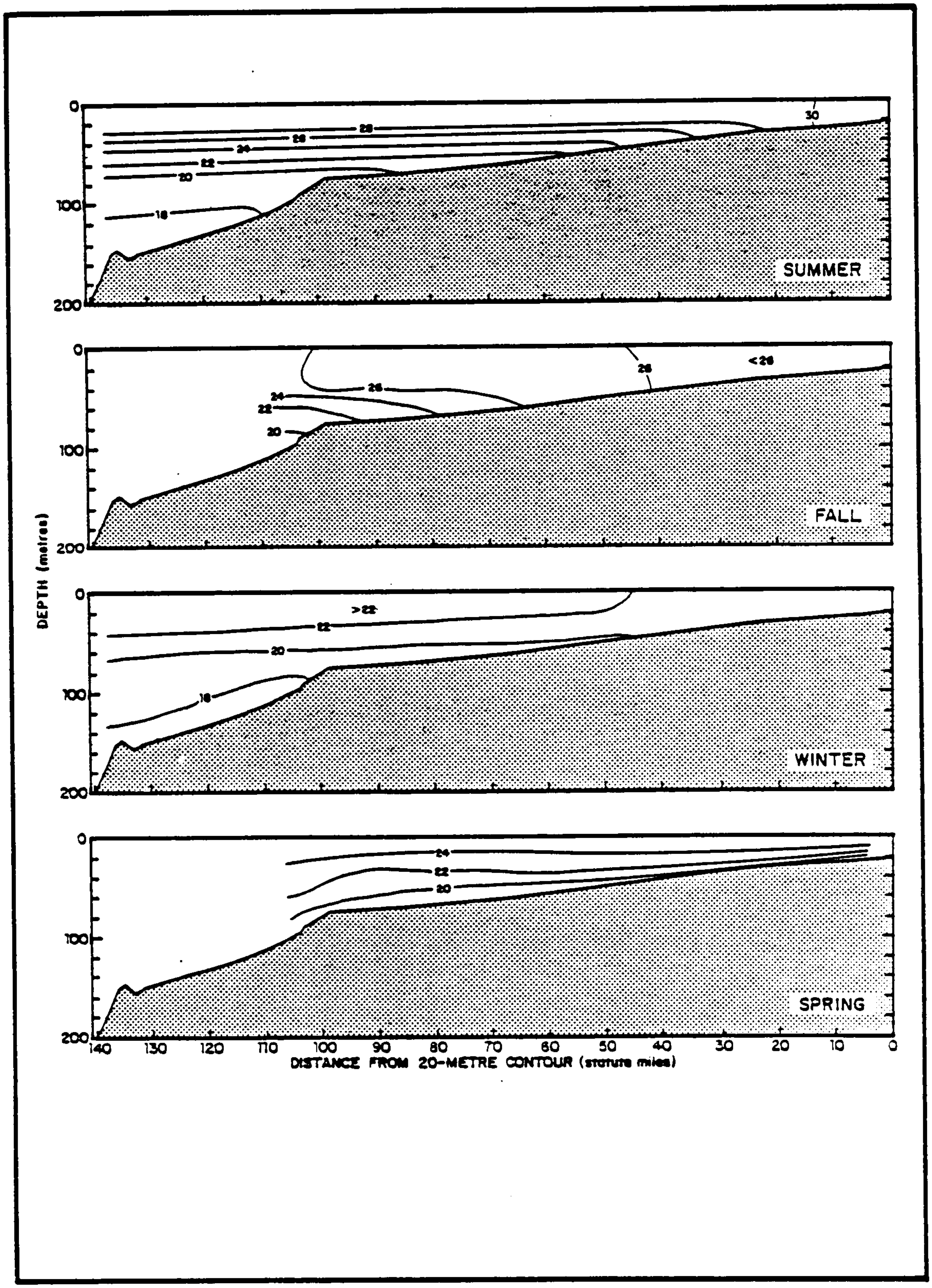


Figure 3.3-9 Cross-shelf seasonal temperature distribution along Transect D (Woodward Clyde Consultants and Skidaway Institute of Oceanography, 1983).

bottom temperatures (13 to 30°C) was more a function of depth than time of year. The greatest bottom temperature variability, in fact, did occur during the summer. Thermal stratification was evident occasionally, particularly during the summer.

Some minor geographic trends were evident in the temperature distribution, with surface and bottom temperatures generally 2 to 4°C warmer north to south. The surface water temperatures during the winter and spring were usually 2 to 4°C warmer offshore. During the summer, there was a 2°C increase toward shore; during the fall, the temperature was virtually constant across the shelf.

Continuous cross-shelf near-bottom temperature data were collected during Years 4 and 5 of the Southwest Florida Shelf Ecosystems Program (Danek and Lewbel, 1986). These data, shown in Figure 3.3-10, indicated several phenomena; the most obvious was the seasonal change in temperature. This change was most pronounced at the shallower stations where near-bottom temperatures varied as much as 14°C (bottom depth of 13 m). In comparison, a station at the 125-m isobath exhibited a seasonal variability of approximately 9°C.

A shorter period phenomenon, evident at all but the two shallowest stations (i.e., within 50 km of shore), was the intrusion on several occasions of the Loop Current or phenomena associated with the Loop Current. These intrusions were characterized by an increase in temperature as high as 5°C for periods as long as 10 days (see Figure 3.3-11). Although changes in temperature were quite pronounced, these changes probably did not have a significant effect on benthic biota other than perhaps a slight increase in stress. Perhaps the most important result of an intrusion is the introduction, through upwelling, of relatively nutrient-rich water to an otherwise nutrient-poor environment. Huh et al. (1981) reported that, in February 1977, a Loop Current intrusion approached within 8 km of the northwest coast of Florida. The

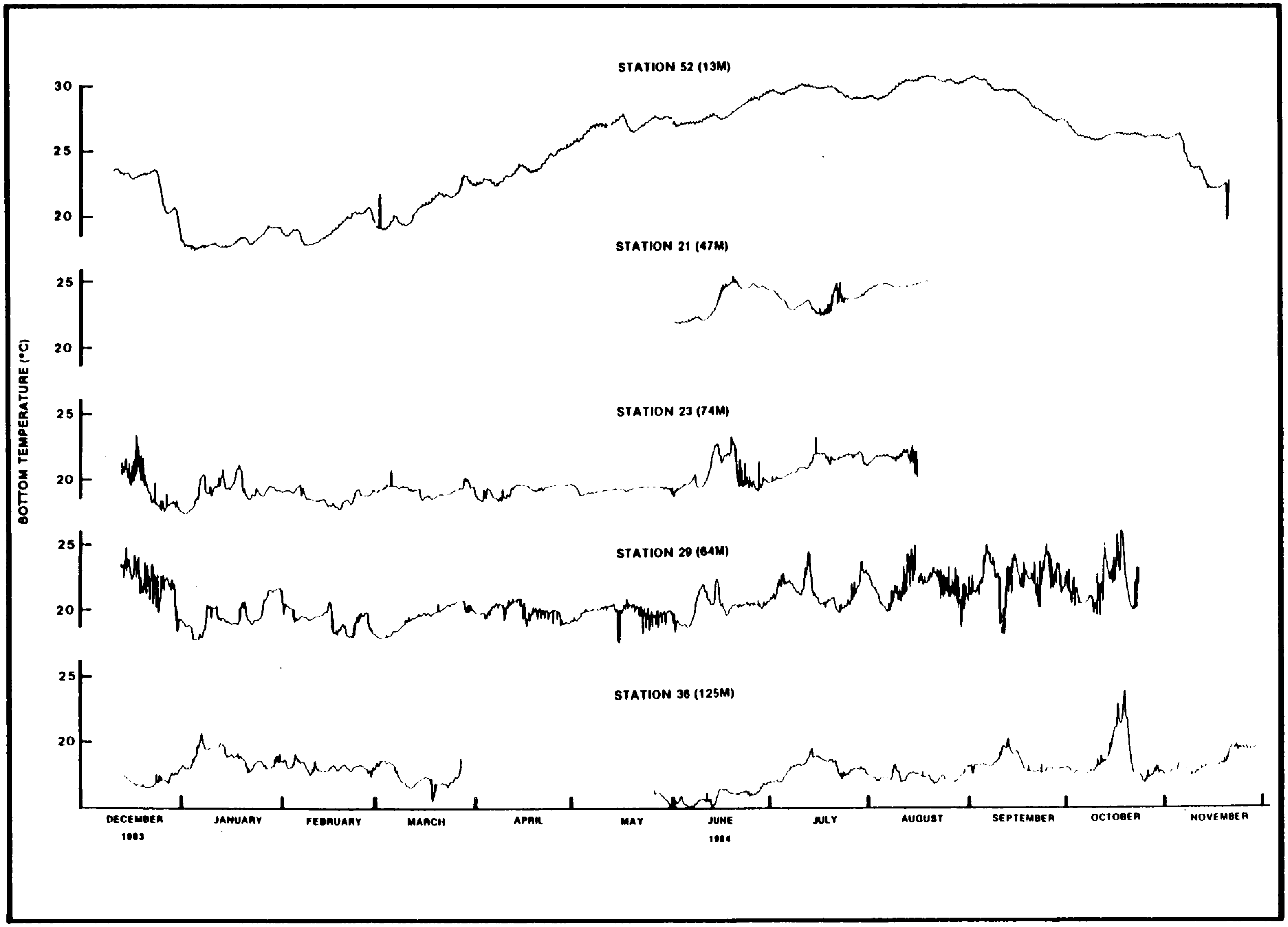


Figure 3.3-10 Continuous near-bottom temperature data.

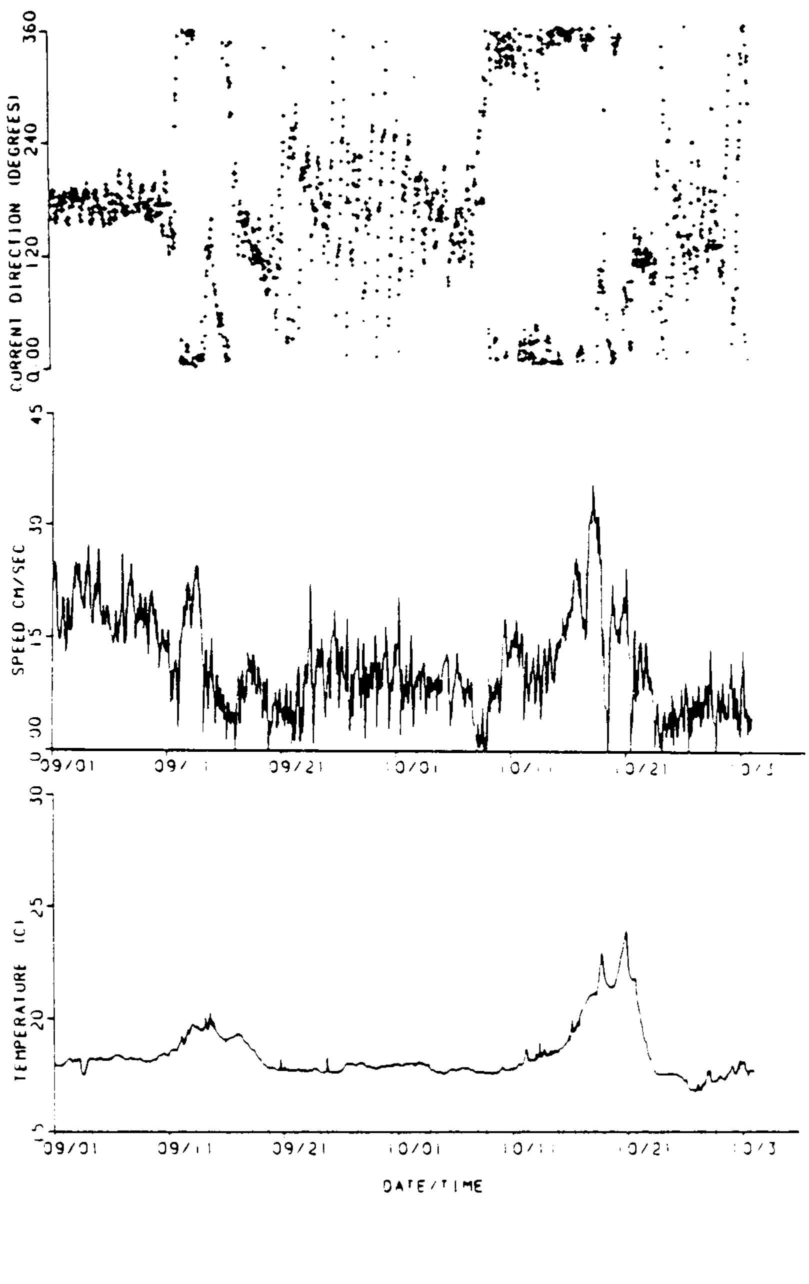


Figure 3.3-11 Station 36 current and temperature data for October 1984 showing the effects of a Loop Current intrusion.

duration of the event was 18 days. Oceanic water advanced across the shelf at speeds of 20 cm/s. At maximum intrusion, 6,650 km^2 of shelf were affected. Approximately one-half of the intruded water receded off the shelf, and half appeared to have been modified in situ. This intrusion undoubtedly contributed large quantities of warm, nutrient-rich water to the shelf.

Another Loop Current phenomenon, discussed previously, is the shedding of large anticyclonic eddies or rings of warm water (see Figure 3.3-3). These rings are thought to contribute significantly to the transfer of temperature in the Gulf of Mexico (Science Applications International Corporation, 1986). Although these rings are an important phenomenon in the Gulf of Mexico, it is unlikely that these rings impact the southwest Florida shelf.

Short-term (hours) temperature variations were observed in the continuous temperature data (see Figure 3.3-10). The magnitude of these temperature fluctuations was generally less than 1°C. The precise cause of these fluctuations is unknown; however, tidal currents or internal waves are possible explanations. These fluctuations are of insufficient magnitude to affect the biota.

Another short-term phenomenon, reported by Leipper (1967), was the upwelling of cooler water resulting from the passage of hurricanes. This upwelling can produce lenses of water that are as much as 5°C cooler than the surrounding water; these lenses can exist for weeks prior to dissipating. An example of both increases and decreases in temperature resulting from the passage of Tropical Storm Bob is presented in Figure 3.3-8.

Salinity

The overall shelf salinity values for all seasons were within ±1 $^{o}/_{oo}$ of 36 $^{o}/oo$; however, within Florida Bay, Schomer and Drew (1982) reported salinity values as low as 13 ^{o}/oo and as high as 66 ^{o}/oo during periods of high precipitation and high evaporation, respectively. Generally, the salinity distribution did not reflect the vertical stratification that was readily apparent in the temperature distribution (particularly during the summer). There were no obvious north-to-south geographic trends evident in the salinity distribution; however, there was a tendency for salinity to increase seaward (by as much as 1 ^{o}/oo), except during the fall when it decreased by approximately 0.2 ^{o}/oo.

The greatest observed salinity variation (0.8 ^{o}/oo) occurred as subsurface or surface intrusions of either higher or lower salinity water. These intrusions were not always evident in the temperature distribution. Several researchers (Chew, 1955; Collier et al., 1958; Maul et al., 1979; Morrison and Nowlin, 1977; Nowlin, 1971; Wennekens, 1959) have suggested that high salinity could result from localized extreme evaporation and subsequent sinking in Florida Bay. An alternate explanation is intrusion of Loop Current or Subtropical Underwater. More recent investigations (Woodward Clyde Consultants and Continental Shelf Associates, 1984; Danek and Lewbel, 1986; Science Applications International Corporation, 1986) support the hypothesis that the high salinity water originated from Subtropical Underwater brought onto the shelf by upwelling induced either by Loop Current intrusions or meteorological processes.

Terrestrial runoff is probably the source of the fresher water; whether this freshwater source is from local runoff or from rivers farther to the north is unknown. Woodward Clyde Consultants and Skidaway Institute of Oceanography (1983) suggest that fresh water from as far north as the Mississippi River may become entrained in the Loop Current and then advected into the study area.

Transmissivity, Light Penetration, and Compensation Depth

Overall, water on the southwest Florida shelf is exceptionally clear (1-m beam transmissivity values in excess of 90%). According to the data collected by Woodward Clyde Consultants and Continental Shelf Associates, Inc. (1983b), there was little evidence of seasonal variation over the major part of the shelf; however, the isolated nearshore areas during the spring and fall appeared more turbid (1-m beam transmissivity values as low as 40%). According to these same researchers, there was progressively more structure or variability southward across the study area. Calder and Haddad (1979) reported that water clarity of the Loop Current was comparable to the Sargasso Sea [compensation depth (i.e., the depth at which light intensity is 1% of surface intensity) greater than 100 m, according to Friedrich (1973)]. These investigators also report for the MAFLA study area the perpetual existence of a nepheloid layer. A nepheloid layer, although occasionally observed on the southwest Florida shelf, was not a permanent phenomenon of shelf waters.

Calder and Haddad (1979) report that water clarity increases with distance from the shore and the bottom; near-bottom clarity increases with a decrease in turbulent energy (currents, seiches, internal waves, and hurricanes) available to act on the bottom. Woodward Clyde Consultants and Skidaway Institute of Oceanography (1983) suggested that the relatively high transmissivity values may be indicative of a lack of significant near-bottom shelf currents capable of resuspending sediments. Ocean current studies conducted by Environmental Science and Engineering, Inc., and LGL Ecological Research Associates, Inc. (Danek and Lewbel, 1986), appear to support this hypothesis. Waves generally contribute more toward sediment resuspension than do currents, but only at water depths less than 50 m. The near-surface turbidity was generally associated with runoff, biological productivity, or surface wave energy in shallow water. In deeper water, turbidity probably resulted from the presence of a nepheloid layer and sediment resuspension induced by internal waves breaking on the shelf break.

The compensation depth can range from between 3 and 4 m for turbid coastal waters to approximately 100 m for the clearest ocean water (Pickard and Emery, 1982). Across the southwest Florida shelf, the estimated compensation depth ranged between 5 and 100 m. The nearshore stations (those with water depths less than 40 m) were generally more turbid and, therefore, had shallower compensation depths with maximum values rarely exceeding 45 m and minimum values as low as 5 m. This means that, although the compensation depth probably exceeds the bottom depth (i.e., there is usually sufficient light for photosynthesis), there are periods during which photosynthesis would cease because of insufficient light. At the midshelf locations (water depths between 40 and 70 m) generally, the compensation depth (50 m) was probably rarely greater than the bottom depth. Algae that exist and thrive at 65 m on the southwest Florida shelf (e.g., Anadyomene) probably rely on the deeper penetrating blue-green light almost exclusively. The compensation depth at the offshore locations (i.e., those beyond the 100-m isobath) generally was high (with a mean value of over 75 m), ranging between approximately 65 and 85 m.

3.4 CHEMICAL OCEANOGRAPHY

3.4.1 DISSOLVED OXYGEN

According to El Sayed et al. (1972), overall dissolved oxygen concentrations in the Gulf of Mexico range from 6.5 to 6.9 mg/l for the upper mixed layer and 4.7 to 6.5 mg/l for depths greater than 100 m. Dissolved oxygen concentrations observed on the southwest Florida shelf range from 3.8 to 11.7 mg/l (Marvin, 1955; Schomer and Drew, 1982; Woodward Clyde Consultants and Continental Shelf Associates, 1983 and 1984; Danek and Lewbel, 1986). The widest ranges in dissolved oxygen concentrations occur in nearshore areas of restricted circulation. On the open shelf, the dissolved oxygen values generally range from 4.4 to 10.3 mg/l. Dissolved oxygen data along a cross-shelf transect (Marvin, 1955) reveal a distinct trend toward lower dissolved oxygen concentrations in the estuaries and nearshore zone increasing approximately 1 to 2 mg/l offshore; this occurs approximately 70% of the time. Generally, dissolved oxygen decreases with depth and rarely exceeds 5 mg/l at depths greater than 100 m.

3.4.2 GELBSTOFF

Gelbstoff (yellow substance) frequently has been used as an indicator of terrestrial influence. It is associated with humic substances resulting from the decomposition of organic matter (e.g., vegetation). Woodward Clyde Consultants and Continental Shelf Associates (1984) reported that the values for Gelbstoff were too close to the detection limit to prepare any reliable plot of concentration. These extremely low values do suggest, however, that terrestrial influence (including the Everglades) on the southwest Florida shelf beyond the 20-m isobath is minimal. Presumably, Gelbstoff values in the very nearshore areas and Florida Bay are higher; however, no data were available for these areas.

3.4.3 NUTRIENTS

The majority of the nutrient data that existed prior to the Southwest Florida Shelf Ecosystems Program were collected in the open Gulf of Mexico. El Sayed et al. (1972) reported that the upper 100 m of water in the Gulf of Mexico generally was nutrient poor, with phosphate, nitrate, and silicate values less than 0.4, 2.0, and 2.0 micromoles (uM), respectively. Nutrient concentrations, although low, do increase below the euphotic zone in the open Gulf of Mexico (Morrison and Nowlin, 1977).

In the Southwest Florida Shelf Ecosystems Program study area, historical nutrient data are sparse; one of the more complete sets of nutrient data was collected monthly from May 1949 to July 1951 on a cross-shelf transect originating from Charlotte Harbor and extending to the 100-fathom (180-m) isobath (Marvin, 1955). During the Southwest Florida Shelf Ecosystems Program, nutrient data were collected during Year 1 (Woodward Clyde Consultants and Continental Shelf Associates, 1983a), Year 2 (Woodward Clyde Consultants and Continental Shelf Associates, 1984), and during the Year 2 Modification (Woodward Clyde Consultants and Skidaway Institute of Oceanography, 1983). Some additional nearshore (Florida Bay and the Gulf side of the Florida Keys) nutrient data were compiled by Schomer and Drew (1982). All of these sources were used to prepare the following discussion of nutrients on the southwest Florida shelf.

Generally, nutrient values are higher offshore at water depths greater than 100 m. The higher nutrient concentrations are typical of deeper water; however, the proximity of these offshore locations to the Loop Current probably contributes to higher nutrient values. Bogdanov et al. (1969) reported apparent upwelling which was associated with either winds or the Loop Current. During Science Applications International Corporation's investigations (1986), doming of isotherms across a cold core perturbation also suggested upwelling (Figure 3.3-3); this upwelling would bring up the more nutrient-rich Subtropical Underwater. Haddad and

Carder (1979) reported that Loop Current intrusions do occur on the shelf. Freeberg and Hyle (1978) reported that a Loop Current intrusion occurred within 4 km of shore accompanied by an 88% increase in orthophosphate concentration and a 129% increase in silicate concentration.

Nitrate-nitrite nitrogen concentrations ranged from less than 0.1 to 19 uM; however, the concentrations rarely exceeded 1 uM at depths less than 60 m. There were no obvious seasonal trends. Historically, the total phosphorus concentration ranged from 0.05 to 1.6 uM, with a mean concentration of 0.3 uM for the upper 100 m of water (Marvin, 1955). The mean total phosphorus concentration at depths greater than 100 m was 1.0 uM (ranging from 0.65 to 1.6 uM). The more recent work of Woodward Clyde Consultants and Continental Shelf Associates (1983a) supports this characterization. One trend apparent in Marvin's (1955) data was a 2- to 3-fold increase in near-surface total phosphorus concentration shoreward of the 20-m isobath. Silicate concentrations on the southwest Florida shelf ranged from less than 1 to 13 uM, with values exceeding 3 uM only at depths greater than approximately 60 m and shoreward of the 20-m isobath. The exception to this trend occurred during the fall, when values greater than 3 uM were observed in a patchy distribution across the shelf.

3.4.4 CHLOROPHYLL

Riley and Chester (1971) report that fertile coastal water in bloom may exhibit chlorophyll values from 10 to 40 mg/m^3. In contrast, El Sayed _et al_. (1972) reported chlorophyll levels of 0.20 ± 0.23 mg/m^3, based on 435 observations throughout the Gulf of Mexico. They also report that the average surface value for chlorophyll was 0.2 mg/m^3 (with a range of 0.05 to 0.3 mg/m^3) and that a chlorophyll maximum coincided with the depth of the euphotic zone.

According to Woodward Clyde Consultants and Continental Shelf Associates (1983a), chlorophyll values on the southwest Florida shelf range from less than 0.1 to 1.5 mg/m^3. These values are higher than the Gulfwide average established by El Sayed et al. (1972), but still considerably lower than the values for fertile coastal water. There were no apparent geographical or seasonal trends with regard to chlorophyll distribution; however, the highest overall chlorophyll concentrations did seem to occur during the fall. Inshore of the 100-m isobath, the lowest chlorophyll values were recorded during the spring and were comparable to the summer values. For both seasons, the inshore chlorophyll values ranged from 0.1 to 0.5 mg/m^3; this was approximately one-third the fall and winter concentrations. This suggests that the phytoplankton bloom had been missed either sometime in the spring or summer. Therefore, it is likely that the maximum values reported by Woodward Clyde Consultants and Continental Shelf Associates (1983a) are low and should be considered conservative when estimating the productivity of the shelf water or comparing this productivity with worldwide values.

3.4.5 HYDROCARBON CHEMISTRY

Introduction

Investigations of the composition and concentration of hydrocarbons in sediment, water, and biota of the southwest Florida shelf provide evidence for ascertaining the extent of existing petroleum contamination and for characterizing the type and amount of hydrocarbons in the study region. These data provide a critical baseline reference with which impacts of future petroleum exploration and production activities can be compared. Such comparisons are essential for developing cause-and-effect relationships and predictive capabilities associated with biological changes.

The presence of hydrocarbons does not necessarily indicate petroleum contamination. Careful attention must be given to characteristic hydrocarbon components to establish the probable origin, because there are many sources of hydrocarbons that may result in ultimate deposition in the marine environment, including: (1) biogenic, synthesized by marine and terrestrial organisms; (2) diagenetic, formed *in situ* (primarily in the surface sediment environment); (3) pyrogenic, formed during combustion of wood and fossil fuels; and (4) petrogenic, formed from petroleum drilling, production, and use (anthropogenic) and from natural seeps. The National Academy of Science (1985) provides a thorough summary of sources and resulting hydrocarbon characteristics.

This comprehensive review of hydrocarbon data for the southwest Florida shelf revealed no evidence for natural seeps or for any significant influx of anthropogenic petroleum contamination. High-molecular-weight hydrocarbons (hydrocarbons within the boiling range of normal alkanes consisting of 14-carbon to 32-carbon compounds: n-C-14 to n-C-32) were dominated by biogenic and diagenetic compounds; however, analysis of select polynuclear aromatic hydrocarbons revealed small amounts of petrogenic and pyrogenic input.

Recent surveys of dissolved and dispersed petroleum hydrocarbons and pelagic tar in surface water found little in the southwest Florida shelf region relative to other areas of the Gulf of Mexico. Although no comprehensive survey of hydrocarbons in biota of the southwest Florida shelf has been conducted, limited studies provided general trends for hydrocarbon composition. These studies showed that zooplankton contained marine biogenic hydrocarbons primarily of phytoplankton origin, whereas epifaunal invertebrates and demersal fish contained biogenic and diagenetic hydrocarbons reflecting the surface sediment hydrocarbon composition in the area where the specimens were collected.

Hydrocarbons in Sediment

The first comprehensive hydrocarbon analyses of sediment from the southwest Florida shelf study area were obtained as part of the 1975 through 1976 monitoring studies of the MAFLA Outer Continental Shelf

[State University System of Florida Institute of Oceanography (SUSIO), 1978], followed by the 1976 through 1978 MAFLA Outer Continental Shelf Baseline Environmental Survey (Dames and Moore, 1979). The SUSIO samples were collected from the transect with Stations 2101 through 2106 (Figure 3.4-1), and the Dames and Moore samples were taken from that transect plus the 2957 through 2960 transect (see Figure 3.4-1). Subsequently, sediment samples were analyzed during the first 3 years (1980 through 1983) of the Southwest Florida Shelf Ecosystems Program (Woodward Clyde Consultants and Continental Shelf Associates, 1983a, 1984; Continental Shelf Associates, 1986). The locations of these sampling stations, plus additional nearshore studies at Charlotte Harbor (Pierce et al., 1983; 1986), are shown in Figure 3.4-1.

The SUSIO MAFLA samples were collected during June and July 1975, September and October 1975, and January and February 1976. Total extractable hydrocarbon content (saturated plus unsaturated hydrocarbons) decreased with distance from shore, with a high of 2.2 ug/g at Station 2101, to a low of 0.7 ug/g at Station 2105, and an increase to 1.9 ug/g at Station 2106. No petroleum hydrocarbons were found in these samples (SUSIO, 1978). The Dames and Moore MAFLA samples were collected during summer 1976, summer 1977, fall 1977, and winter 1978 (Dames and Moore, 1979). Considering Transect Stations 2101 through 2106 (off Charlotte Harbor), the total extractable hydrocarbon content ranged from 1.8 ug/g (Station 2101) to 0.9 ug/g (Station 2105) and increased again at the deepest station (Station 2106), showing agreement with concentrations observed during the SUSIO study. The southernmost MAFLA study transect, Stations 2957 through 2960, did not exhibit any trend with depth, but ranged between 1 and 2 ug/g. The variability observed from replicate samples indicated that the southern transect station hydrocarbon concentrations were probably not significantly different from each other.

During Year 1 of the Southwest Florida Shelf Ecosystems Program, hydrocarbons were analyzed from 15 soft-bottom stations along five

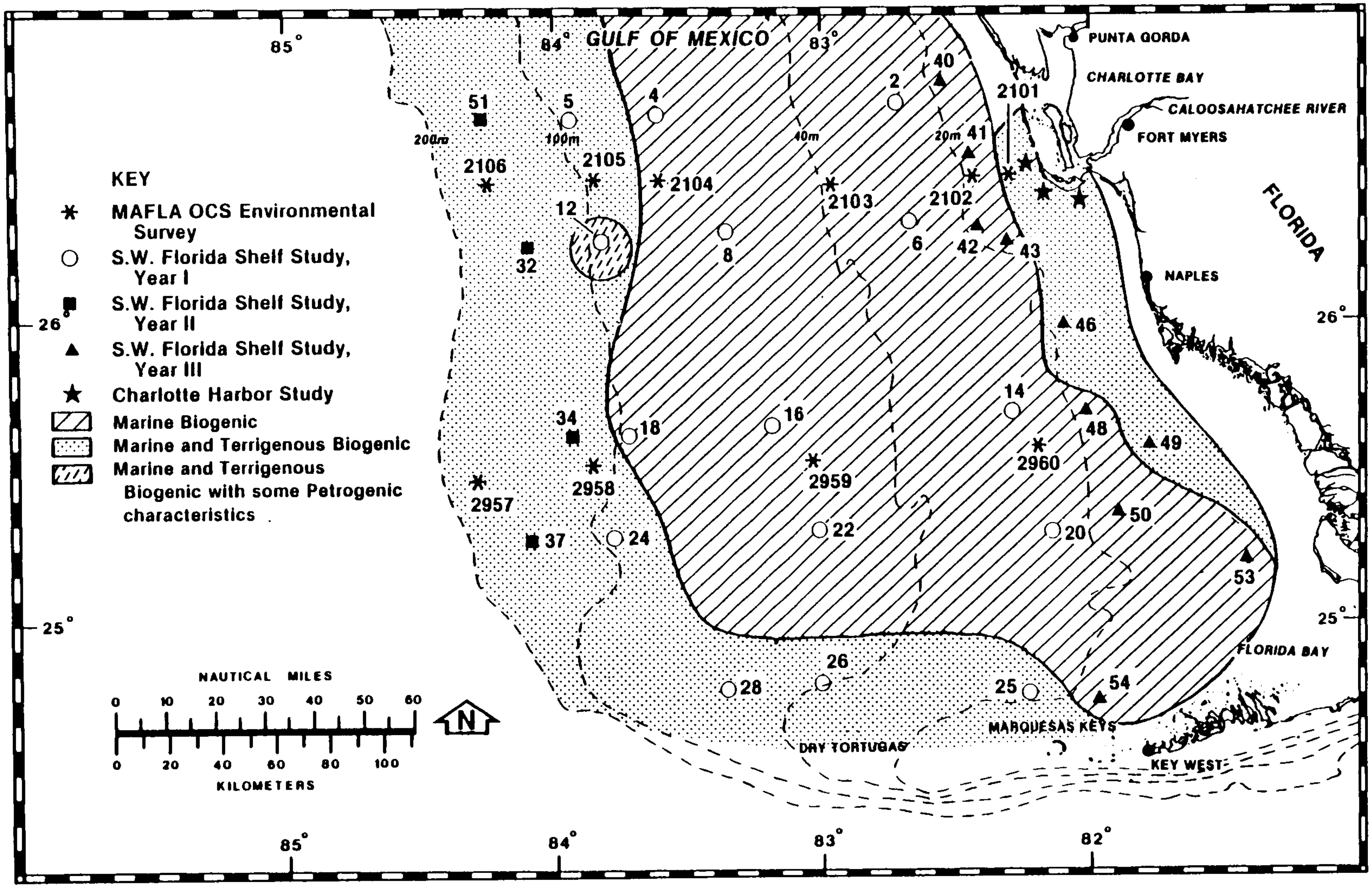


Figure 3.4-1 Surface sediment sample stations and hydrocarbon source characteristic distribution.

transects ranging from approximately 25 to 100 m in depth (Stations 2 through 28) (see Figure 3.4-1). The Year 2 study dealt with four deeper stations (Stations 31, 32, 34, and 37 at approximately 150 m), whereas Year 3 samples were collected from 10 shallow water samples inshore from the 20-m isobath (Stations 40 through 54) (Figure 3.4-1).

Total extractable hydrocarbon content exhibited a trend similar to the MAFLA results; surface sediment hydrocarbons diminished with distance from shore. Year 2 stations (150-m depth) averaged 0.25 ±0.13 ug/g dry-weight sediment; Year 1 transects A through D ranged from 0.25 ±0.06 ug/g at the 100-m isobath, 0.50 ±0.23 ug/g at the 50-m isobath, to 0.76 ±0.23 ug/g at the 25-m isobath. The southernmost transect (Transect E) exhibited relatively high hydrocarbon concentrations at all three stations, probably due to their proximity to more productive shallow waters.

Seasonal samples were collected for Year 3 during December 1982 and June 1983. Total extractable hydrocarbons ranged from 0.3 ug/g (Station 40) to 4.3 ug/g (Station 43) in December and 1.3 ug/g (Station 41) to 4.5 ug/g (Station 40) during June, reflecting an increase in productivity during the summer months. Additional studies of the Charlotte Harbor estuary and nearshore shelf sediment revealed localized petroleum contamination near marinas and municipal stormwater runoff, but these contaminants did not appear to be exported from the estuary to the continental shelf (Pierce et al., 1983, 1986). These data showed that estuarine and nearshore shelf sediment hydrocarbon content ranged from obvious petroleum contamination of 142 ug/g sediment at commercial boat docks to a mixture of marine and terrestrial biogenic hydrocarbons, with 1.3 ug/g sediment collected 1 mi offshore from the barrier island chain.

Identification of the source of the hydrocarbons (i.e., marine or terrigenous biogenic, diagenetic, pyrogenic, or petrogenic) was established by considering specific characteristics observed from high-resolution capillary gas chromatographic analysis with a flame-ionization detector. Mass spectrometric analysis was obtained to verify the composition of certain polynuclear aromatic hydrocarbons in select samples.

For both the MAFLA and southwest Florida shelf studies, most samples contained as predominant features the normal alkane, heptadecane (n-C-17), the isoprenoid, phytane, and a cluster of cycloalkene compounds with 25 carbons eluting near a retention time corresponding with the Kovats Index of 2085, all of which are indicative of marine biogenic-diagenetic sources (Blumer et al., 1971; Farrington and Tripp, 1977; Requejo and Quinn, 1983). The deeper stations from the MAFLA and Southwest Florida Shelf Ecosystems Program studies exhibited an influx of higher molecular weight n-alkanes with an odd number of carbon atoms (n-C-25 through n-C-31) which are characteristic of terrigenous biogenic hydrocarbons synthesized by vascular plants (Wakeham and Farrington, 1980; Boehm and Requejo, 1986; National Academy of Science, 1985). These same characteristics were observed for some shallow shelf stations from Year 3 (Continental Shelf Associates, 1986) and from nearshore sites from other studies (Pierce et al., 1983, 1986), indicating export of terrigenous biogenic hydrocarbons from estuaries.

Several of the deeper stations from the MAFLA study exhibited patterns from gas chromatographic analysis with a flame-ionization detector that were characteristic of petrogenic hydrocarbons as evidenced by an unresolved complex mixture and intermediate range n-alkanes (n-C-20 to n-C-24), with an odd-to-even carbon-number ratio close to one (Dames and Moore, 1979). Only one Year 1 station (Station 12) from the southwest Florida shelf study and no Year 2 stations exhibited the unresolved complex mixture characteristic of petroleum. The small amount of terrigenous and petrogenic hydrocarbon in the presence of marine biogenic hydrocarbons suggests that these nonmarine hydrocarbons were associated with particulates derived from the Mississippi River that were transported to the southwest Florida OCS region by the Loop Current (Dames and Moore, 1979; Continental Shelf Associates, 1986; Boehm and Requejo, 1986).

The distribution of hydrocarbons in surface sediment of the southwest Florida shelf according to source characteristics is shown in Figure 3.4-1. Three major source regimes were observed: (1) predominantly marine biogenic, found primarily in the midshelf to outer continental shelf areas; (2) marine and terrigenous biogenic, found at the deepest stations and those closest to land (<20-m depth); and (3) marine and terrigenous biogenic with some petrogenic characteristics found in a few outer stations influenced by transport from the Loop Current. The small amount of pyrogenic hydrocarbons indicated by gas chromatography/mass spectrometry of alkyl homologues of select polynuclear aromatic hydrocarbons was not considered to represent a major source for any of the samples (Continental Shelf Associates, 1986; Pierce et al., 1983).

Hydrocarbons in Marine Organisms

The hydrocarbon composition was investigated in select benthic organisms and zooplankton collected from stations within the southwest Florida study area during the MAFLA survey (SUSIO, 1978; Dames and Moore, 1979). Analysis of muscle tissue from the demersal fish, *Syacium papillosum*, exhibited primarily biogenic hydrocarbons with no definitive evidence for petroleum contamination.

Macroepifauna consisting of various shrimp, crabs, bivalve molluscs, and echinoderms also were analyzed for hydrocarbon content. Because only small numbers of individuals were obtained for many species, general trends rather than species-specific composition were provided. These data showed no petroleum contamination and a wide variation in specific branched and olefinic compounds, most indicative of marine biogenic and diagenetic hydrocarbons (Dames and Moore, 1979).

In both the demersal fish and macroepifaunal invertebrates, the hydrocarbon composition reflected that found in surface sediment with seasonal and interstation variability indicating acquisition from benthic dietary sources rather than from the water column (Dames and Moore, 1979).

Hydrocarbons in zooplankton showed seasonal changes most likely reflecting uptake from phytoplankton. Pristane was the most abundant compound, along with a group of peaks centering around a Kovats Index of 2080 (Dames and Moore, 1979). The lack of petrogenic contamination in biota indicates the absence of petrogenic hydrocarbons in the water column as well as in sediments.

Pelagic Tar

Floating particulate petroleum residue (pelagic tar or tar balls) represents a relatively persistent phase of weathered oil in the marine environment. These lumps of tar range in size from less than 1 mm to several centimeters in diameter and vary in residence time from a few days to a year (Butler, 1975; Butler and Harris, 1975; Morris, 1971).

Pelagic tar has been found throughout the Gulf of Mexico, with an average concentration of 1.35 mg/m^2 (Jeffrey, 1980). Koons and Monaghan (1973) estimated a standing crop in excess of 2,000 metric tons (based on 1 mg/m^2), which represents about 20% of the organic matter in the surface water.

Studies of the eastern Gulf show high concentrations in the Loop Current (0.6 to 2.2 mg/m^2) with low concentrations recovered from the southwest Florida continental shelf (<0.1 mg/m^2) (Jeffrey, 1980; Van Vleet et al., 1984). About half the tar in the eastern Gulf of Mexico Loop Current system appears to enter the Gulf through the Yucatan Straits (Van Vleet et al., 1984). In the Gulf, as with other ocean areas where tar has been investigated, pelagic tar was transported by surface currents and wind and was most abundant along tanker routes where the composition of many tar balls resembled crude oil sludge (tanker wall washings) (Butler et al., 1973; Van Vleet et al., 1984). Natural oil seeps appear to be a significant source in the western Gulf of Mexico but are not a factor for the southwest Florida shelf (Koons and Monaghan, 1973; National Academy of Science, 1985). Other potential sources, such as petroleum exploration and production activities and discharge from the Mississippi River, were not observed to produce significant amounts of floating tar (Van Vleet et al., 1984).

Although most pelagic tar in the Loop Current system is transported out through the Florida Straits, much of which is blown ashore onto the Florida Keys and southeastern Florida beaches, infrequent tar loading does occur along the southwest Florida beaches, primarily from tanker washings during a prevailing westerly wind (Romero et al., 1981; Atwood et al., 1986; Van Vleet and Pauley, 1986; Pierce, unpublished results). In addition to presenting an aesthetic nuisance to coastal residents, bathers, and boaters, pelagic tar has been implicated in the deaths of sea turtles along the southwest Florida and southeast Florida coasts (Van Vleet and Pauley, 1986).

Dissolved and Dispersed Petroleum Hydrocarbons

Dissolved and dispersed petroleum hydrocarbons in the eastern and northern Gulf of Mexico were investigated by the SUSIO MAFLA study (SUSIO, 1978) and by Atwood et al. (1986). The dissolved and dispersed petroleum hydrocarbons results followed those reported for pelagic tar by Van Vleet et al. (1984), showing that surface water with a high incidence of pelagic tar also contained high concentrations of dissolved and dispersed petroleum hydrocarbons. Highest values were observed in the southern Florida Straits, whereas very little was found in the southwest Florida shelf area (Atwood et al., 1986). Although the source for dissolved and dispersed petroleum hydrocarbons could not be established, the correlation with pelagic tar would implicate tanker discharge as a major contributor in the Yucatan Straits and the Straits of Florida with oil drilling production and Mississippi River discharge as potential contributing factors in the northern and eastern Gulf of Mexico.

The dissolved and dispersed petroleum hydrocarbons have shorter residence times than do tar balls; therefore, high concentrations of this fraction generally indicate recent tanker spills or dissolution/dispersion of an oil slick (Macko et al., 1982; Atwood et al., 1986). High concentrations of dissolved and dispersed petroleum hydrocarbons would be of concern during oil and gas exploration/production, due to the abundance of highly toxic polynuclear aromatic hydrocarbons. However, the probability of oil being released during these operations is very low.

Significance of Hydrocarbon Studies Results

Investigations of hydrocarbons in sediment, water, and biota of the southwest Florida shelf have shown that this region is relatively free from petroleum contamination other than an occasional influx of pelagic tar that most probably originates from tanker washings. A comparison of these results with investigations of other continental shelf regions of the Gulf of Mexico shows a gradation to increased petrogenic and other anthropogenic input going north and west. Central and north Florida shelf environments also exhibited very little petroleum contamination; however, petrogenic input from Mobile Bay, Mississippi Sound, and the Mississippi River, as well as oil and gas exploration/production activities, was apparent in shelf areas studied off Alabama, Mississippi, and Louisiana (SUSIO, 1978; Dames and Moore, 1979; Boehm and Requejo, 1986). Oil and gas exploration/production activities as well as natural seeps result in much higher hydrocarbon concentrations with characteristic petroleum components in the western Gulf of Mexico (University of Texas, 1977; Texas A&M University, 1982). Although gaseous and volatile hydrocarbons were not investigated in the southwest Florida shelf area, these components have been observed to result from oil and gas exploration/production activities as well as from natural seeps (Brooks et al., 1977; Sauer et al., 1978; University of Texas, 1977), suggesting the importance of monitoring for these chemicals before and after the initiation of drilling and production.

The most probable sources for petroleum contamination from oil and gas exploration/production on the southwest Florida shelf would be from spent drilling fluids (Pierce et al., 1985), release of produced (formation) waters (Menzie, 1982), underwater gas venting (Brooks et al., 1977), and from transportation of crude and refined products (National Academy of Science, 1985). Increases in coastal contamination would result primarily from onshore support facilities, with spillage and seepage associated with transfer, storage, and processing (National Academy of Science, 1985). Contamination from catastrophic events (e.g., oil well blowout or tanker accidents) is less likely than from routine operations, but the possibility must be considered. In most instances, however, the amount of environmental contamination can be minimized through appropriate regulations and attention to proper operational procedures.

The significance of these baseline hydrocarbon data is manifested in biological as well as analytical implications. These data show that, unlike biota of the western and northern Gulf of Mexico, flora and fauna of the southwest Florida shelf have not been exposed to chronic petroleum contamination. The possibility for stress from a sudden influx of petroleum hydrocarbons, therefore, is of concern. Analytical implications are that the type and amount of hydrocarbons present in southwest Florida shelf sediment have been characterized. Establishing the presence of certain petroleum-like hydrocarbon characteristics in some deeper sediment, attributed to Mississippi River origin and in nearshore sediments originating from emergent estuarine plants, is very important baseline information for avoiding erroneous conclusions following analyses after future oil exploration/production activities. This data set assures that any increase in petroleum hydrocarbon content would be readily apparent and, with appropriate monitoring and surveillance programs, the source could be rapidly identified, allowing implementation of mitigative as well as punitive action.

3.5 GEOLOGY

Information concerning the geology of the southwest Florida shelf is available from the literature (e.g., Gould and Stewart, 1955; Ballard and Uchupi, 1970; Doyle and Sparks, 1980; Holmes, 1981, 1985) and from sampling and surveying conducted during the Southwest Florida Shelf Ecosystems Study. The latter source includes geophysical mapping (side-scan sonar, subbottom profiler, and precision fathometer) along several transects (see Figure 3.5-1) and sediment sampling at 40 discrete stations (shown in Section 3.5-2). Detailed descriptions of the methodology and results of the geophysical studies are presented in the Year 1 report (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a) and two Marine Habitat Atlases (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983b; Continental Shelf Associates, Inc., 1985). Results of sediment sampling are summarized in the Year 3 report (Continental Shelf Associates, Inc., 1987) and Year 5 report (Danek and Lewbel, 1986).

3.5.1 GENERAL GEOLOGY OF THE SOUTHWEST FLORIDA SHELF

A profound lithologic change occurs in the continental margins of the Gulf of Mexico across a line extending from DeSoto Canyon in the northeast to Campeche Canyon in the southwest. Since Jurassic time, carbonates and evaporites have been accumulating on the shelves southeast of this line while land-derived Tertiary sediment filled the subsiding Gulf coast geosyncline to the northwest. The carbonate platforms of Florida and the Yucatan continued their upward growth in pace with subsidence and maintained their tops near sea level (Garrison and Martin, 1973), resulting in massive carbonate banks characterized by steep, seaward-facing escarpments and great thicknesses of limestone and evaporites. Uchupi (1975) describes the Florida platform as consisting of a thick section of Late Jurassic-Cenozoic carbonate and evaporite deposits resting on Paleozoic and Triassic rocks.

The surface of the southwest Florida shelf is one of low relief broken only by reef structures or remnants of shoreline features associated with

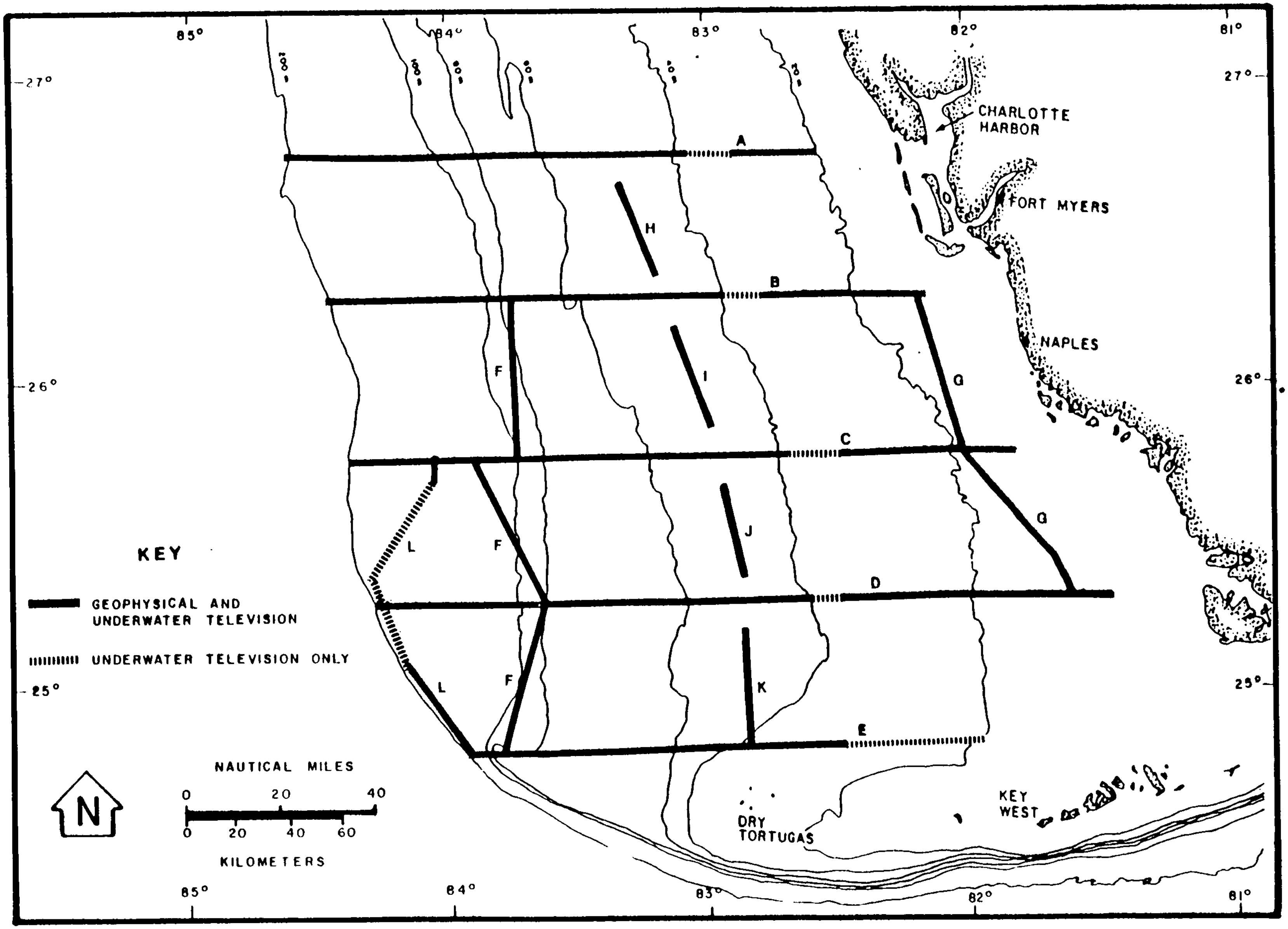


Figure 3.5-1 Geophysical and television survey transects surveyed during the Southwest Florida Shelf Ecosystems Program.

former periods of lower sea level. Partially buried reef complexes are present on the middle shelf in a depth of about 70 m and on the outer shelf in a depth of approximately 150 m (Holmes, 1985). Unconsolidated sediments are thin and discontinuous, with the vast majority of the sediment veneer being of biogenic origin. Scattered low-relief limestone outcrops provide a substratum for growth of corals, algae, sponges, and other sessile epibiota.

Stratigraphic information from high-resolution seismic surveying conducted across the southwest Florida platform indicates that the modern shelf is a constructional platform with Pliocene (?)-Pleistocene and Holocene sediments resting on an eroded, karstic Miocene platform (Holmes, 1985). The Miocene surface dips away from the coastline, with significant breaks in slope occurring on the middle shelf and at the shelf edge. At the southwest corner of the platform, the Miocene surface crops out to form a terrace that is progressively buried to the southeast by younger deposits (reefs and sediments) so that it has no surface expression in the Florida Straits area. Holmes (1981) indicates that, geomorphologically and geologically, the southwestern Florida margin can be divided into eight units: southern banks, inner shelf, outer shelf, upper slope, central slope, escarpment, basin, and Miocene(?) surface. The first three are discussed in the following subsections. Holmes (1981) placed the boundary between inner and outer shelf at the 70-m isobath, corresponding to the location of the central reef complex (Pulley Ridge). In the following discussion, the shelf is divided into inner, middle, and outer shelf units following Woodward Clyde Consultants and Continental Shelf Associates, Inc. (1983a). The boundary between inner and middle shelf is at the 40-m isobath, and the boundary between the middle and outer shelf is at the 100-m isobath.

Geomorphic Units

Southern Banks

On the southern end of the shelf off west Florida is Florida Bay, a broad area of water less than 3 m deep that is subdivided by mud banks and separated from the open sea by the Florida Keys (Uchupi, 1975). West of the bay, a series of banks and reefs occurs along the Florida Straits segment of the platform. These banks trend east-west, become progressively deeper in a westward direction, and are crowned in the shallower areas by coral growth (Holmes, 1981). The easternmost bank (i.e., the Marquesas Keys) is composed of Halimeda sands resting on a Pleistocene platform of reef rock or oolite (Shinn et al., 1982). A dissected platform forms the Dry Tortugas and Tortugas Bank complex to the west. These features currently are being constructed by various massive and branching hermatypic corals that form fringing reefs around islands (Shinn et al., 1977). Holmes (1985) states that slightly elevated banks are present farther west along this trend, with the substratum being a fused pavement of coralline algae and growths of plate corals (Agaricia). This description apparently refers to a localized area of coralline algal pavement with agariciid growth identified during the Southwest Florida Shelf Ecosystems Study at a water depth of 64 to 80 m along Transect E. Holmes (1985) further states that it appears the southern sequence of banks mirrors the phylogeny of reef development in the area, progressing from oldest to youngest in an east-west direction.

Inner Shelf

The inner shelf extends from the coastline out to a water depth of 40 m. Bathymetric profiles show the seafloor to be smooth and gently sloping to the west at less than 0.3 m/km (<0.02°) (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a). Bathymetric charts published by the National Ocean Survey (NOS) for the Charlotte Harbor and Pulley Ridge leasing areas indicate that this region contains circular or elongate depressions up to 2 km in diameter. Holmes (1981) has noted a similarity between these features and active karst features and suggests that the depressions were formed in the Miocene(?) bedrock during periods of lower sea level. He also indicates that some of the depressions may be undergoing modification by water flow from active subsea springs.

Side-scan sonar data indicate that between 25 and 27°N, the Miocene bedrock is exposed or covered by a thin layer of mobile sand with local small-scale outcrops of exposed rock (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a). South of 25°N, the surficial sediment appeared to be finer grained (i.e., silt) overlying Holocene and Pleistocene sediment, with no indications of bedrock outcrops. This sediment distribution agrees with the findings of Grady (1971), who reported fine material (silt) immediately north of the Dry Tortugas.

Middle Shelf

The area between the 40-m and 100-m isobaths is designated as the middle shelf (Woodward-Clyde Consultants and Continental Shelf Associates, Inc., 1983a). The seafloor is relatively smooth between water depths of 40 to 75 m, dipping to the west with slopes of 0.02° to 0.04° (0.3 to 0.7 m/km). Between the 70-m and 100-m isobaths, the slope increases slightly with local zones of rough seafloor, depressions, and areas of steeper slopes; this region corresponds to the partially buried, 10-km-wide reef complex known as Pulley Ridge (Figure 3.5-2) (Holmes, 1981, 1985). Holmes (1981) describes the feature as a series of carbonate reef-like structures that drop the shelf stepwise from 70 to 90 m. Woodward Clyde Consultants and Continental Shelf Associates, Inc. (1983a) reported local zones of irregular (rough) topography, areas of locally steep slopes, and depressions between the 70- and 100-m isobaths corresponding to the buried reef feature. Subbottom profiler records show this feature to be partially exposed or covered by a thin sand veneer on Transects B, C, D, and E.

Inshore from the 70-m isobath, a variably thin veneer of sand covers a wedge of late Tertiary to Quaternary sediments. Subbottom profiler data show that the karst surface that crops out shoreward is buried by a thickening wedge of younger sediments (Holmes, 1981). Woodward Clyde Consultants and Continental Shelf Associates, Inc. (1983a) reported that the estimated thickness of this sediment wedge increased from 5 m to

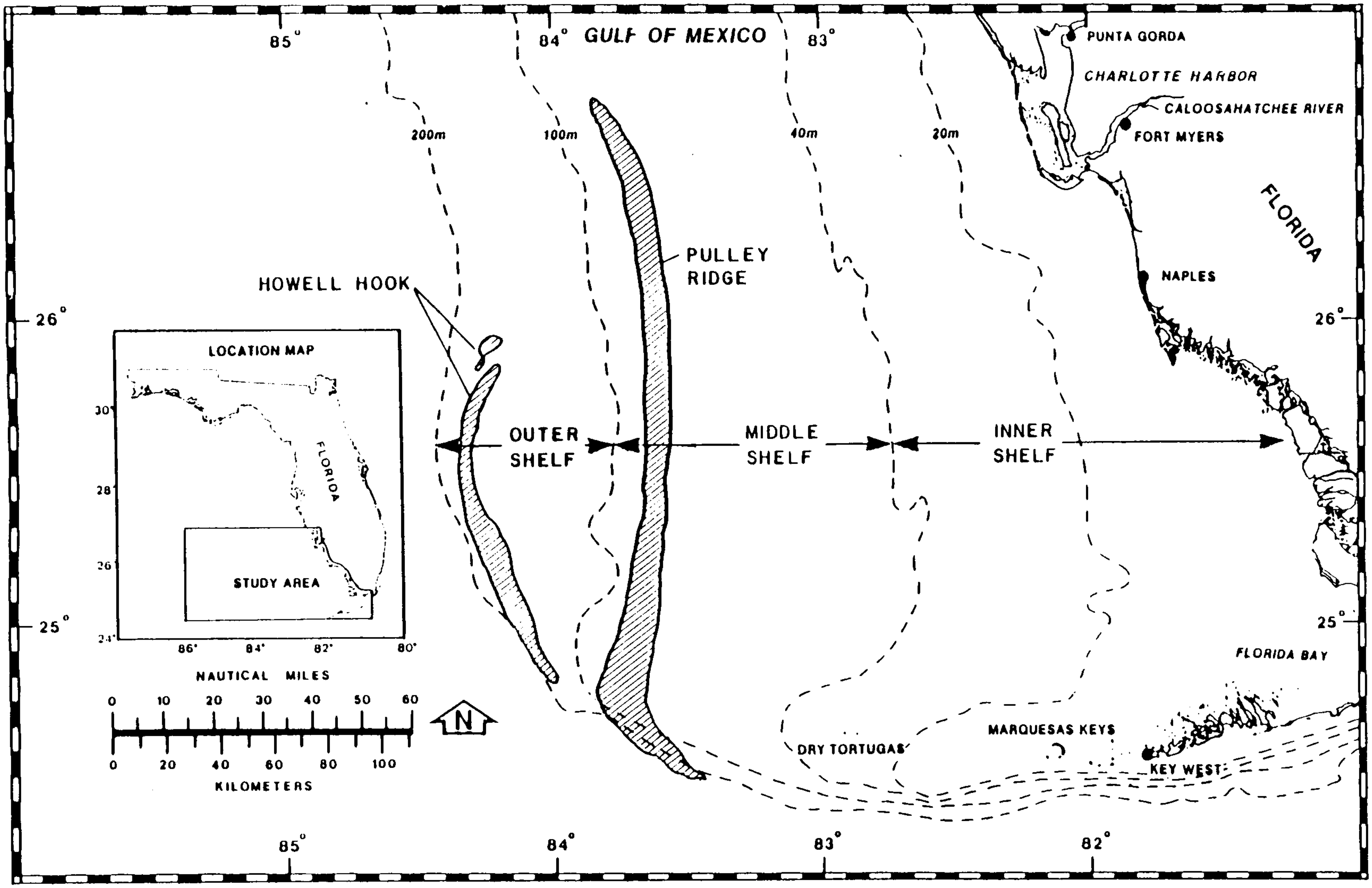


Figure 3.5-2 Locations of major reef features on the southwest Florida shelf.

approximately 20 m between the 40-m and 70-m isobaths, filling any depressions or channels and forming a nearly featureless plain.

Outer Shelf

The outer shelf extends from the 100-m isobath to the 200-m isobath and ranges in width from about 10 km near the southern limit of the study area to approximately 65 km to the north. The slope averages about 0.2° (3.5 m/km), with locally steep slopes of up to 1.0° (17 m/km). The outer shelf is broken by wave-cut terraces, 2 to 3 m in height, that are believed to have been formed during hiatuses in sea level rise (Holmes, 1981). Seafloor depressions noted on the middle shelf by Woodward Clyde Consultants and Continental Shelf Associates, Inc. (1983a) are also found on the outer shelf, primarily in water depths of 100 to 150 m. Holmes (1981) relates similar structures, referred to as pockmarks, to the paleohydrology of southern Florida.

The seafloor on the outer shelf is generally covered with a sand veneer. However, there are two major reef features on the outer shelf and slope. The shallowest reef, cresting in a water depth of 130 to 150 m, veers landward north of 25°30′ and forms the feature known as Howell Hook (Figure 3.5-2) (Jordan and Stewart, 1959). The lower reef crests at a water depth of 210 m in the south and at 235 m in the north, forming a west-facing scarp 40 m in height (Holmes, 1981). Both reef features abruptly turn east at about 24°54′ and are buried by the Pleistocene reefs that border the Florida Straits (Shinn et al., 1977).

Jordan and Stewart (1959) described Howell Hook, the more prominent feature of the outer shelf reef complex, as an arcuate ridge 105 km long impounding a lagoon with a pronounced lagoon channel. The ridge crest and the bottom of the lagoon are generally smooth, but there are some isolated rises. Jordan and Stewart (1959) interpreted Howell Hook as a drowned barrier spit, with the channeled depression behind it representing a former lagoon inlet passing north of the end of the spit. Due to the lack of internal clinoform bedforms common in spits and the presence of an internal structure similar to that of actively growing bioherms, Holmes (1981) interpreted this feature as a bioherm.

During the Southwest Florida Shelf Ecosystems Study, the presence of "dead coral" pinnacles or prominences protruding 1 to 5 m above the surrounding sand was noted along portions of Transects C and L. The position of these features is consistent with the location of Howell Hook (Figure 3.5-2).

The diagrammatic cross section of the southwest Florida shelf shown in Figure 3.5-3 was taken from Holmes (1981) to show the relationship of the two reef complexes discussed previously (the middle shelf reef and the shelf and slope double reef complex) with other stratigraphic features in the area. The deeper reefs were formed at the beginning of a late Pleistocene transgression, with the lower reef being formed first. With formation of the upper reef (Howell Hook), the shelf started its southward movement overlapping the Miocene shelf break to the south (Holmes, 1981). Pulley Ridge may have been formed during a standstill possibly associated with the Holocene-Pleistocene boundary when reef development could have been vigorous. Holmes (1981) suggests that Pulley Ridge produced and impounded the sediment that was deposited landward on the inner shelf.

Substratum Types

During the Southwest Florida Shelf study, geophysical data were integrated with the results of underwater television and still-camera photographic surveys to develop a classification scheme for seafloor substrata (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a). Because of the limited resolution of subbottom profilers, visual observations of presence of sessile epibiota (sponges, corals, etc.) were useful in delineating areas where the hard bottom was overlain by a thin sand veneer and also in recognizing certain other substratum types that could not be definitively identified from geophysical data alone.

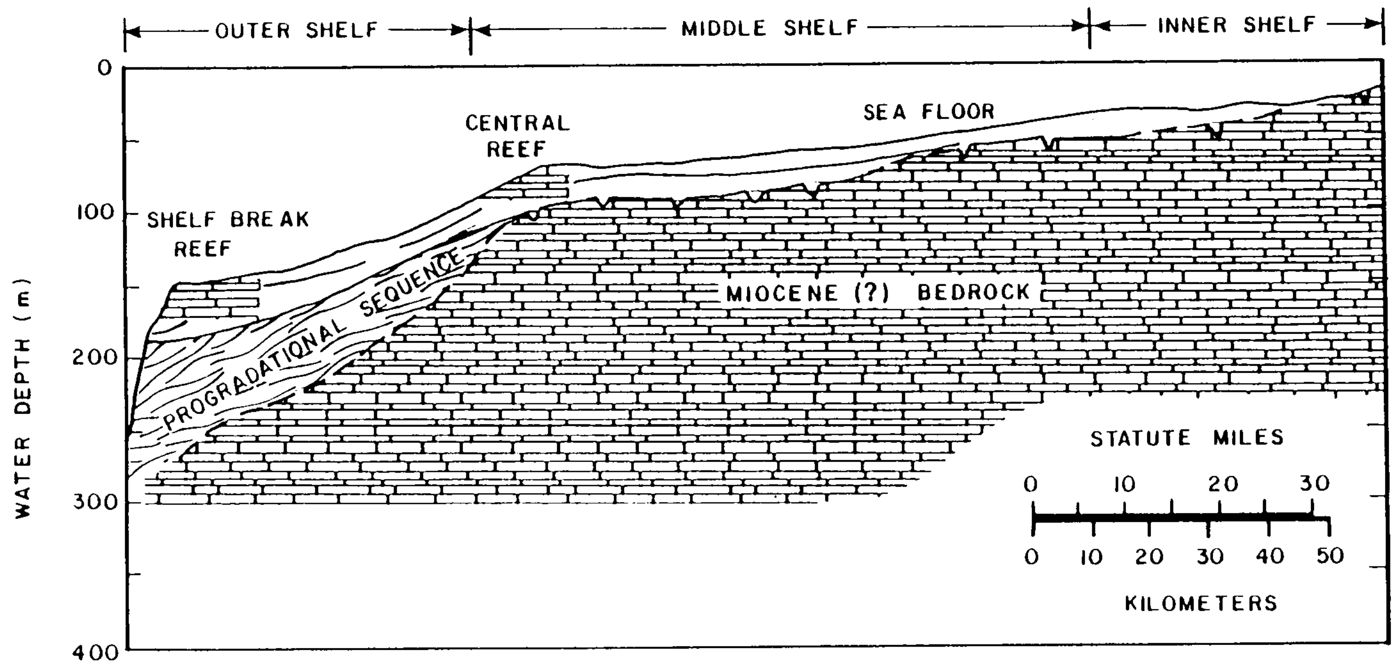


Figure 3.5-3 Geologic cross section of the southwest Florida shelf.

Figure 3.5-4 schematically depicts the major substratum types seen on the shelf, and Figure 3.5-5 shows the occurrence patterns of these substrata along the survey transects based on visual observations. The substratum types are described briefly in the following paragraphs.

Rock Outcrops/Hard Bottom

This substratum type includes hard bottom in the form of low- or high-relief bedrock outcrops or ledges, as well as bioherms. Indicator epibiota such as corals, sponges, gorgonians, and others typically are attached to the hard bottom. Except in association with particular reef features on the outer shelf (e.g., pinnacles), the outcrops are widely scattered and of low relief (<1 m).

Thin Sand Over Hard Bottom

This substratum type is transitional between the rock outcrop and sand bottom types and is very widely distributed on the shelf. In terms of the subbottom profiler records, thin refers to a thickness of 50 to 60 cm or less. However, biological investigations conducted during other parts of this study have shown that sessile epifauna are attached almost exclusively to hard bottom covered by a veneer thinner than 10 cm. Since the main focus of the substratum mapping efforts was related to habitat for benthic epibiota, this substratum type was usually mapped on the basis of visual evidence (presence of indicator epifauna).

The presence of sessile epifauna in areas of thin sand over hard bottom indicates that the underlying hard bottom must periodically be exposed by sediment movement, since most of these organisms must originally attach to hard substratum. Sediment movement is discussed in Section 3.5.3.

Coralline Algal Nodules

This designation refers to areas where the substratum consists of sand bottom covered by various thicknesses of coralline algal (_Lithothamnium_,

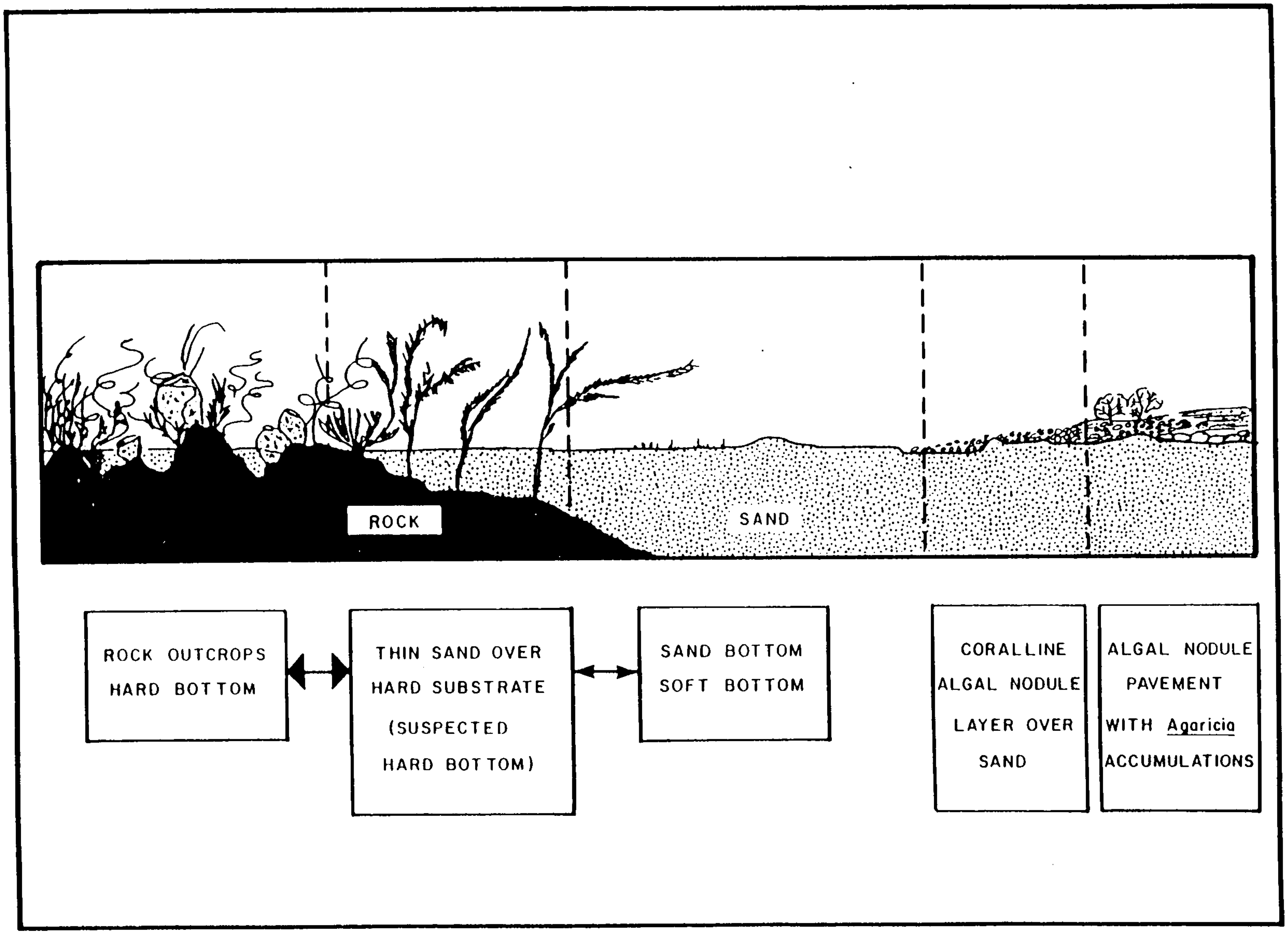


Figure 3.5-4 **Schematic illustration of the substratum types.**

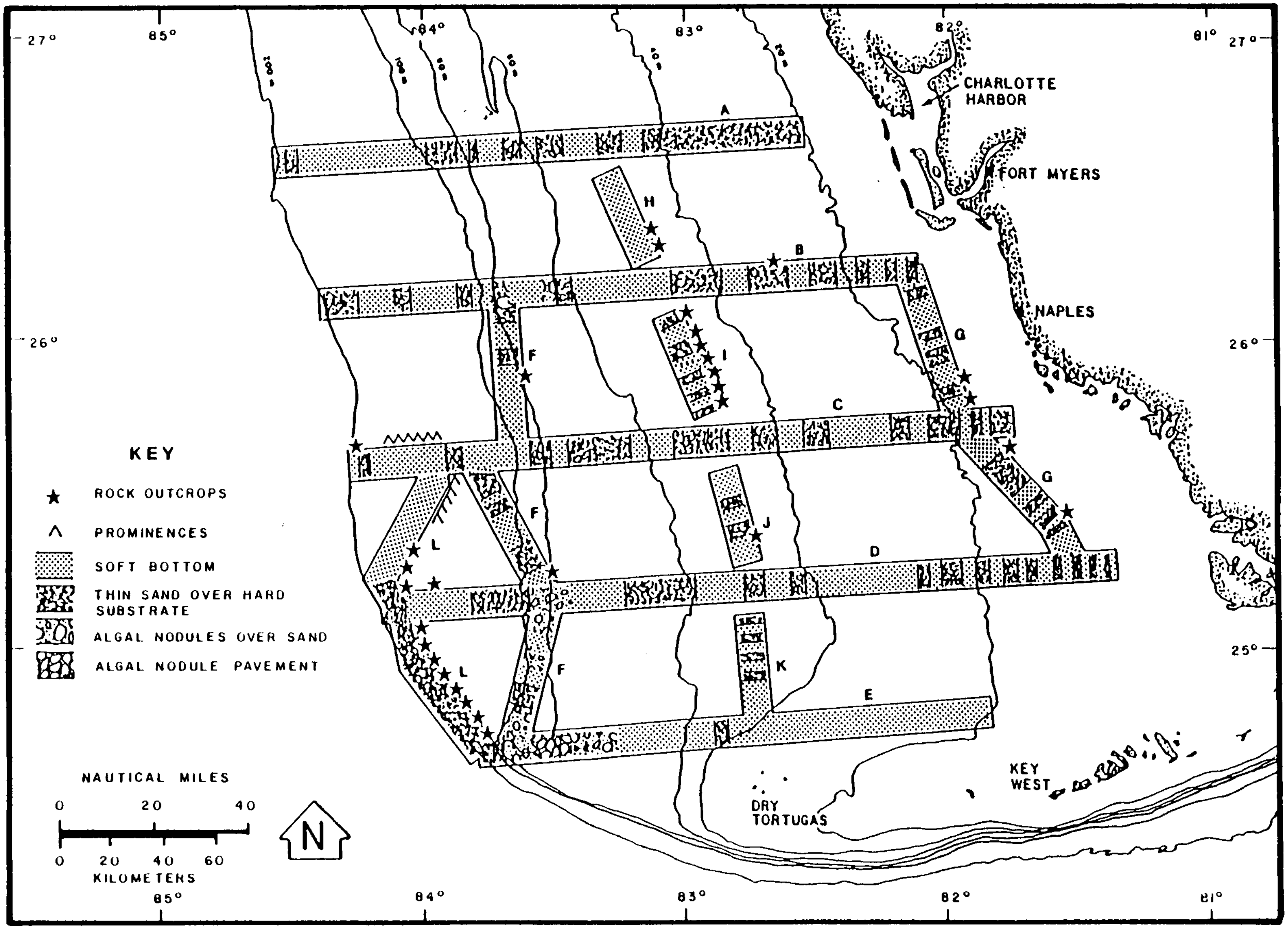


Figure 3.5-5 Distribution of substratum types and geologic features along survey transects.

Lithophyllum) growth. Usually the growths occurred in the form of nodules a few centimeters in diameter. Nodules were seen on the middle shelf (water depths of about 60 to 100 m) along Transects B, D, E, F, and L (Figure 3.5-5), but not on Transects A or C. Nodule areas at the southern end of transect L are not visible on Figure 3.5-5. Nodule densities were highest on the southern transects in this depth range.

Coralline Algal Nodule Pavement

Another form of coralline algal growth is the flattened crust or pavement seen only along Transect E in water 64 to 80 m deep. Typically associated with the pavement were plate corals, *Agaricia*. The pavement is believed to overlie a relatively thin layer of sand (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a). Positive identification of this substratum type depended upon visual observations.

Sand Bottom/Soft Bottom

Sand bottom, including thick sand, silt, or mud bottoms, was the most widely distributed substratum type on the shelf. Several morphological forms were seen, including areas of sand waves and ripples, bioturbated areas, and sandy bottoms covered with algae. Grain size and carbonate composition of the unconsolidated sediments are discussed in the following sections.

3.5.2 COMPOSITION OF UNCONSOLIDATED SEDIMENTS

Sediment samples were collected at 40 stations during Years 1 through 5 of the Southwest Florida Shelf Ecosystems Program. Station locations are shown on Figure 3.5-6, and the sampling schedule is listed in Table 3.5-1. Replicate grab samples were obtained at each station during each cruise, with the shallow (<20 m) stations being sampled by diver-operated corer and the deeper stations by grab or box core sampler. The diver-operated corers were 0.016 m^2 in area and collected sediment to a depth of 15 cm. The box corer was a modified Reineck sampler, 0.06 m^2 in area and 40 cm deep. The grap sampler was a 0.1 m^2 Smith-McIntyre grab. Grain size composition was determined for all samples by sieve and

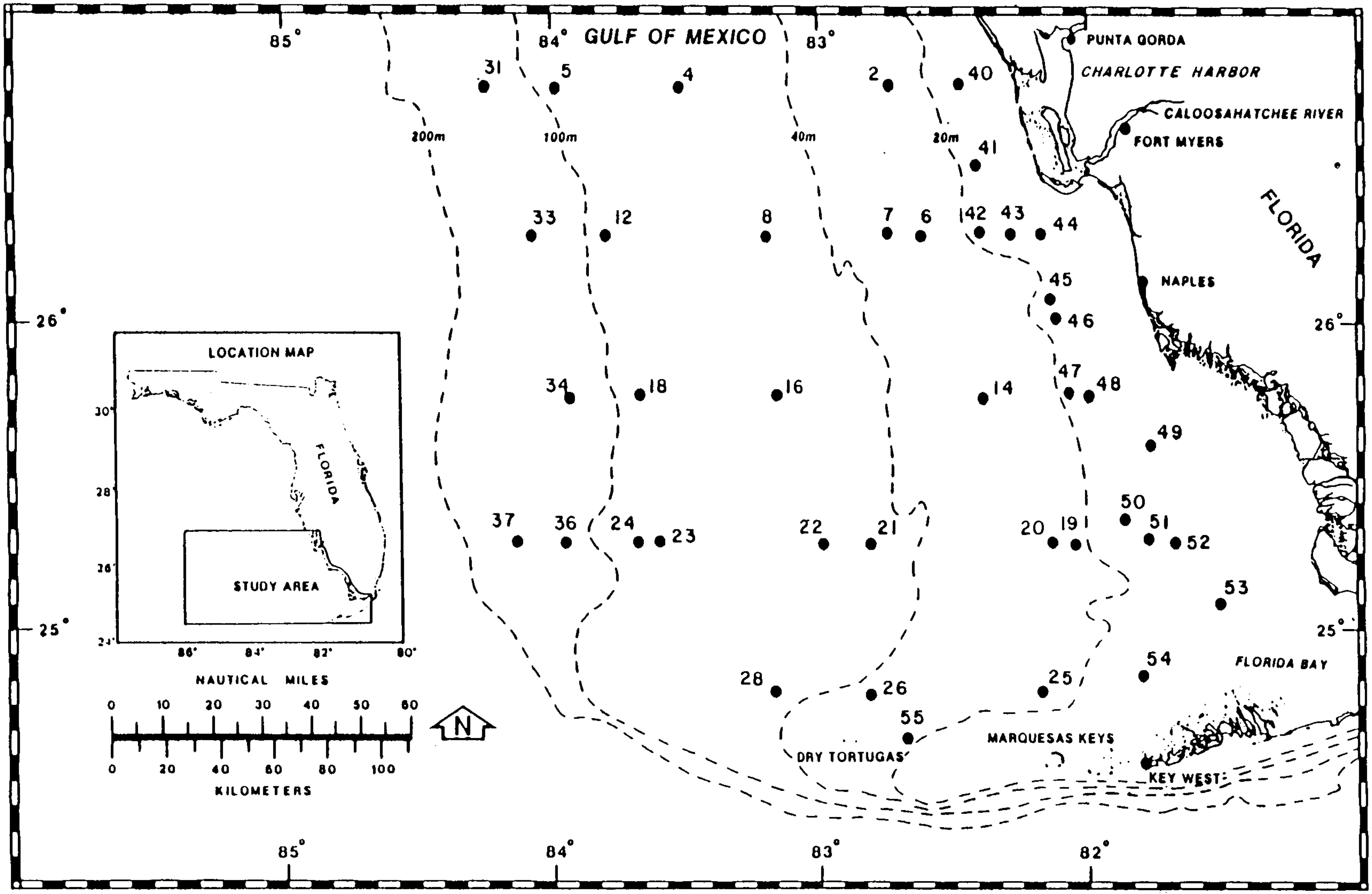


Figure 3.5-6 Sediment sampling locations for the Southwest Florida Shelf Ecosystems Program.

Table 3.5-1. Stations and sampling dates for sediments analyzed for grain size and carbonate.

			Sampling Date							
			Year 1		Year 2		Year 3		Year 4	Year 5
Station	Substratum Type+	Water Depth (m)	Oct 1980	April 1981	July 1981	Jan 1982	Dec 1982	June 1983	Dec 1983	Dec 1984
2	S	25	B*	B						
4	S	55	B*	B	B**	B**				
5	S	90	B*	B	B**	B**				
6	S	26	B*	B	B**	B**				
7	TS	30								G***
8	S	48	B*	B						
12	S	90	B*	B	B**	B**				
14	S	26	B*	B	B**	B**				
16	S	54	B*	B	B**	B**				
18	S	86	B*	B						
19	TS	22							G***	
20	S	23	B*	B	B**	B**				
21	TS	44							G***	G***
22	S	52	B*	B	B**	B**				
23	N	70							G***	G***
24	S	88	B*	B	B**	B**				
25	S	24	B*	B	B**	B**				
26	S	38	B*	B						
28	S	59	B*	B	B**	B**				
31	S	142			B	B				
33	S	146			B	B				
34	S	136			B	B				
36	TS	127							G***	G***
37	S	148			B	B				
40	S	18					D	D		
41	S	16					D	D		
42	S	17					D	D		
43	S	16					D	D	D***	
44	TS	13							D***	D***
45	TS	17							D***	
46	S	18					D	D	D***	
47	TS	19							D***	
48	S	16					D	D	D***	
49	S	12					D	D	D***	
50	S	16					D	D	D***	
51	TS	16							D***	

Table 3.5-1. (Cont.).

Station	Substratum Type+	Water Depth (m)	Sampling Date Year 1 Oct 1980	Year 1 April 1981	Year 2 July 1981	Year 2 Jan 1982	Year 3 Dec 1982	Year 3 June 1983	Year 4 Dec 1983	Year 5 Dec 1984
52	TS	14					D	D	D***	D***
53	S	10					D	D		
54	S	17					D	D		
55	TS	27								D***

*Trace metals also analyzed.
+Substratum types correspond to those shown in Figure 3.5-5:
S = soft bottom,
TS = thin sand over hard substratum (usually interspersed with soft bottom within a station), and
N = algal nodules over sand.
**Grain size analysis only (no carbonate).
++Collection Methods:
B = remotely-operated box core,
D = diver-operated core, and
G = grab.
***Total organic carbon also analyzed.

pipette methods, but analysis of other sediment parameters (carbonate content, total organic carbon, and selected trace metals) varied from year to year (Table 3.5-1).

Supplemental information is available from earlier sampling summarized by Gould and Stewart (1955) and from the MAFLA study conducted by the Bureau of Land Management (Doyle and Sparks, 1980; Doyle and Feldhausen, 1981). Ten MAFLA stations along two east-west transects were occupied in the study area, the southernmost stations being located off Cape Romano.

Grain Size Composition and Sediment Texture

An overview of the distribution of sediment textures within the study area is provided in Figure 3.5-7. Sediments at all but three stations (25, 26, and 54) were predominantly sand (>75% by weight). These three stations are located in the southern part of the study area in the vicinity of the Tortugas pink shrimp grounds. Sediments at Stations 25 and 26 contained about 60% silt and 20 to 30% sand and can be classified as sandy silt. Sediments at Station 54 were intermediate in texture (silty sand--60 to 70% sand and 25 to 35% silt). The silty area is bordered on all sides by sandy sediments.

Mean grain size ranged from 59 um (coarse silt) to 660 um (coarse sand) (Table 3.5-2). The lowest values correspond to the silty sediments of Stations 25 and 26. In general, high mean grain sizes were noted at several nearshore stations south of Fort Myers (Stations 20, 41, 43, 45, 46, 52, and 53), on the middle shelf in the northern part of the study area (Stations 4 and 5), and on the outer shelf toward the southwest (Stations 36 and 37). Sediments at these stations contained <10% silt- and clay-size particles.

In general, nearshore sediments were moderately sorted (phi sorting values of 0.71 to 1.00) to moderately well sorted (0.50 to 0.71) (Table 3.5-2). However, nearshore sediments in the southeastern corner (offshore Florida Bay) were poorly to very poorly sorted (two phi sorting

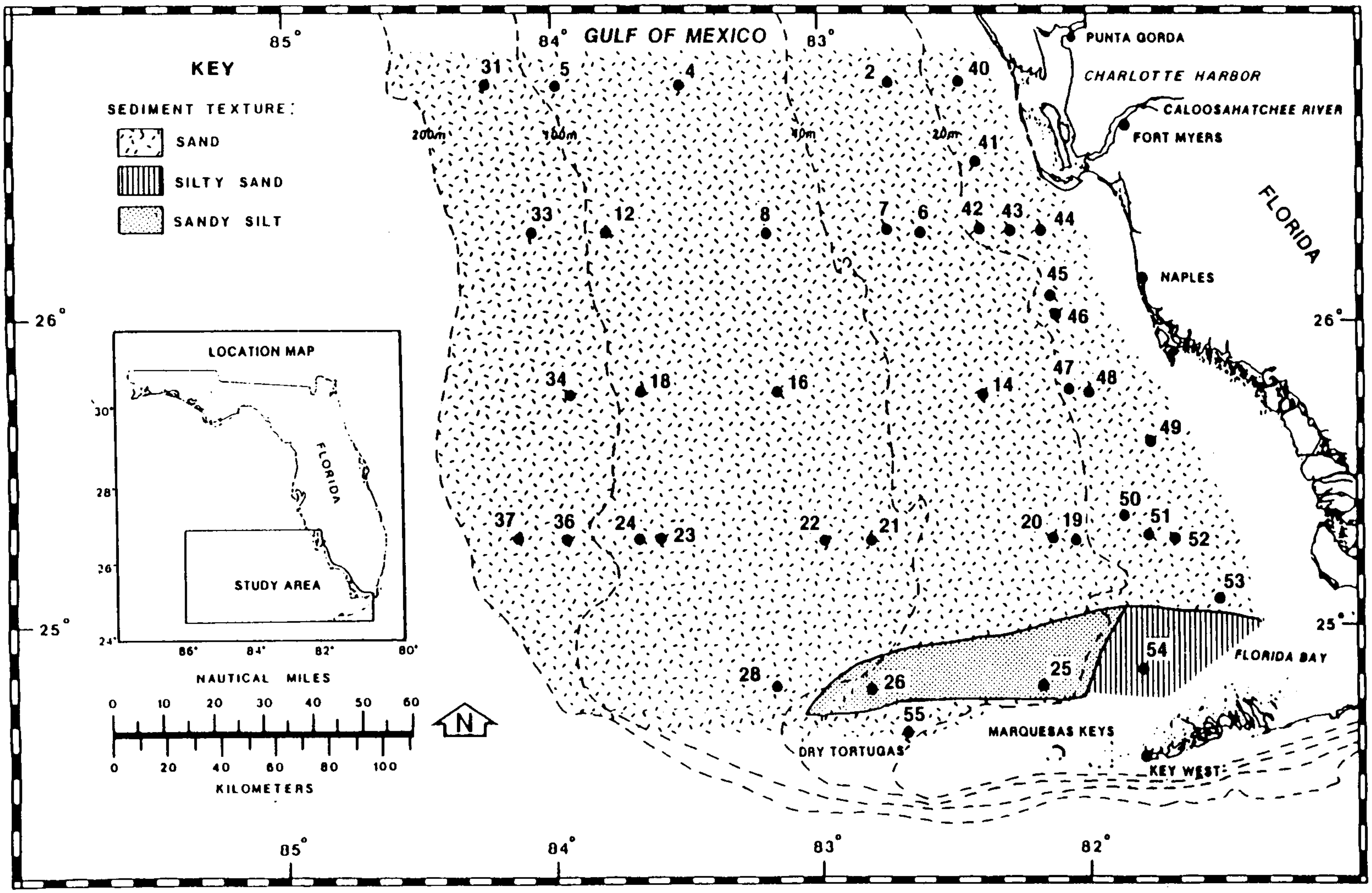


Figure 3.5-7 **Sediment texture map.**

Table 3.5-2. Summary of sediment composition data from Years 1 through 5 sampling stations.*

Station	Water Depth (m)	Mean Grain Size (um)		Sorting (ϕ)	Skewness (ϕ)	Kurtosis (ϕ)	Percent Carbonate		Organic Carbon (%)
		Mean	Range				Mean	Range	
2	25	294	155-432	0.93	0.06	1.24	56	41-72	---
4	55	496	361-611	1.50	0.20	1.27	98	97-99	---
5	90	535	511-551	1.38	0.19	1.07	96	94-97	---
6	26	117	104-133	1.04	-0.44	1.22	84	83-86	---
7	30	406	---	0.90	-0.30	1.20	53	---	1.6
8	48	161	147-176	1.31	0.10	1.06	94	93-96	---
12	90	192	170-218	1.58	0.03	1.24	96	96-97	---
14	26	137	129-143	1.05	0.12	1.24	95	94-96	---
16	54	278	183-420	1.49	-0.10	1.26	95	94-96	---
18	86	337	316-358	1.30	0.02	1.07	99	98-99	---
19	22	435	---	---**	---**	---**	93	---	2.1
20	23	526	480-611	0.88	-0.05	1.02	98	98-99	---
21	44	308	287-330	1.00**	-0.10**	1.20**	92	91-92	2.6
22	52	224	182-279	1.72	-0.32	1.04	95	94-96	---
23	70	396	218-574	1.30	0.10	1.20	96	95-96	---
24	88	294	257-321	1.29	-0.44	1.19	97	96-98	---
25	24	59	56-61	0.88	-0.48	1.46	91	90-91	---
26	38	61	60-61	1.12	-0.54	2.09	92	91-93	---
28	59	220	206-235	1.30	-0.01	1.40	96	94-98	---
31	142	182	167-196	1.70	-0.16	1.09	88	80-97	---
33	146	189	155-224	1.53	-0.95	1.01	89	82-96	---
34	136	299	297-301	1.44	0.03	1.12	96	96-96	---
36	127	555	536-574	1.30**	0.20**	0.80**	95	94-95	---
37	148	401	374-429	1.56	0.14	0.90	95	95-95	---
40	18	134	125-142	0.98	0.32	2.03	23	21-24	---
41	16	512	476-547	0.94	-0.24	0.88	42	36-49	---
42	17	324	285-364	0.57	-0.26	1.48	34	29-38	---
43	16	340	338-343	0.55	-0.19	1.41	88	88-88	3.0
44	13	617	574-660	1.40**	0.00**	1.20**	88	87-88	1.5

Table 3.5-2. (Cont.).

Station	Water Depth (m)	Mean Grain Size (um)		Sorting (φ)	Skewness (φ)	Kurtosis (φ)	Percent Carbonate		Organic Carbon (%)
		Mean	Range				Mean	Range	
45	17	660	---	---**	---**	---**	91	---	2.0
46	18	285	227-343	0.73	-0.08	1.12	96	95-97	2.9
47	19	268	---	---**	---**	---**	90	---	2.9
48	16	197	175-219	0.64	-0.09	1.18	90	88-91	2.9
49	12	230	190-271	0.88	-0.46	1.76	21	18-25	0.9
50	16	214	212-215	0.88	-0.32	1.30	86	82-90	2.3
51	16	190	---	---**	---**	---**	92	---	2.2
52	14	504	313-733	1.50	0.10	1.10	96	93-98	2.2
53	10	351	319-383	1.86	-0.20	1.48	99	98-99	---
54	17	176	137-214	2.91	0.00	1.00	98	97-99	---
55	27	435	---	1.40	0.10	1.00	97	---	3.0

*Values from individual replicates were averaged for each sampling date. The averages were used to calculate grand means for each parameter and ranges for mean grain size and carbonate.

**Year 4 sorting, skewness, and kurtosis values were calculated using Inman (1952) rather than Folk (1974) as for remaining values. For stations sampled only during Year 4, no values are presented; for those sampled during Years 4 and 5, the Year 5 values are presented.

values greater than 2.00), containing a mixture of shell hash, sand, silt, and clay. For example, individual replicates at Station 52 contained up to 40% shell hash (particles >2 mm in diameter); at Station 54, the percentage of particles greater than 2 mm in diameter averaged 10%, and the silt fraction averaged 30%. Sediments at stations deeper than about 25 m were, in general, poorly sorted (Table 3.5-2).

Examination of the grain size data and percentages of sediment in the various size fractions suggest that there is no progressive change in grain size with increasing water depth. The lack of such a pattern reflects the varied sources and composition of shelf sediments (Gould and Stewart, 1955). Nearshore sediments are predominantly detrital quartz from beaches and older coastal plain sediments, along with local accumulations of molluscan shell fragments. Seaward from this zone is a carbonate sand facies in which shell fragments, coralline algae, foraminifera, and oolites may be abundant in certain mappable zones (Doyle and Sparks, 1980). Silt-sized sediments north of the Dry Tortugas are essentially carbonate muds probably consisting of comminuted algal and mollusc remains.

Outer shelf sediments in the southern portion of the study area apparently are coarser than those seen farther north. Danek and Lewbel (1986) suggested that the predominance of coarse sand and shell rubble at Station 36 (127 m) may reflect winnowing by breaking internal waves near the shelf break, which steepens toward the south within the study area. Alternatively, the data could reflect scour by the Loop Current or a relief texture from a lower sea level.

Carbonate and Total Organic Carbon Content

Figure 3.5-8 shows contours drawn from sediment carbonate data; categories were chosen to correspond with those of Doyle and Sparks (1980). A zone of predominantly quartz sediments (<25% carbonate) roughly parallels the coast, extending about 30 to 50 km from shore. The quartz sediments are derived from adjacent beaches and rivers, as well as

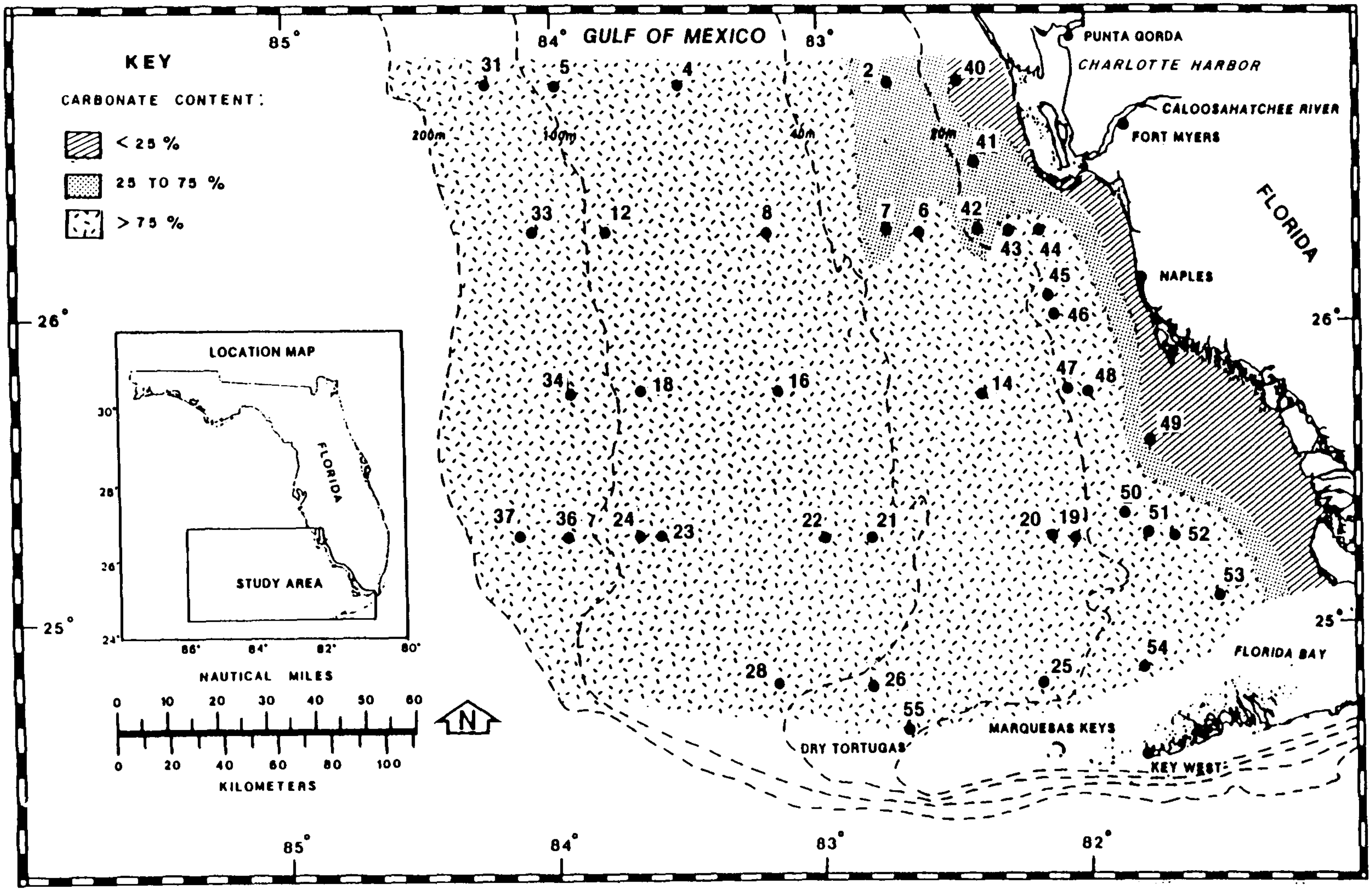


Figure 3.5-8 Generalized carbonate contours.

from reworking of former coastal plain sediments that have become submerged as a result of sea level rise (Gould and Stewart, 1955). Doyle and Sparks (1980) showed the quartz zone widening south of Charlotte Harbor, but the present data from additional stations indicate that this widening does not continue southward. Transitional sediments (25 to 75% carbonate) occur in a zone that is narrow along most of the coastline, with the exception of the Charlotte Harbor area. The actual spatial distribution of sediments of low-to-intermediate carbonate content probably is more complex than indicated by the contours, particularly nearshore. Gould and Stewart (1955) attributed the greater seaward extent of low-carbonate sediments off Tampa Bay and Charlotte Harbor to the action of strong tidal currents that transport coastal sediments offshore. Seaward of this transitional zone, carbonate sediments predominate.

Organic carbon values in shelf sediments are spatially uniform, ranging from about 1 to 3% (Table 3.5-2).

Trace Metals

Samples for analysis of nine trace metals were collected at 15 stations during Year 1 (Table 3.5-1). Sediment samples from all stations were analyzed for trace metals after partial digestion with 1 N nitric acid. In addition, samples from eight stations (Stations 4, 5, 8, 14, 16, 20, 22, and 28) were analyzed after total digestion with concentrated hydrofluoric, nitric, and perchloric acids. Chromium, iron, and zinc were analyzed by flame atomic absorption spectrophotometry (AAS); cadmium, copper, nickel, and lead by flameless AAS; and barium and vanadium by instrumental neutron activation analysis.

A summary of the results obtained following total dissolution is given in Table 3.5-3. These data, as well as previous findings from central and southwest Florida shelf sediments (Alexander *et al.*, 1977; Presley *et al.*, 1975; Trefry *et al.*, 1978) show the area to have very low and spatially uniform trace metal levels. The observed low concentrations

Table 3.5-3. Mean trace metal concentrations in southwest Florida shelf surficial sediments, other west Florida shelf sediments, carbonate rocks, and Mississippi River particulates.

Location	Metal								
	Ba	Cd	Cr	Cu	Fe	Ni	Pb	V	Zn
SW Florida shelf (this study)	12	0.08	8	1	1,450	3	3	7	6
MAFLA carbonates (Trefry _et_ _al_., 1978)	20	0.15	13	1	1,900	3	2	5	6
Carbonate rocks (Graf, 1960; Turekian and Wedepohl, 1961)	10	0.2	9	10	3,800	12	8	20	26
Mississippi River particulates (Trefry and Presley, 1976)	740	1.4	80	42	47,000	56	45	150	180

All metal concentrations are in ppm (dry weight). Some values have been rounded for ease of comparison.

are directly attributable to sediment mineralogy, as low metal-bearing calcium carbonate and quartz sands predominate in the area. Total dissolution trace metal concentrations are somewhat lower than average carbonate rock values reported by Graf (1960) and Turekian and Wedepohl (1961) (Table 3.5-3). In addition, the total dissolution values are about 20-fold lower than concentrations in continental weathering products (Mississippi River suspended matter) reported by Trefry and Presley (1976).

Not included in Table 3.5-3 are trace metal concentrations determined from samples that were subjected to partial digestion. When partial digestion values were compared with total dissolution values, cadmium and chromium showed nearly complete removal by partial digestion; iron, nickel, and lead had a high percent removed; copper and barium were about one-half removed; and zinc and vanadium showed very low removal (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a).

The uniformly low trace metal concentration over the area should make it easy to detect effects of pollutant discharges if drilling should occur in the area. However, the low values also make it difficult to recognize correlations among the trace metals or between trace metals and various environmental parameters. Some statistically significant correlations were noted in the Year 1 report (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983a). Iron, chromium, and vanadium were found to be negatively correlated with water depth (decrease in metal concentration with increasing depth). A positive correlation was found between water depth and zinc. Copper and zinc were the only trace metals whose concentrations were significantly correlated with sediment grain size. Both copper and zinc tended to be present in higher concentrations in sediments of finer grain size.

3.5.3 SEDIMENT DYNAMICS

Overview of Sampling Conducted

The first 3 years of Southwest Florida Shelf studies included only discrete sampling of sediments for analysis of the parameters discussed above. The final 2 years focused on sediment dynamics. The potential for sediment transport and deposition was evaluated through a combination of sediment traps, current meters, wave gauges, and time-lapse cameras installed on fixed arrays deployed at several stations (Stations 7, 21, 23, 29, 36, 44, 52, and 55).

During Year 4, arrays were deployed at five hard-bottom stations (Table 3.5-4). Each array contained a recording current meter (ENDECO® Model 174MR) and 15 sediment traps (five 4-cm diameter, 40-cm-long tubes at each of three heights above the seafloor: 0.5, 1.0, and 1.5 m). The arrays at Stations 21 and 52 also contained a Sea Data Model 635-11 wave and tide gauge and a time-lapse camera. Arrays were deployed in December 1983 and serviced quarterly.

During Year 5, the same arrays were deployed at eight hard-bottom stations: the five sampled in Year 4 plus Stations 7, 44, and 55 (see Table 3.5-4). All arrays contained the current meter, sediment traps, and (except for Station 36) a time-lapse camera. Wave/tide gauges were included at Stations 52 and 55. The arrays were deployed in December 1984 and serviced quarterly.

The following section discusses the results of the *in situ* sampling pertaining to sediment dynamics. Data from the current meters and wave gauges have been reviewed in Section 3.3. The time-lapse camera records were used primarily for biological purposes (e.g., fish counts) rather than sedimentological study, although episodes of severe turbidity were noted. The sediment trap data are summarized briefly under the subsection Suspended Load.

Table 3.5-4. Equipment included on *in situ* arrays to study sediment dynamics.

Station	Water Depth (m)	Year 4 Current Meter	Year 4 Wave Gauge	Year 4 Sediment Traps	Year 4 Time-Lapse Camera	Year 5 Current Meter	Year 5 Wave Gauge	Year 5 Sediment Traps	Year 5 Time-Lapse Camera
7	32					X		X	X
21	47	X		X	X	X		X	X
23	74	X		X		X		X	X
29	64	X		X		X		X	X
36	125	X		X		X		X	
44	13					X		X	X
52	13	X		X	X	X	X	X	X
55	27					X	X	X	X

Discussion of Sediment Transport and Deposition

Sediment may be transported along the seafloor as bed load, suspended load, or a combination of the two. Sediment transport depends upon numerous factors including the particle size and density of sediments, the density and viscosity of water, the unidirectional or oscillatory nature of water motion, and seafloor roughness. Figure 3.5-9 illustrates basic modes of transport and indicates types of grain motion seen in bed load and suspended load transport; in nature, processes are considerably more complex than depicted in the figure.

Sediment movement may be induced by unidirectional currents, wave action, or some combination of the two. The influence of surface waves declines with increasing water depth; Komar (1976) reports that the influence of surface waves is important to depths of 125 m or more on the continental shelf. However, the influence of unidirectional currents has been more intensely studied and is better understood.

Bed Load

Bed load transport due to unidirectional currents can be predicted on theoretical grounds given certain information concerning near-bottom current velocities and sediment characteristics. Empirical methods, in which the seafloor is viewed by time-lapse camera while current velocities are being recorded, also are useful. Both approaches were utilized during Years 4 and 5 to evaluate the potential for bed load transport (Danek and Lewbel, 1986).

The potential for current-induced bed load transport was evaluated in part by calculating the percentage of time of current speeds (measured at 3 m above bottom) exceeding 20 cm/s. This value was chosen on the basis of concurrent time-lapse camera observations and current measurements reported by Wimbush and Lesht (1979) as being the minimum needed to initiate sediment motion. Currents in excess of 20 cm/s occurred at all stations, but with a frequency less than 18% at most stations during most seasons.

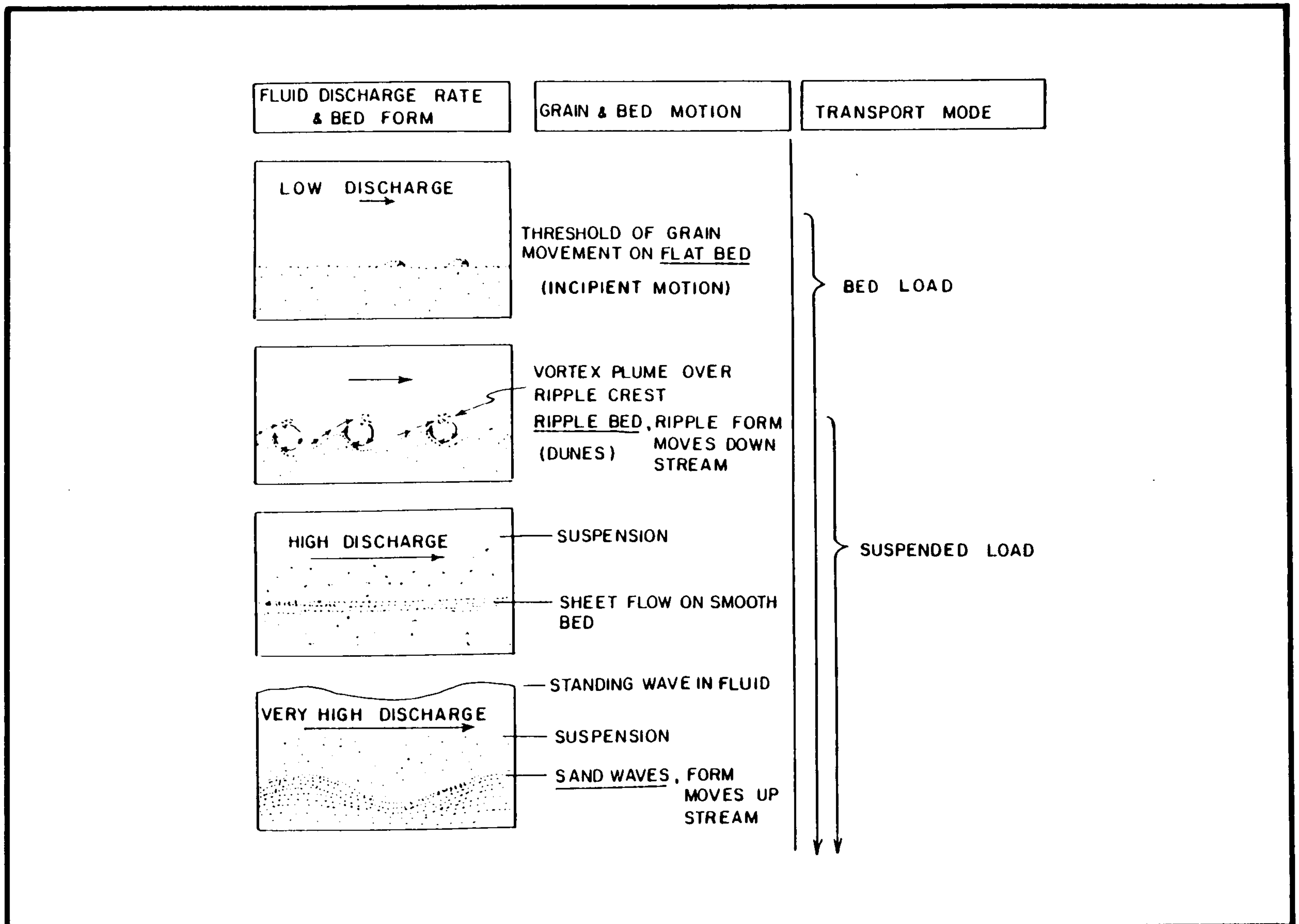


Figure 3.5-9 **Schematic representation of the various modes of transport and types of grain motion (Shepard, 1973).**

Bed load transport calculations were made on the basis of the Year 4 and 5 current meter data, following the methods of Sternberg (1972). Most of the resulting values were less than 1 kg/km/day, and all values were less than 10 kg/km/day (Danek and Lewbel, 1986). Thus, bed load transport due to unidirectional currents alone is essentially negligible on the southwest Florida shelf. Wave energy undoubtedly augments the amount transported due to currents, but the influence of waves could not be quantified.

Suspended Load

Transport of sediments as suspended load cannot be estimated similarly on theoretical grounds. For this reason, the evaluation of resuspension focused on sediment trap data and the relationship between sedimentation and currents and waves (Danek and Lewbel, 1986).

Sedimentation rates in traps located 1 m above the bottom ranged from 1 to 848 metric tons/km^2/day. The highest sedimentation rates were observed at the shallowest locations (Stations 44 and 52, both at 13-m depth), and the lowest rates were noted at the deepest stations (Station 23--74 m; Station 29--64 m; and Station 36--125 m). Seasonal average sedimentation rates correlated positively with both the percentage of current speeds greater than 20 cm/s ($r = 0.53$) and the percentage of wave orbital velocities greater than 20 cm/s ($r = 0.67$). High sedimentation rates in winter, summer, and fall occurred during periods of high winds caused by the passage of cold air outbreaks (northers) and tropical cyclones. Calm winds during spring produced the lowest seasonal sedimentation rates. In addition, both time-lapse observations and evidence of layering in sediment traps suggest that resuspension is episodic, and the correlations would probably be much better if current speeds, wave surge, and deposition could be measured concurrently over short time periods.

In general, trapped sediments were much finer than the ambient surficial sediments. Silt and clay constituted 86% of the trapped material and only about 3% of the ambient sediments. Also, in general, the quantities deposited and the mean diameter of trapped sediments decreased with increasing height of the traps above bottom. Apparently, most of the sediments that are resuspended, especially the sand particles, are lifted less than 1 m above bottom.

Although resuspension depends on both waves and currents, waves probably are the more important influence in the study area, especially in shallow water (Danek and Lewbel, 1986). The decline in sedimentation rates with water depth presumably reflects the declining influence of surface waves. Nearshore (e.g., Station 52), wave energy can easily and frequently penetrate to the bottom. Over most of the shelf, wave energy probably reaches the bottom only during major storms, such as hurricanes. Energy from surface waves probably never reaches the bottom on the outer shelf (e.g., Station 36), but breaking internal waves near the shelf break could exert some influence (Danek and Lewbel, 1986).

3.6 INFAUNA

There are two main sources of information concerning southwest Florida shelf infauna: the MMS Southwest Florida Shelf Ecosystems study and the earlier BLM MAFLA environmental baseline study. A considerable body of data is available concerning estuarine areas (see bibliography by Mahadevan et al., 1984), but relatively little was known of the shelf infauna prior to the MAFLA and southwest Florida shelf studies.

The MAFLA program was conducted from 1975 through 1978 and encompassed a large area of the continental shelf between Fort Myers, Florida, and the Gulf coast of Mississippi. Ten stations were located within the study area. At most stations, nine 0.065-m^2 box core samples were collected on each of seven sampling periods. MAFLA infaunal results were summarized by Blake (1979) (molluscs), Heard (1979) (crustaceans), and Vittor (1979) (polychaetes) in chapters within the final MAFLA report (Dames and Moore, 1979). Additional information was provided by Bishof (1980), who wrote a master's thesis based upon MAFLA infaunal molluscs in the study area. More recently, Barry A. Vittor & Associates, Inc. reanalyzed the polychaete samples and prepared reports for MMS (Barry A. Vittor, personal communication). The MAFLA data are of limited usefulness for this characterization because there is no overall synthesis of the data and because only summary statistics and analyses are presented in the MAFLA report chapters (i.e., it is difficult to extract information other than summary statistics for the stations in the study area).

Infaunal stations occupied during the Southwest Florida Shelf Ecosystems Program are also shown in Figure 3.6-1, and water depths and sampling schedules are provided in Table 3.6-1. During 1980 and 1981, 15 stations in water depths of 20 to 90 m were sampled during two cruises (fall and spring). During 1981 and 1982, 4 of these 15 stations were replaced by new stations in water depths of 136 to 148 m. The new stations and the remaining Year 1 stations were sampled twice (summer and winter). During Year 3 (1982 and 1983), 10 stations in water depths of 10 to 18 m were

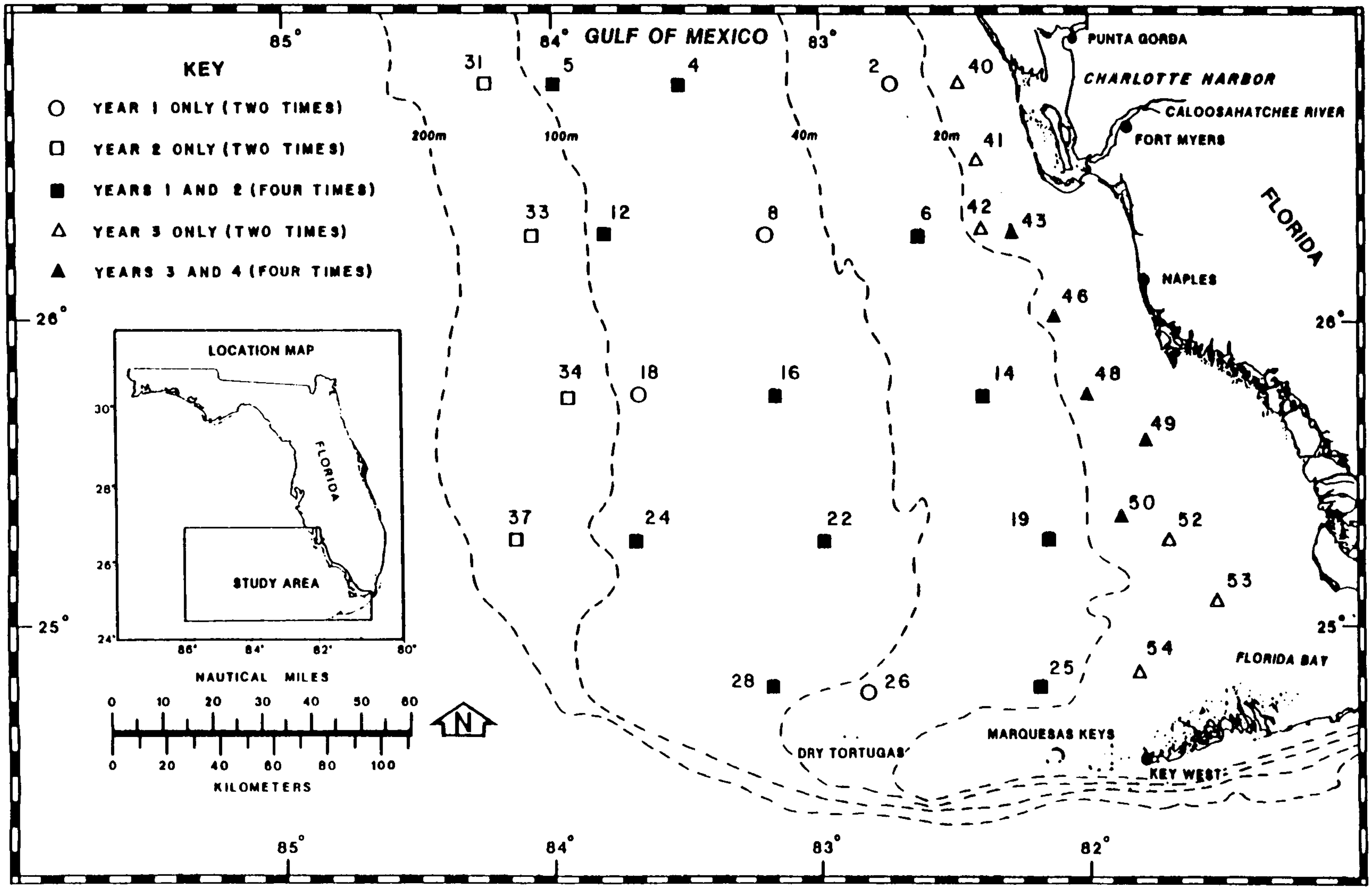


Figure 3.6-1 Locations of infaunal stations sampled during the Southwest Florida Shelf Ecosystems Program.

Table 3.6-1. Water depths and sampling dates for infaunal stations sampled during the Southwest Florida Shelf Ecosystems Program.

			Sampling Date							
		Water	Year 1*		Year 2*		Year 3*		Year 4*	
		Depth	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise
Station	Transect	(m)	III	IV	II	III	II	III	I	III
2	A	25	X	X	-	-	-	-	-	-
4	A	55	X	X	X	X	-	-	-	-
5	A	90	X	X	X	X	-	-	-	-
6	B	26	X	X	X	X	-	-	-	-
8	B	48	X	X	-	-	-	-	-	-
12	B	90	X	X	X	X	-	-	-	-
14	C	26	X	X	X	x	-	-	-	-
16	C	54	X	X	X	X	-	-	-	-
18	C	86	X	X	-	-	-	-	-	-
20	D	23	X	X	X	X	-	-	-	-
22	D	52	X	X	X	X	-	-	-	-
24	D	88	X	X	X	X	-	-	-	-
25	E	24	X	X	X	X	-	-	-	-
26	E	38	X	X	-	-	-	-	-	-
28	E	59	X	X	X	X	-	-	-	-
31	A	142	-	-	X	X	-	-	-	-
33	B	146	-	-	X	X	-	-	-	-
34	C	136	-	-	X	X	-	-	-	-
37	D	148	-	-	X	X	-	-	-	-
40	A	18	-	-	-	-	X	X	-	-
41	none	16	-	-	-	-	X	X	-	-
42	B	17	-	-	-	-	X	X	-	-
43	B	16	-	-	-	-	X	X	X	X
46	G	18	-	-	-	-	X	X	X	X
48	C	16	-	-	-	-	X	X	X	X
49	none	12	-	-	-	-	X	X	X	X
50	none	16	-	-	-	-	X	X	X	X
52	D	14	-	-	-	-	X	X	-	-
53	none	10	-	-	-	-	X	X	-	-
54	E	17	-	-	-	-	X	X	-	-

*Sampling dates for benthic stations: Year 1, Cruise III = October-November 1980; Year 1, Cruise IV = April-May 1981; Year 2, Cruise II = July-August 1981; Year 2, Cruise III = January-February 1982; Year 3, Cruise II = December 1982; Year 3, Cruise III = May-June 1983; Year 4, Cruise I = December 1983; Year 4, Cruise III = May 1984. During Years 1 and 2 sampling, five 0.057-m^2 box core samples were collected at each station. During Years 3 and 4 sampling, ten 0.016-m^2 diver-operated core samples were collected at each station (8 were processed during Year 3 and all 10 were processed during Year 4).

sampled during fall and spring. Five of these stations were again sampled during fall and spring of Year 4 (1983 and 1984). At each Year 1 and Year 2 station, five samples were collected on each cruise with a 0.057-m^2 box core sampler. At the Year 3 and Year 4 stations, 10 samples were collected on each cruise by divers with 0.016-m^2 core samplers. All samples were sieved through a 0.5-mm mesh.

Data from the Southwest Florida Shelf Ecosystems Program are the primary basis for the discussion presented in the following subsections. Because the Years 1 through 3 data set and the Year 4 data set were collected, analyzed, and encoded by two different contractors, the data sets were not merged for new computer analyses. However, summary statistics from both sources were combined, where possible, for purposes of presentation. Pertinent MAFLA data are cited as supplemental information.

3.6.1 ABUNDANCE

During Years 1 through 4 of the Southwest Florida Shelf Ecosystems Program, the abundance of macroinfauna ranged from 1,280 to 14,202 individuals per square meter (range of station means from individual sampling dates). Densities averaged over seasons generally decreased with increasing water depth (see Figure 3.6-2). The apparent peak in density in the 20- to 30-m depth range on Transects B and C is due in part to very large populations of two species at Stations 6 and 14--notably, the spionid polychaete Prionospio cristata (summer cruise at both stations) and the syllid Haplosyllis spongicola (winter cruise at Station 14).

The most abundant group of macroinfaunal individuals collected during the study was polychaetes (64%). Crustaceans were the next most abundant group (17%), followed by molluscs (10%). The average abundance of all three major groups declined with increasing water depth, but polychaetes accounted for an increasing percentage of the total as water depth increased (see Figure 3.6-3). Depth-related decreases in abundance of

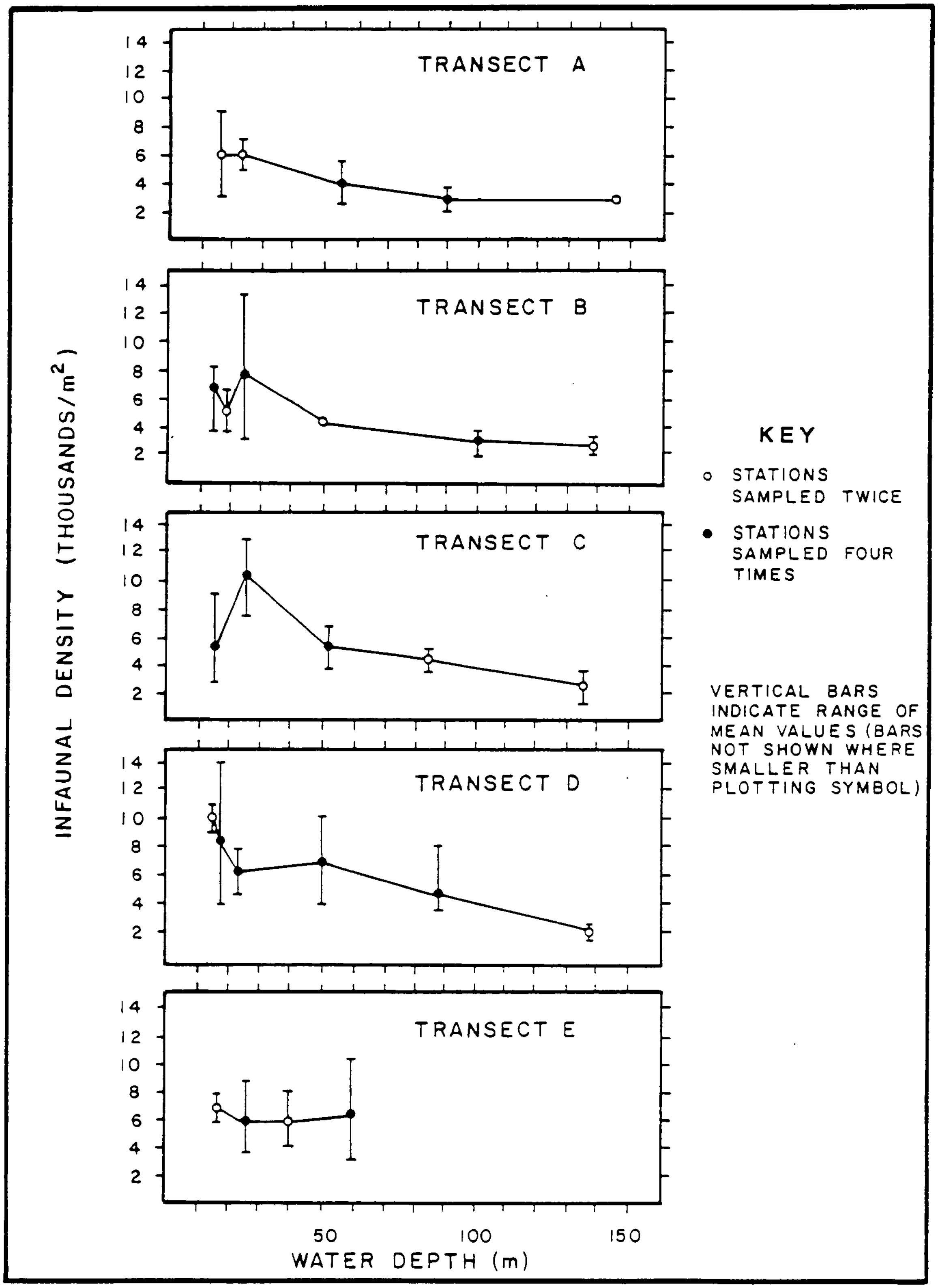


Figure 3.6-2 Relationship between infaunal density and water depth along five east-west transects.

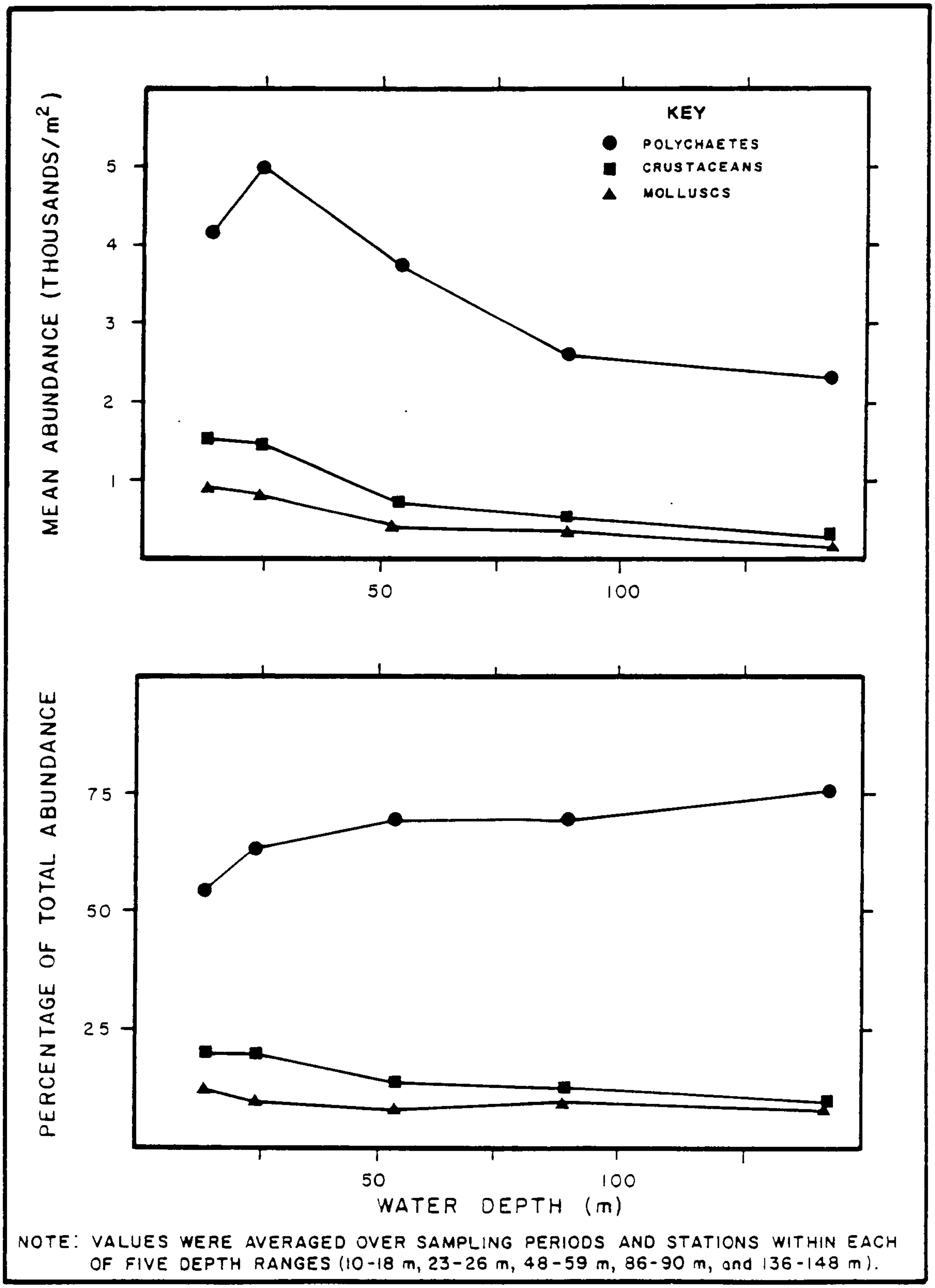


Figure 3.6-3 Depth-related variations in abundance and relative abundance of infaunal polychaetes, crustaceans, and molluscs.

crustaceans, molluscs, and polychaetes were also noted during the MAFLA study (Heard, 1979; Blake, 1979; Vittor, 1979; Bishof, 1980).

Pronounced temporal variability in abundance was evident at the southwest Florida shelf stations (see Figure 3.6-4). None of the stations was sampled during all four seasons of 1 year; however, the cruises have been re-ordered in the figure to help make any seasonal patterns evident. Several of the stations sampled during four seasons exhibited higher densities during summer than during any other season, and summer cruise densities were higher than winter cruise densities at all four of the outer shelf stations sampled only during those two seasons. Of the five nearshore stations sampled during fall and spring (December and May) of 2 successive years, only one (Station 43) exhibited repeatable abundance patterns. This suggests that it would be necessary to sample seasonally over a period of several years to separate seasonal from interannual and other long-term density variations.

The abundance of certain species varied temporally in a consistent pattern across stations. For example, Prionospio cristata, which occurred primarily at stations in the 20- to 60-m depth range, was typically most abundant during summer, reaching densities of 4,700 per square meter (Station 6). Similarly, the serpulid polychaete (Filograna implexa) was collected only during the summer cruise and was abundant (393 to 2,719 per square meter) at middle to outer shelf stations in the southern part of the study area (Stations 22, 24, 25, 28, and 37). Another polychaete, orbiniid Haploscoloplos sp., occurred at most stations but almost exclusively during the winter cruise, when abundances were as high as 1,702 per square meter (Station 37).

Seasonal and interannual variability in abundance is also evident in the MAFLA infaunal data from the study area (Blake, 1979; Heard, 1979; Vittor, 1979). Blake (1979) determined that densities of infaunal molluscs were highly variable seasonally at the shallowest MAFLA station

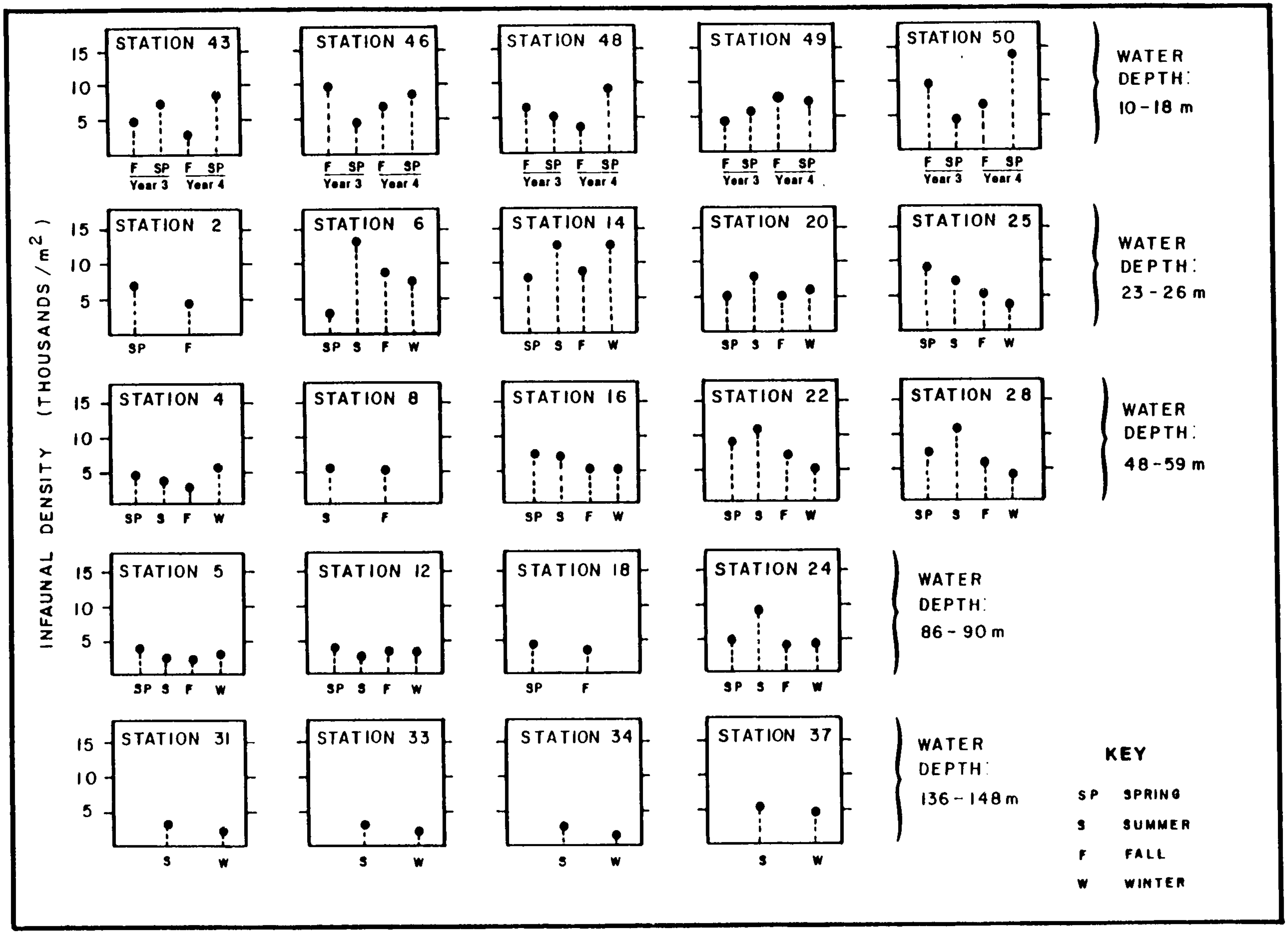


Figure 3.6-4 Temporal variations in infaunal abundance at stations in various depth ranges.

in the study area (11-m depth near Sanibel Island, Florida). The timing of peak abundances of bivalves (e,g., Parvilucina multilineata and Tellina versicolor) suggested that recruitment occurs during spring or early summer (Blake, 1979). This seasonal variation at nearshore (<20 m) stations was also evident during the southwest Florida shelf study during Year 3, when abundances of several bivalve species (e.g., Crenella divaricata, Diplodonta punctata, Lucina nassula, and Tellina versicolor) were much greater during spring (May) than during fall (December) (Continental Shelf Associates, Inc., 1987). However, the pattern was not repeated the following year (Environmental Science and Engineering, Inc., and LGL Ecological Research Associates, Inc., 1985).

Data from the Southwest Florida Shelf Ecosystems Program do not reveal any relationships between total infaunal density and sediment parameters such as mean grain size, silt/clay percentage, carbonate content, or organic carbon content (the latter was measured only in sediments from five Year 4 stations). In contrast, Vittor (1979) indicated that polychaete density was generally lowest at the MAFLA stations characterized by the finest sediments. However, the MAFLA stations having the lowest polychaete densities and the finest sediments were in the northern Gulf of Mexico off Alabama and Mississippi; therefore, the same trend is not expected off southwest Florida.

One reason that there is no overall correlation between abundance and sediment composition is that various species exhibit different affinities for particular sediment types. An example of a species with strong sediment-type affinities is Prionospio cristata. Johnson (1984) noted that the species is typically associated with a substratum of fine sand to silty or clayey sand. In the southwest Florida shelf study area, the species was present at most stations (<100 m in depth) but was abundant primarily at stations in 20- to 60-m depth characterized by high percentages of very fine sand (62 to 125 um) and/or silt (4 to 62 um). The abundance of P. cristata varied seasonally (as noted previously), with the peak during summer. The abundance of *Prionospio cristata* during the summer cruise was positively correlated with the percentage of very fine sand (see Figure 3.6-5).

3.6.2 BIOMASS

Infaunal biomass was not estimated during the southwest Florida shelf study; however, polychaete biomass was estimated in the MAFLA samples from the study area. Wet weight biomass at stations in the study area ranged from 0.3 to 212.4 g/m^2, with most values <20 g/m^2 (Vittor, 1979). Polychaete biomass (averaged over three sampling periods from 1977 and 1978) generally decreased with increasing water depth (Figure 3.6-6), a trend similar to the one presented for total density.

Additional biomass data are available from a sampling site slightly north of the study area in 20- to 25-m depths off Tampa Bay (Continental Shelf Associates, Inc., 1986). Eighteen stations were sampled on two surveys in 1984 and 1985. The results are summarized as follows:

	Wet Biomass (g/m^2)	Percent of Total
Polychaetes	0.8 to 5.6	8 to 84
Molluscs	0.3 to 7.7	3 to 58
Crustaceans	0.2 to 3.7	3 to 25
Echinoderms	0.0 to 11.4	0 to 71
All groups	2.0 to 16.1	

3.6.3 SPECIES RICHNESS, DIVERSITY, AND EQUITABILITY

It is of interest to know how species richness and related parameters vary in relation to depth and other factors on the southwest Florida shelf. However, most such comparisons are tenuous at best because sampling at a given station almost never is adequate to obtain all species present (i.e., to level the species-area curve). Differences in

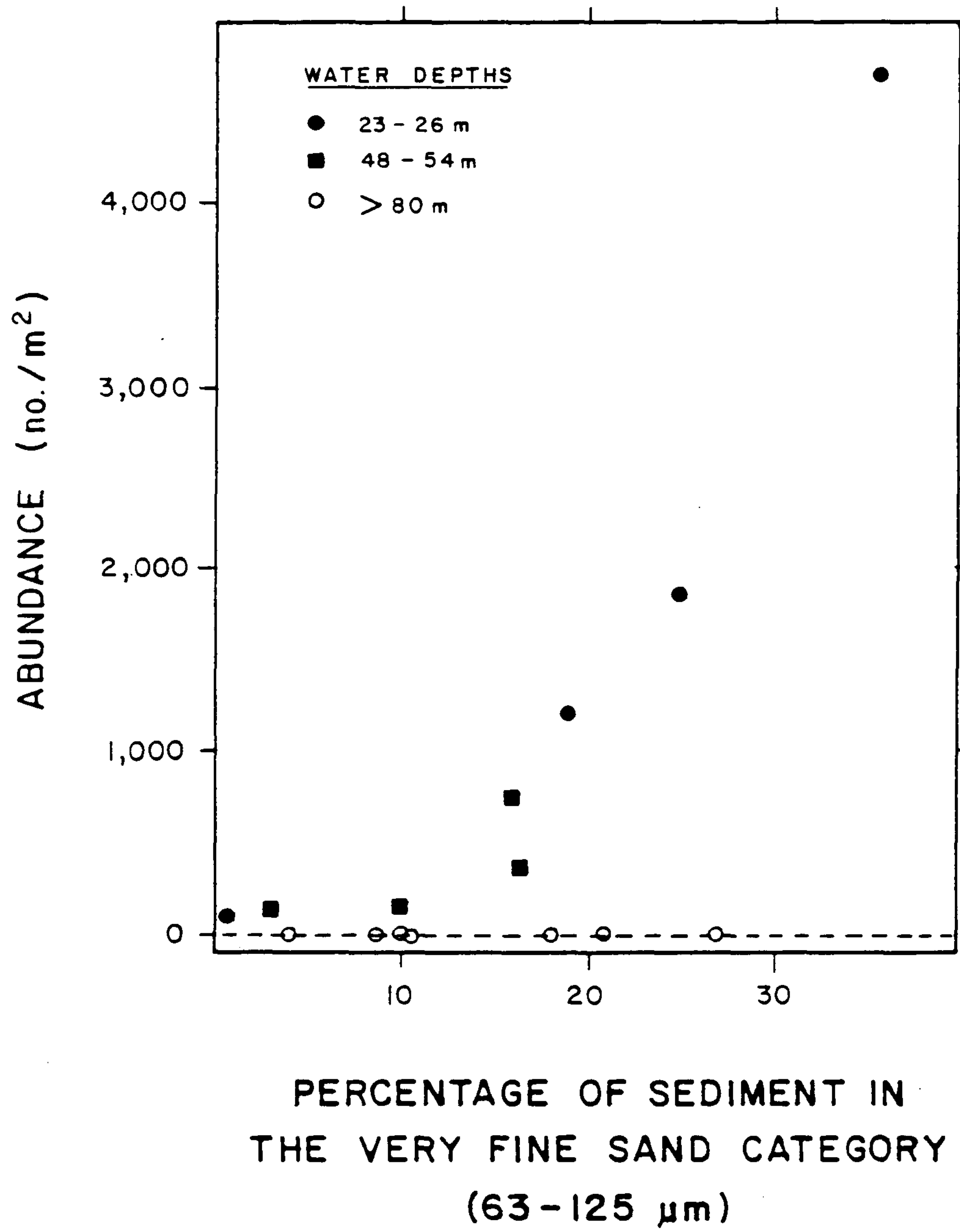


Figure 3.6-5 Relationship of *Prionospio cristata* abundance to fine sand percentage of sediments, Year 2 summer cruise.

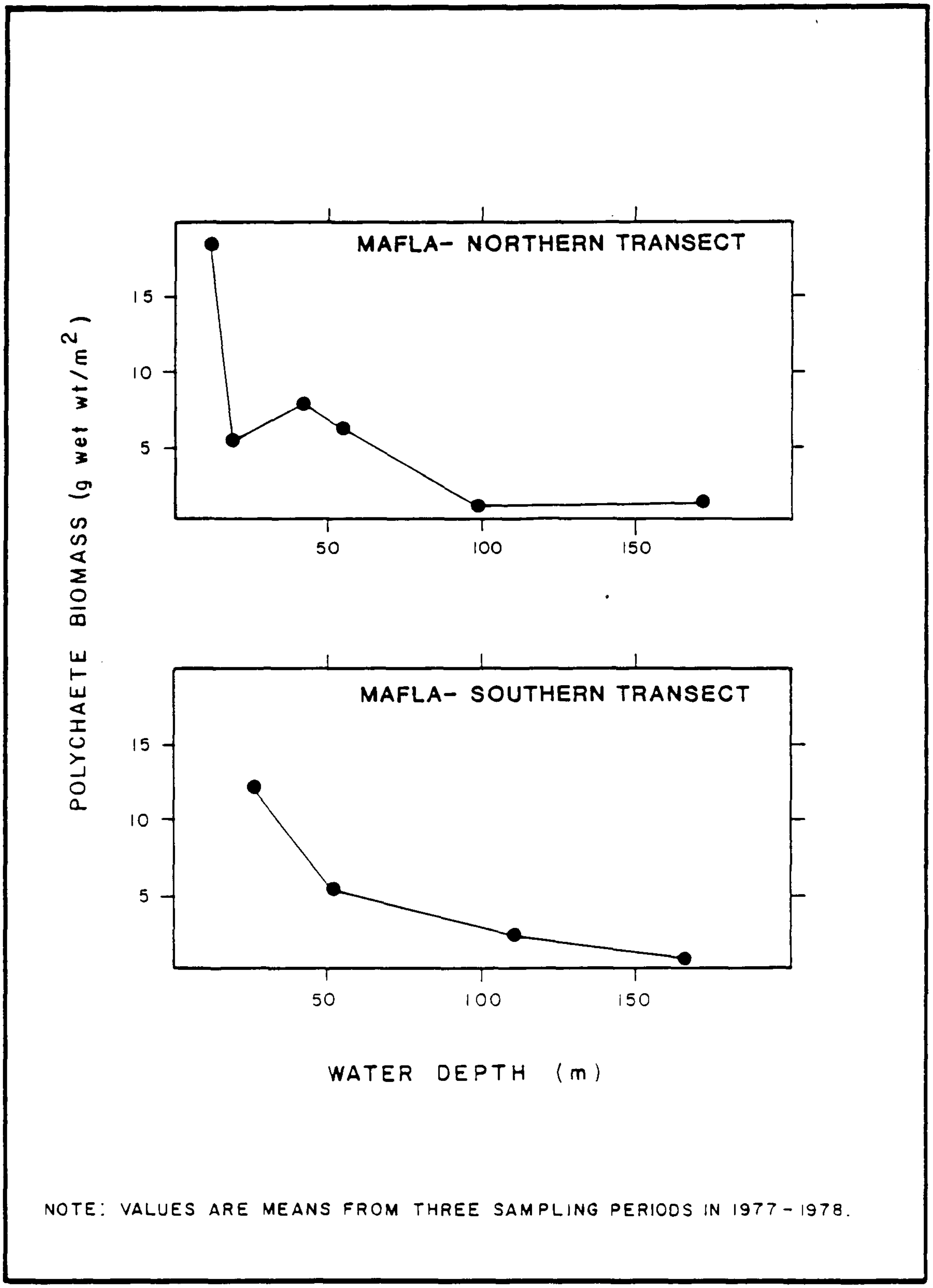


Figure 3.6-6 Relationship between infaunal polychaete biomass and water depth along two MAFLA transects in the study area.

sampling methodology used over the course of a study also make such comparisons difficult. For example, during the southwest Florida shelf study, different sizes and numbers of core samples were taken in Years 1 and 2 than in Years 3 and 4. Density and biomass estimates can be standardized to a common areal basis (1 m^2). However, estimates of species richness and diversity cannot be similarly standardized because the number of species collected at a station varies in relation to the number of individuals collected, which, in turn, depends on abundance and the total area sampled.

One solution to the problem of inadequate and variable sampling effort is to calculate expected species richness (E_s) for a fixed number of individuals (Simberloff, 1978). Bishof (1980) used the index to evaluate trends in species richness of infaunal molluscs in the study area and found that expected species richness increased with increasing mean grain size (i.e., was higher in coarser sediments). There was no correlation between E_s and water depth.

Expected species richness values are not available for the stations sampled during the southwest Florida shelf study. However, equitability (Pielou's J') was calculated for the Years 1 through 3 samples using a truncated database consisting only of individuals identified to species (Continental Shelf Associates, Inc., 1987). Both J' and E_s are measures of how evenly individuals are apportioned among species, but J' has the advantage of being bounded by 0 and 1. Equitability values ranged from 0.41 to 0.87, with most values greater than 0.70. In general, individuals were most equitably apportioned among species at the nearshore (<20-m) stations and on the middle shelf (Stations 4, 16, 20, 22, and 28). Equitability was not significantly correlated with sediment composition variables (mean grain size, sorting, carbonate content) within the southwest Florida shelf data set.

In general, the high equitability values reflect a lack of dominance in most samples; the most abundant species in a sample typically contributed <15% of the total abundance. Species that constituted more than 15% of the total at one or more stations during one or more sampling periods can be classified into two groups. First, polychaetes such as Prionospio cristata, Filograna implexa, and Haploscoloplos sp. were abundant at several stations primarily during one or two seasons (see Subsection 3.5.1). Second, there were species such as Synelmis albini, which was the most abundant species (15 to 25% of the total population) at several middle-to-outer shelf stations (Stations 4, 5, 12, 18, 24, 31, 33, and 34) during most or all sampling periods. The lowest equitability (J' = 0.41) was noted in samples at Station 40 during the Year 3 fall cruise, when Paraprionospio pinnata and Mediomastus californiensis together comprised 75% of the total population.

3.6.4 SPECIES COMPOSITION

In all, 1,121 species were identified during the southwest Florida shelf program (Years 1 through 3). Crustaceans comprised the largest single percentage of the total (452 species, 40%), followed by polychaetes (413 species, 37%) and molluscs (231 species, 21%). About 53% of the mollusc species were bivalves. Polychaetes accounted for about 45% of the total number of species in all depth ranges except on the outer shelf, where they accounted for 60% (see Table 3.6-2).

Figure 3.6-7 shows the frequency distribution of species occurrences at the southwest Florida shelf stations. Most species occurred at only one or a few stations. Only three species (Armandia maculata, Mediomastus californiensis, and Myriochele oculata) occurred at least once at all 30 stations.

Common Species

Table 3.6-3 lists the 25 most abundant species collected during the Southwest Florida Shelf Ecosystems Program (Years 1 through 3). Most of

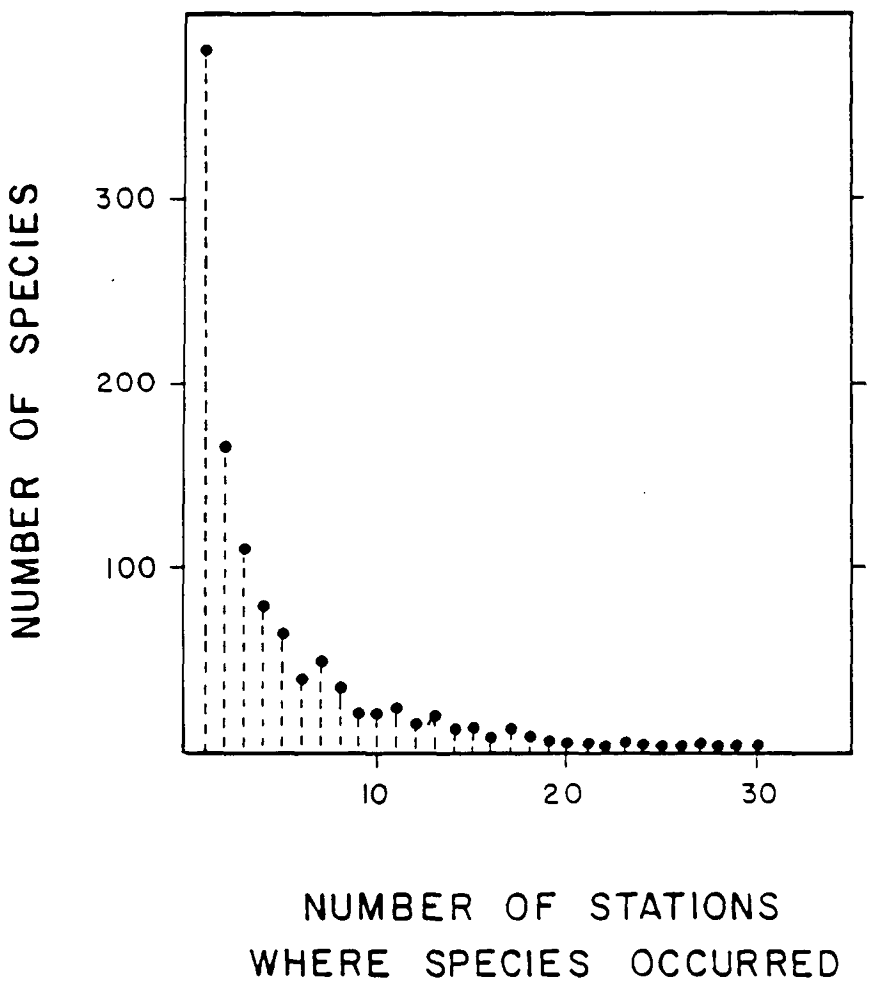
Table 3.6-2. Taxonomic breakdown of infaunal species richness within five depth ranges.

Water Depth (m)*	Total Area Sampled (m^2)	Total Number of Species**	Percent Contribution		
			Polychaetes	Crustaceans	Molluscs
10-18	3.75	579	42	32	21
23-26	3.93	491	45	38	15
48-59	3.99	537	46	37	15
86-90	3.99	469	48	13	37
136-148	2.28	265	60	29	10
10-148	20.75	1,121	37	40	21

*Stations included in the computations for each depth range:

10-18 m--Stations 40, 41, 42, 43, 46, 48, 49, 50, 51, 52, 53, and 54.
23-26 m--Stations 2, 6, 14, and 20.
48-59 m--Stations 4, 8, 16, and 22.
86-90 m--Stations 5, 12, 18, and 24.
136-148 m--Stations 31, 33, 34, and 37.
10-148 m--All stations sampled during Years 1 through 3 (i.e., all stations listed, plus Stations 25, 26, and 28).

**Number of species that were collected at least once at one or more stations in the stated depth range.



Explanation: The graph shows the number of species that occured at 1, 2,... up to 30 stations. For example, 379 species occurred at only 1 station, and only 3 species occurred at 30 stations.

Figure 3.6-7 Frequency distribution of infaunal species occurrences.

Table 3.6-3. List of most abundant infaunal species.

Species*	Number of Stations	Grand Mean Abundance (No./m^2)	Life Mode**	Feeding Type***
Prionospio cristata (P)	26	334	T	DF/SF
Synelmis albini (P)	29	314	B	C/S
Mediomastus californiensis (P)	30	160	B	DF
Paraprionospio pinnata (P)	25	142	T	DF/SF
Armandia maculata (P)	30	112	B	DF
Cirrophorus americanus (P)	26	109	B	DF
Myriochele oculata (P)	30	108	T	DF
Filograna implexa (P)	8	91	T	SF
Aricidea fragilis (P)	24	84	B	DF
Haplosyllis spongicola (P)	21	83	F	C/S
Lucina radians (B)	12	79	B	SF
Prionospio cirrifera (P)	23	67	T	DF/SF
Cyclaspis sp. A (C)	20	66	B	DF
Goniadides carolinae (P)	15	66	B	C/S
Magelona pettiboneae (P)	18	62	B	DF
Lumbrineris verrilli (P)	25	48	F	C/S
Leptochelia sp. A (T)	21	47	B	C/S
Aricidea catherinae (P)	26	44	B	DF
Levinsenia gracilis (P)	19	43	B	DF
Axiothella sp. A (P)	28	42	T	DF
Ceratonereis irritabilis (P)	4	42	F	C/S
Aricidea taylori (P)	18	41	B	DF
Ceratocephale oculata (P)	21	41	F	C/S
Sigambra tentaculata (P)	18	41	B	C/S

*B = bivalve, C = cumacean, P = polychaete, T = tanaid.
**B = burrower, T = tube dweller, F = free surface dweller.
***C/S = carnivore/scavenger, DF = deposit feeder, SF = suspension feeder.

the species listed were widely distributed. The most abundant species (Prionospio cristata) occurred at most stations in water depths <100 m, but was most abundant at Stations 2, 6, 14, and 25 (water depth of 23 to 26 m). The second most abundant species (Synelmis albini) occurred at nearly all stations and was most abundant on the middle shelf (Stations 5, 12, 18, 22, 24, and 28; water depth of 52 to 90 m). The third-ranked species (Mediomastus californiensis) was most abundant at about a 20-m depth (Stations 6, 14, 40, and 53), although it occurred at all stations. Paraprionospio pinnata occurred throughout stations in <100-m depth (often with Prionospio cristata and M. californiensis), but was most abundant at Station 40 (18 m) during the Year 3 fall cruise and Station 46 (18 m) during the Year 4 spring cruise. Species that appear on the list because of high localized abundance include a gregarious serpulid (Filograna implexa) that was present in dense aggregations at a few middle-to-outer shelf stations during the summer cruise; and a nereid polychaete (Ceratonereis irritabilis) that was very abundant at Station 52 during the Year 3 spring cruise.

Most of the species listed in Table 3.6-3 are polychaetes. Particularly well represented is the polychaete family Paraonidae (Aricidea catherinae, A. fragilis, A. taylori, Cirrophorus americanus, and Levinsenia gracilis). The paraonids as well as other species on the list (e.g., M. californiensis and Armandia maculata) are burrowing, subsurface deposit feeders. Spionids, which are typically tubicolous, surface deposit feeders or suspension feeders, are also well represented (Prionospio cristata, Paraprionospio pinnata, and Prionospio cirrifera).

There are few molluscs and crustaceans in the list of most abundant species. Among the molluscs, relatively abundant species (in addition to Lucina radians, see Table 3.6-3) include two solenogasters (Aplacophora sp. A and B) and a variety of bivalves (Caecum pulchellum, Crassinella lunulata, Crenella divaricata, Lucina nassula, Nuculana concentrica, and Tellina versicolor). All the most abundant crustaceans were peracarids:

the cumaceans *Apseudes* sp. A, *Cumella* sp. A and B, *Cyclaspis* sp. A; the amphipods *Ampelisca agassizi*, *Microdeutopus myersi*, *Photis* sp. A, and *Synchelidium americanum*; and the tanaid *Leptochelia* sp. A.

Cluster Analysis and Relationships to Environmental Variables

To investigate spatial and temporal patterns in species composition, normal and inverse classification analysis was conducted with the data set from Years 1 through 3 of the southwest Florida shelf study. Each sampling of each station was considered an entity to be clustered. Because of computer program limitations, the data set consisting of 1,121 species had to be truncated to a set consisting of fewer than 256. This was accomplished by ranking the species by grand mean abundance and selecting the top 230, plus any lower-ranked species that occurred at 10 or more of the 30 stations. The truncation process produced a data set consisting of 251 species. Classification was accomplished using the quantitative Bray-Curtis index as the similarity measure. Abundances were not transformed. Flexible sorting was used, with $\beta = -0.25$.

The normal classification analysis grouped stations primarily according to water depth (see Figure 3.6-8), a result similar to that noted in the MAFLA study (Blake, 1979; Heard, 1979; Vittor, 1979; Vittor, unpublished). The inner shelf group consists of stations in water depths of 10 to 23 m. The middle shelf group consists of stations in water depths of 24 to 48 m. Finally, the middle-to-outer shelf group encompasses the widest range of water depths (52 to 148 m). Depth-related clustering is also evident within the middle-to-outer shelf group.

Temporal variability is apparent in the dendrogram (Figure 3.6-9). Five middle-to-outer shelf stations in the southwest corner of the study area (Stations 16, 22, 24, 28, and 37) grouped across depth contours during the Year 2 summer cruise (see shaded area in Figure 3.6-8). A contributing factor was the high relative abundance of the serpulid

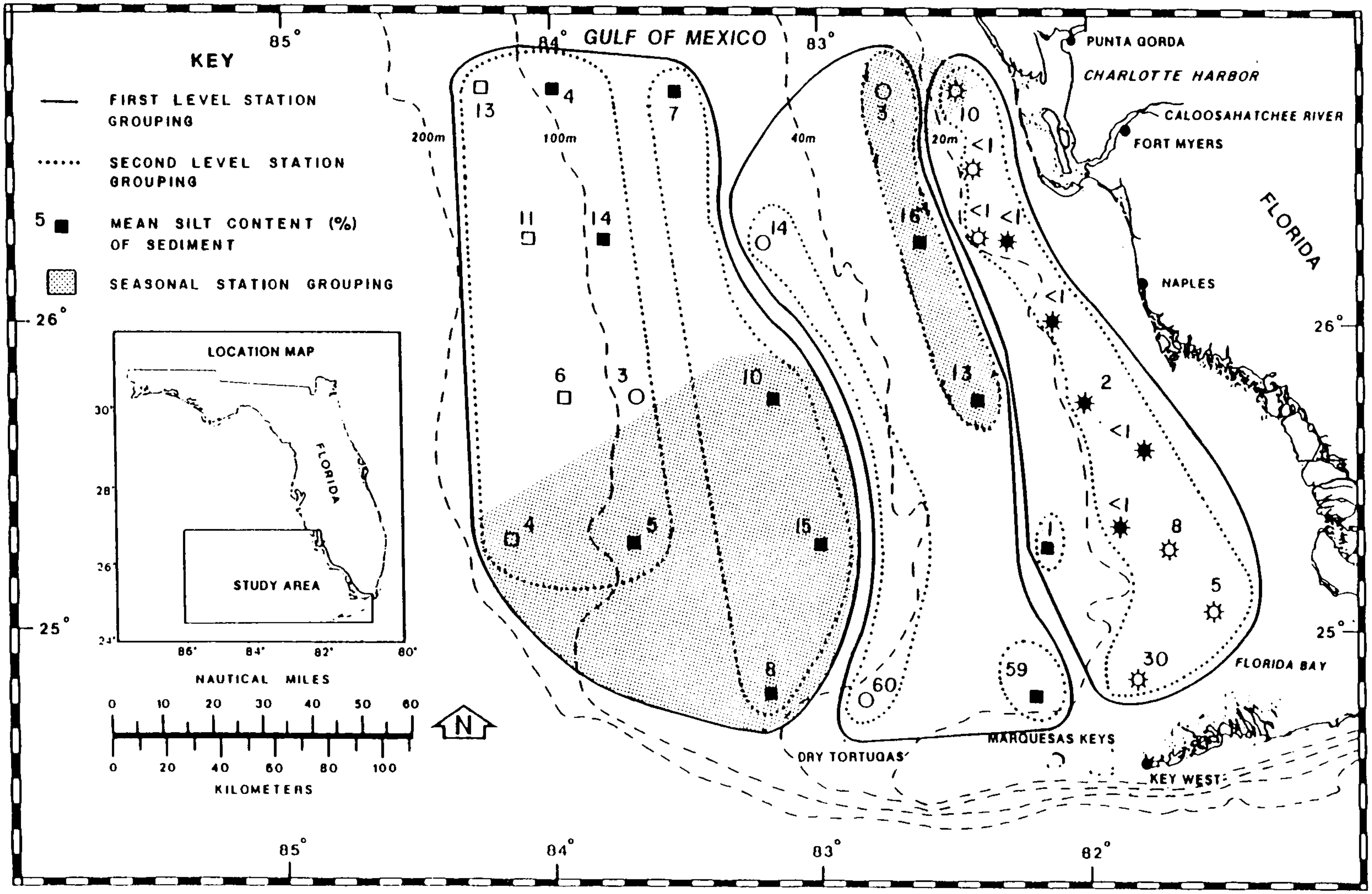


Figure 3.6-8 Station groupings from normal classification analysis of infaunal data.

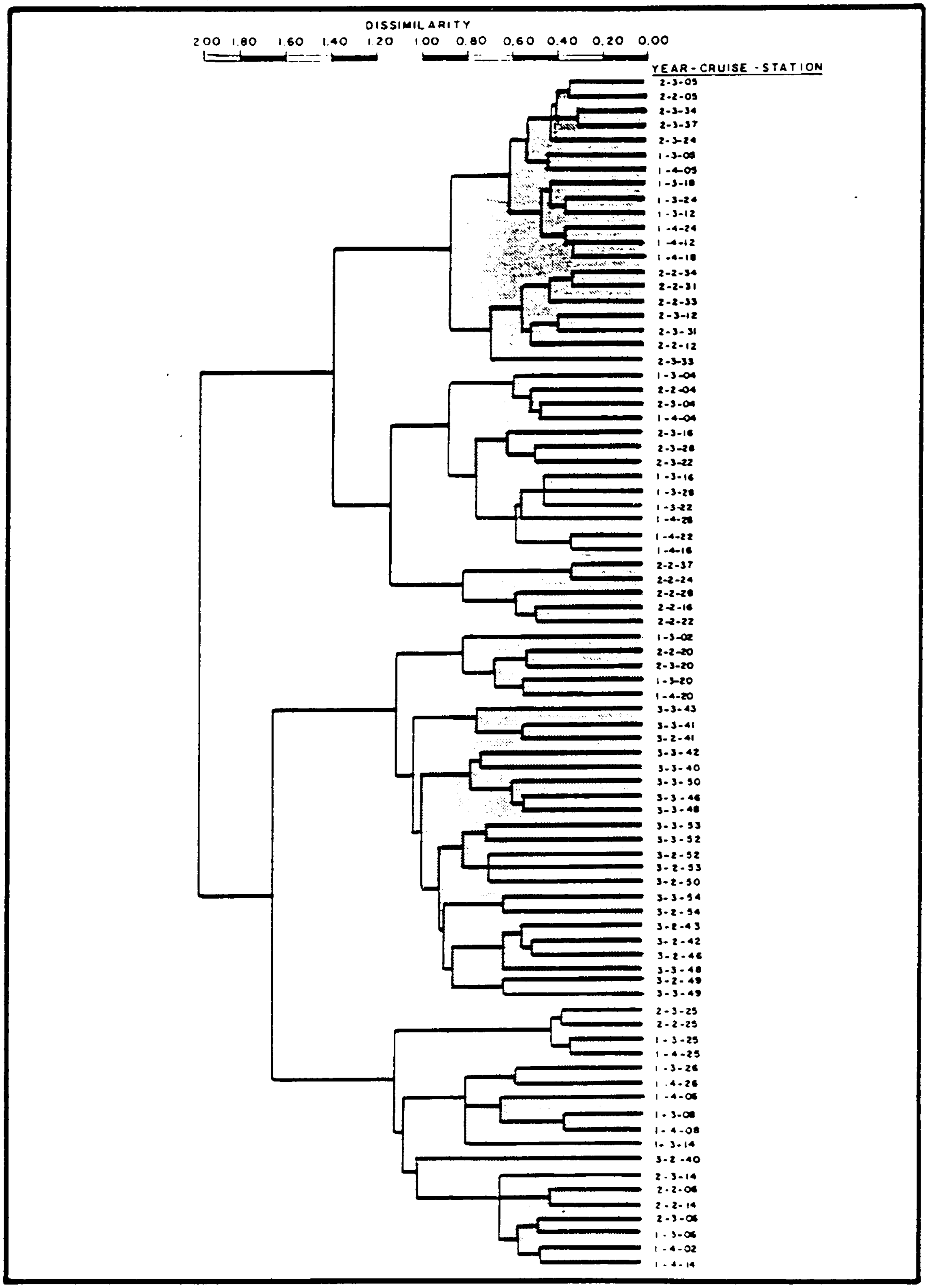


Figure 3.6-9 Dendrogram from normal classification analysis of infaunal data.

Filograna implexa at those stations during summer. Two stations near Charlotte Harbor (Stations 2 and 40) were characterized by a high degree of temporal variability in species composition, and, in general, there was a great deal of "noise" in the portion of the dendrogram that includes the shallow (<20 m) Year 3 stations.

To identify other variables that may explain the groupings of stations, a discriminant analysis was conducted using nine station groups selected from the dendrogram (see Figure 3.6-9). Environmental variables (potential discriminators) included in the analysis were water depth, sediment carbonate content, weight percentages in eight size classes of sediment ranging from shell hash (>2 mm) to clay (<4 um), and season (represented by the declination of the sun calculated for each sampling date). The discriminant function was significant at $p<0.001$ and accounted for 40% of the among-group variability. Water depth and sediment silt content (4- to 62-um fraction) showed the highest degree of correlation ($r^2 = 0.50$ for both variables) with the discriminant scores.

The influence of water depth is obvious in the map showing station groupings (Figure 3.6-8). The influence of the silt fraction is indicated on Figure 3.6-8 by the mean silt content values next to each station. Low silt content at Station 20 helps to explain its grouping with shallower stations rather than with those in its depth range. Abundant species at other stations in the 20- to 30-m depth range included Aricidea fragilis, Prionospio cristata, Magelona pettiboneae, and Mediomastus californiensis, which were present in low numbers at Station 20. These species apparently prefer sediments containing some minimum percentage of silt and/or very fine sand.

The apparent importance of silt content as a discriminator among station groups from classification analysis is due in part to the group consisting of Station 25, which was easily separable from most other station groups on the basis of its very high silt content. On closer examination, however, silt content appears to be of secondary importance to depth-related variables, as Stations 25 and 26 grouped most closely with stations in their respective depth ranges rather than with each other despite similarly high silt content (60%) of sediments. Station 25 was characterized by a seasonally consistent assemblage consisting primarily of *Prionospio cristata*, *P. cirrifera*, *Magelona pettiboneae*, and *Mediomastus californiensis*; these species accounted for 35 to 40% of total abundance on all four sampling dates. *Prionospio cristata* was among the most abundant species collected at Station 26, but other species (e.g., *Sigambra tentaculata*, *Caecum pulchellum*, and *Lucina radians*) were also major contributors and the assemblage was not as consistent seasonally. *Lucina radians* was also among the more abundant species at Stations 6, 8, and 14, but not at Station 25.

Species groupings from inverse classification analysis are listed in Table 3.6-4. The purpose of the inverse analysis is to group species according to their station occurrences (Boesch, 1977). The species were selected as most representative of the respective groups. In general, each species group has fairly distinct depth affinities or affinities for a particular station or season.

3.6.5 DISCUSSION

Infaunal communities of the southwest Florida shelf can be characterized as very diverse. There is a large number of species, and individuals are relatively evenly distributed among species. Polychaetes dominate in terms of abundance and species richness. Bivalve molluscs and peracarid crustaceans are also important components of shelf infaunal communities.

Water depth and sediment composition are the major environmental correlates of infaunal abundance, biomass, and species composition on the shelf. In terms of species composition, variations in relation to depth and sediment type are due to distributional limits and sediment

Table 3.6-4. Species groupings from inverse classification analysis of infaunal data from Years 1 through 3 infaunal stations, all cruises.

Group	Representative Species*	Station/Depth Affinities
A	Calozodion wadei (T) Isolda pulchella (P) Sphaerosyllis glandulata (P) Syllis gracilis (P)	Stations 52 (14 m) and 53 (10 m)
B	Cyclaspis sp. D (C) Diplodonta punctata (B) Eudevenopus honduranus (A) Metharpinia floridana (A)	Primarily stations <20 m
C	Ehlersia ferrugina (P) Haplosyllis spongicola (P) Phoronis architecta (Ph) Parasterope pollex (O)	Not strongly associated with any station group
D	Aricidea taylori (P) A. wassi (P) Lucina radiana (B) Magelona pettiboneae (P) Mediomastus californiensis (P) Paraprionospio pinnata (P) Prionospio cristata (P) Prionospio cirrifera (P) Sigambra tentaculata (P)	Occurred primarily at stations <80 m; most abundant at one or more of Stations 2, 6, 14, 25, 26, or 40
E	Ampelisca sp. D (A) Erichthonius brasiliensis (A) Microdeutopus myersi (A) Photis sp. A (A)	Station 14 (26 m), fall cruise
F	Armandia maculata (P) Exogone dispar (P) Myriochele oculata (P) Nereis riisei (P) Pionosyllis gesae (P)	Widely distributed; most abundant at one or more stations <25 m
G	Ancistrosyllis hartmanae (P) Apseudes propinquus (T) Aricidea cerrutii (P) Cirrophorus lyra (P)	Station 20 (23 m)

Table 3.6-4. (Cont.).

Group	Representative Species*	Station/Depth Affinities
H	Aricidea fragilis (P) A. philbinae (P) Lumbrineris ernesti (P) Rutiderma licinum (O) Synchelidium americanum (A)	Occurred primarily at stations in 20-60 m; most abundant at Station 2, 6, or 14
I	Aglaophamus verrilli (P) Aplacophora sp. A (S) Euchone incolor (P) Notomastus americanus (P) Synelmis albini (P) Tharyx marioni (P)	Occurred primarily at stations >20 m; most abundant mid-outer shelf (>50 m)
J	Amaena trilobata (P) Amphicteis scaphobranchiata (P) Cossura soyeri (P) Odontosyllis enopla (P) Scoloplos rubra (P)	Not strongly associated with any station group
K	Exogone atlantica (P) Lumbrineris coccinea (P) Pholoe minuta (P) Protodorvillea minuta (P) Scoloplos capensis (P)	Occurred primarily at stations >40 m; most abundant in 50-80 m
L	Callianassa marginata (D) Platidia clepsydra (Br) Polydora socialis (P) Prionospio cirribranchiata (P) Spiophanes wigleyi (P)	Occurred primarily mid-outer shelf (>40 m); most abundant >80 m

*A = amphipod.
B = bivalve.
Br = brachiopod.
C = cumacean.
D = decapod.
O = ostracod.
P = polychaete.
Ph = phoronid.
S = solenogaster.
T = tanaid.

affinities of particular species. Zones or station groupings are apparent because sets of species have similar distributional patterns.

The factor that is most likely to control abundance and biomass is food availability. Most of the infauna of the southwest Florida shelf are deposit or suspension feeders. Both types depend on supplies of particulate organic matter from phytoplankton production in the overlying water column. In terms of phytoplankton primary production, the shelf can be categorized as oligotrophic (Woodward Clyde Consultants and Skidaway Institute of Oceanography, 1983). Sediment trap data collected during Years 4 and 5 of the Southwest Florida Shelf Ecosystems Program show that deposition rate of particulate organic material declines rapidly with increasing water depth (Danek and Lewbel, 1986). Thus, the decline in abundance and biomass of infauna with increasing water depth may reflect the concurrent decline in allochthonous food inputs. Autochthonous food supplies such as benthic microalgae (which many deposit feeders also consume) also presumably decline in abundance with increasing water depth due to light attenuation.

Many species of infauna found on the continental shelf are opportunists that are able to respond to suddenly favorable conditions such as a pulse of food. Transient primary productivity events in the water column associated with Gulf Stream meanders were proposed to be a source of food pulses to benthos on the continental shelf off the U.S. south Atlantic coast (Hanson et al., 1981). On the southwest Florida shelf, Loop Current intrusions have been shown to produce similar, transient increases in water column primary productivity (Woodward Clyde Consultants and Skidaway Institute of Oceanography, 1983) and could provide sporadic inputs of food to deposit- and suspension-feeding benthic infauna.

Food for infauna is also present in the form of benthic macroalgae and sessile epibiota, such as sponges and hydroids, especially in and near hard-bottom areas. Numerous species of motile carnivores and omnivorous scavengers are adapted to use these food sources. Sampling near dense concentrations of sessile epibiota at Station 52 during Year 3 showed that there was a distinct infauna characterized by an atypically large number of syllid polychaete species (e.g., Haplosyllis spongicola) (Continental Shelf Associates, Inc., 1987).

Certain species exhibit a propensity for large fluctuations in population size. In some instances, this appears to be a localized phenomenon of unknown cause; for example, there was a high abundance of Paraprionospio pinnata at Station 40 during the Year 3 fall cruise (the species was not present in spring cruise samples and was not particularly abundant at any other station during the fall cruise). In other cases, the increase may represent a seasonal pattern. Examples of the latter are high abundances of Prionospio cristata and Filograna implexa at several stations during summer and Haploscoloplos sp. at most stations during winter. Filograna implexa broods its young with its calcareous tube and can form dense, localized tube clusters. Spionids such as Prionospio cristata and Paraprionospio pinnata attach their egg masses to the substratum, also facilitating rapid population growth in a particular area (Johnson, 1984).

Table 3.6-5 presents a comparison of data from the southwest Florida shelf with data from three other continental shelf environments: the south Texas continental shelf, the South Atlantic Bight, and the mid-Atlantic coast. The comparison indicates that abundances and polychaete biomass in the various continental shelf environments are generally comparable. Also, many of the genera and even species found on the shelf in the study area are widely distributed [see the overview of continental shelf benthos by Rabalais and Boesch (1985) and the guide to polychaetes of the Gulf of Mexico by Uebelacker and Johnson (1984)].

Table 3.6-5. Comparison of selected infaunal data from various continental shelf environments.*

	Mid-Atlantic**	South Atlantic***	South Texas+	Southwest Florida++
Density (No./m^2)	1,000-10,000	3,500-8,500	200-6,000	2,000-10,000
Polychaete Biomass (g/m^2)	10-50	10-80+++	<4+++	1-20

*Values shown are typical ranges, not maximum and minimum values.
**Boesch, 1979.
***Tenore, 1979; Hanson et al., 1981.
+Flint and Rabalais, 1981.
++Abundance data from the Southwest Florida Shelf Ecosystems Program; MAFLA biomass data from Vittor, 1979.
+++Total macrofaunal biomass; polychaetes presumed to be major contributor.

Finally, the main factors controlling species composition appear to be similar in the various regions: variables related to water depth and sediment type.

3.7 SESSILE EPIFAUNA

Since the time of the earliest dredge sampling conducted by the Blake (1877-1880), Albatross (1884), and Fish Hawk (1901-1902), the southwest Florida shelf has been recognized for the diversity of its sessile epifauna. The warm climate and the presence of rock outcrops and thinly covered hard substratum favor colonization by various tropical species of corals, sponges, and gorgonians typically associated with south Florida and Caribbean reefs, as well as many widely distributed species of fouling organisms found on hard substrata in both temperate and tropical environments.

Recent data concerning epifauna of the continental shelf are available from several sources. Between 1965 and 1967, the Florida Department of Natural Resources conducted the Hourglass Cruises, with monthly sampling by dredge and trawl at 10 primary stations on two cross-shelf transects off Tampa Bay and Sanibel Island (Joyce and Williams, 1969). However, the stations were not intentionally located in hard-bottom areas or locations where sessile epibiota were abundant. Hourglass collections of ahermatypic corals were summarized by Cairns (1977). Between 1974 and 1978, dredge and trawl sampling was also conducted at several stations in the study area as part of the Bureau of Land Management MAFLA program. However, there has been no synthesis of the data, and station-specific data are not available in the final report from the project (Hopkins, 1979).

The following discussion is based primarily on dredge collections and photographic sampling conducted during Years 1 through 5 of the Southwest Florida Shelf Ecosystems Program (1980-1985). During this study, 26 stations were occupied in areas where dense concentrations of sessile epifauna were present (live-bottom stations). Figure 3.7-1 shows the sampling locations, and Table 3.7-1 summarizes the sampling schedule for the 5-year program.

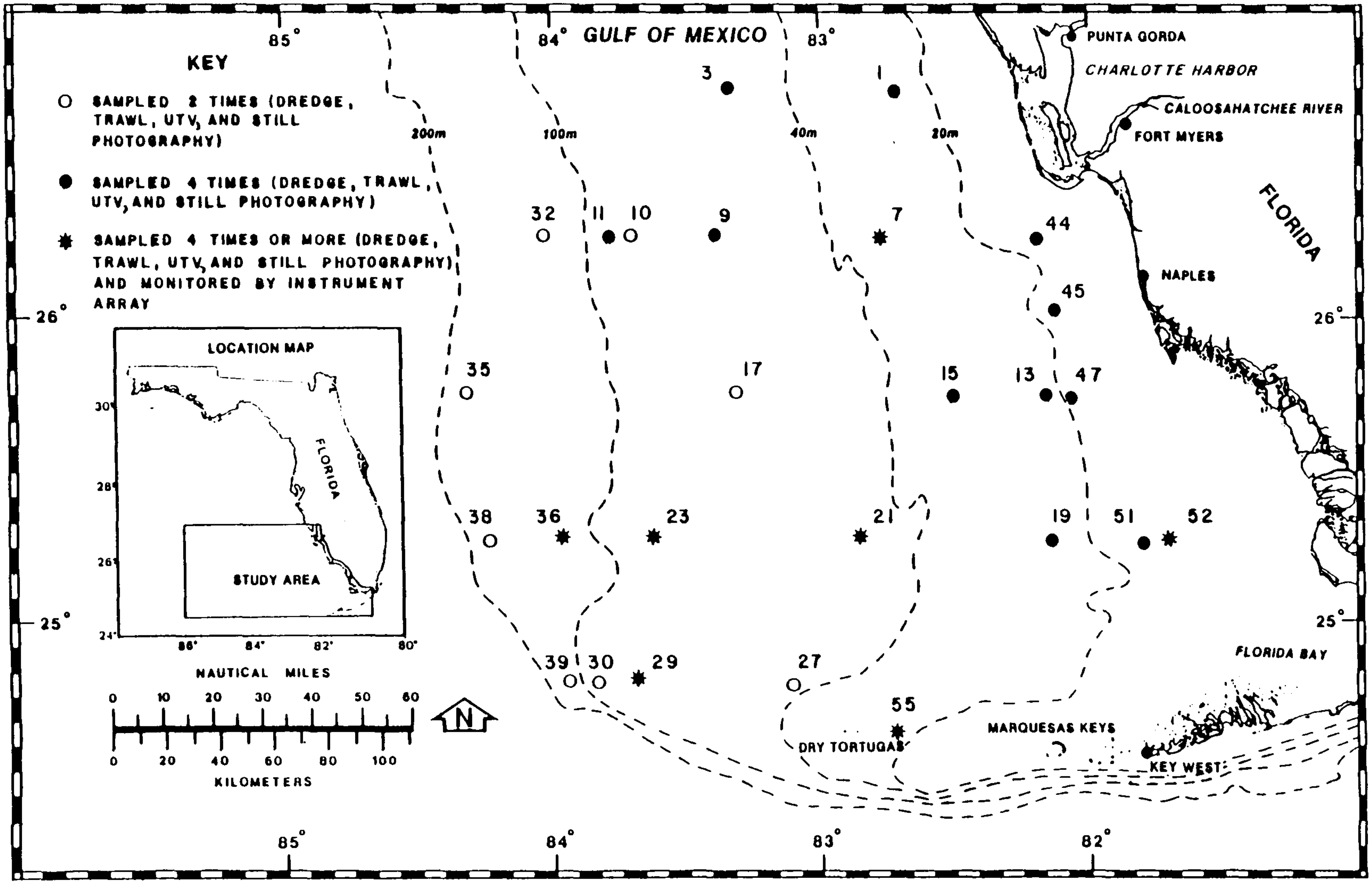


Figure 3.7-1 Locations of live-bottom stations sampled during the Southwest Florida Shelf Ecosystems Program.

Table 3.7-1. Water depths and sampling schedule for live-bottom stations.

		Sampling Date														
	Water	Year 1		Year 2		Year 3		Year 4				Year 5				
	Depth	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise	Cruise
Station	(m)	III	IV	II	III	II	III	I	II	III	IV	I	II	III	IV	V
1	24	X	X	X	X											
3	50	X	X	X	X											
7	30	X	X	X	X							X	X	X	X	
9	56	X	X	X	X											
10	71	X	X													
11	77	X	X	X	X											
13	20	X	X	X	X											
15	32	X	X	X	X											
17	58	X	X													
19	22	X	X					X		X						
21	44	X*	X	X	X				X	X	X	X**	X**	X**	X**	
23	70	X	X	X	X			X*	X	X	X	X**	X**	X**		X**
27	54	X	X													
29	62	X	X	X	X			X	X	X	X	X**	X**	X**		X**
30	76	X	X													
32	137			X	X											
35	159			X	X											
36	127			X	X			X*	X	X	X	X**	X**	X**		X**
38	159			X	X											
39	152			X***	X***											
44	13					X	X	X		X						
45	17					X	X*	X		X						
47	19					X	X	X		X						
51	16					X	X	X		X						
52	14					X	X	X*	X	X	X	X**	X**	X**	X**	
55	27											X	X	X	X	

Except where noted otherwise, an underwater photographic survey was conducted and three dredge samples and one trawl sample were collected at each station each time it was sampled. Sampling dates for benthic stations: Year 1, Cruise III = October-November 1980; Year 1, Cruise IV = April-May 1981; Year 2, Cruise II = July-August 1981; Year 2, Cruise III = January-February 1982; Year 3, Cruise II = December 1982; Year 3, Cruise III = May-June 1983; Year 4, Cruise I = December 1983; Year 4, Cruise II = March 1984; Year 4, Cruise III = May 1984; Year 4, Cruise IV = August 1984; Year 5, Cruise I = December 1984; Year 5, Cruise II = March 1985; Year 5, Cruise III = June-July 1985; Year 5, Cruise IV = September 1985; Year 5, Cruise V = December 1985.

* No trawl sampling.

** No dredge sampling.

*** Due to steep terrain, samples were collected using a rock dredge only.

This discussion focuses on sessile epifauna associated with hard-bottom areas of the continental shelf. Related habitats in the study area include shallow water reefs (located along the Florida Keys and in Florida Bay) and seagrass beds (located primarily in Florida Bay). Other sources of data concerning the reefs and their epifauna are Marszalek et al. (1977), Marszalek (1982), and Jaap (1984). Additional information concerning the south Florida seagrass beds is provided by Zieman (1982) and Iverson and Bittaker (in press).

3.7.1 OVERVIEW OF SUBSTRATUM TYPES

Several habitat types for benthic organisms can be distinguished on the basis of substratum characteristics. Because this section focuses on sessile epifauna, hard-bottom habitats are of primary interest.

The geology of the shelf has been reviewed in Section 3.5. To summarize briefly, the shelf consists of a broad, gently sloping carbonate platform overlain by a variably thick sand veneer. A major buried reef feature on the middle shelf (central shelf reef complex) impounds sediments of the inner to middle shelf and is capped by growths of coralline algae in the form of algal nodules and, in certain locations, an algal pavement. Near the shelf break, a second major feature occurs in the form of an outer shelf double reef complex.

Figure 3.7-2 shows a schematic illustration of major substratum types on the shelf. Five major types may be recognized:

1. High-relief hard bottom,
2. Low-relief exposed or thinly covered hard bottom,
3. Thick sand bottom,
4. Coralline algal nodules, and
5. Coralline algal pavement.

Exposed rock or hard bottom is generally rare, widely scattered, and of low relief (<1 m). The most widely distributed substratum type

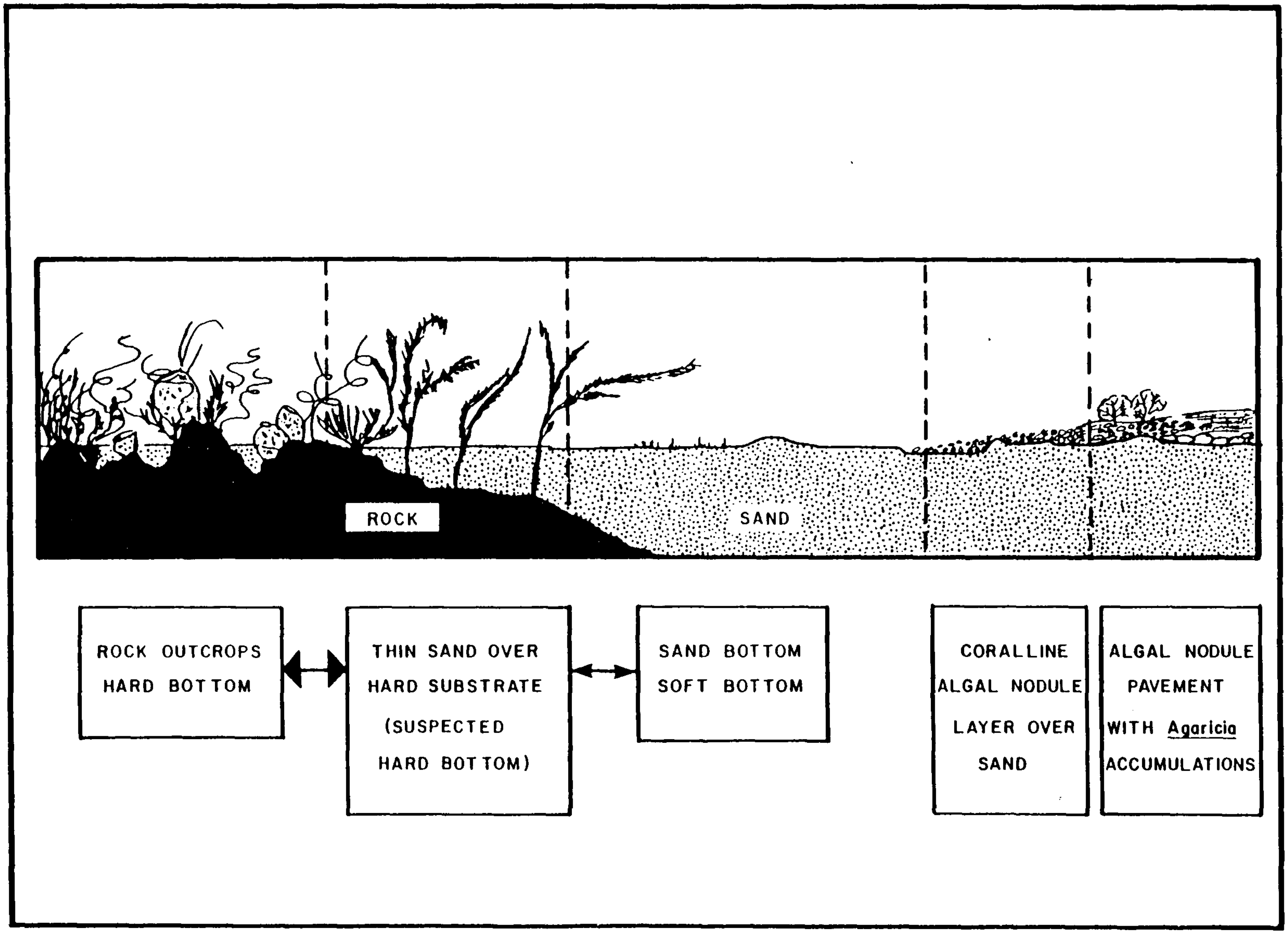


Figure 3.7-2 Schematic diagram of shelf substratum types.

supporting dense growths of sessile epifauna is a thin veneer of sand overlying hard bottom. The major distinction in this case is not between hard and soft bottom but between low- and high-relief outcrops and between thick and thin sand layers overlying hard bottom. The reason is that sand movement may readily bury exposed, low-relief, hard bottom or expose hard bottom buried by only a thin sand layer. The distinction is significant because sessile epibiota (other than some algae) occur primarily in areas where the sand veneer is thin enough to allow intermittent exposure and colonization of the hard substratum. Sand thickness measurements made during Year 3 sampling at five shallow water hard-bottom stations indicated that sessile epifauna were sparse in areas where the mean sediment thickness exceeded approximately 5 cm, although some sponges and corals were present in quadrats where the mean thickness was nearly 10 cm. Similarly, Marine Resources Research Institute (1984) reported that 95% of corals and sponges in hard-bottom areas of the South Atlantic Bight were attached in areas where the substratum was covered by less than 5 cm of sediment. The breakpoint between areas of thick sand and thin sand bottom might conservatively be placed at a mean thickness of about 10 cm, a thickness less than the resolution of most subbottom profilers. For this reason, the distribution of this substratum type can best be mapped by using a combination of geophysical data and visual sitings of sessile epibiota (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983; Continental Shelf Associates, Inc., 1985).

Although not widely distributed on the shelf, coralline algae in the form of nodules or crusts form an important substratum type for sessile epifauna in the 60- to 100-m depth range. The nodules, which range in size from a few millimeters to several centimeters in diameter, are believed to be formed by two genera of coralline algae, Lithothamnium and Lithophyllum. In the southern portion of this depth range (e.g., Station 29), the coralline algae produce a flattened pavement rather than loose nodules. Additional information is provided in subsequent sections.

3.7.2 DISTRIBUTION OF CONSPICUOUS SESSILE EPIFAUNA

Overview

A review of the overall distribution of sessile epibiota on the shelf is necessary before proceeding with a discussion of individual taxonomic groups. A major source of information is the remote photographic survey work conducted during Years 1, 2, and 3, the results of which were summarized in two marine habitat atlases (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983; Continental Shelf Associates, Inc., 1985).

Most of the inner and middle shelf (to about 70 m) consists of a mosaic of thick sand bottom and hard bottom covered by a thin sand veneer, with occasional low-relief rock outcrops, including patch reefs. The patch reefs typically are undercut ledge systems oriented parallel to isobaths and probably representing shoreline features preserved during a gradual rise in sea level (Smith, 1976). The hard coral and gorgonian fauna associated with patch reefs in water depths of 10 to 30 m off Tampa Bay and Sarasota, as described by Smith (1976) and Rice (1984), are similar to those described in subsequent paragraphs for areas of thinly covered hard bottom on the inner shelf surveyed during the southwest Florida shelf study. However, the rock ledges support a somewhat different biota than the surrounding areas of thinly covered hard bottom, including serpulid and sabellid polychaetes, boring sponges (Cliona), and hydrozoan fire coral (Millepora alcicornis) (Smith, 1976).

Hard-bottom areas, ranging from 10 to 20 m deep, are typified by dense populations of gorgonians (Eunicea spp., Muricea spp., Plexaurella spp., Pseudopterogorgia spp., etc.) and large sponges such as Spheciospongia vesparium (loggerhead), Ircinia campana (vase sponge), I. felix, I. strobilina, Haliclona sp. (finger sponge), Cinachyra alloclada, and Geodia gibberosa. Small scleractinian corals (Solenastrea hyades, Cladocora arbuscula, Siderastrea radians, Phyllangia americana, and others) also are present, though inconspicuous among the dense gorgonians. Sand-bottom areas interspersed with hard bottom in the same depth range are characterized by populations of seagrass (Halophila decipiens) and algae (Halimeda, Caulerpa, Udotea, Penicillus, etc.). Halophila decipiens is not a major bed former and typically occurs at the outer fringe of Thalassia-Halodule-Syringodium beds on the west Florida shelf (Continental Shelf Associates, Inc. and Martel Laboratories, Inc., 1985; Iverson and Bittaker, in press).

Beyond about the 25-m depth and extending to the 60- or 70-m depth, the thickness of the sand veneer overlying hard bottom generally increases, and rock outcrops and live bottom are encountered less frequently than at shallower depths. Algae (Caulerpa, Halimeda, Udotea, etc.) typically are present in soft-bottom areas to depths of about 70 m. In hard-bottom areas, the dense gorgonian populations are no longer seen beyond depths of about 20 m; sponges (many of the same species cited previously) and algae are the major conspicuous forms of sessile epibiota. Small hard corals (the same species cited previously, with the addition of some species with affinities for deeper water) also are present to depths of about 40 to 50 m.

Water depths of about 60 to 100 m on the shelf are typified by a mosaic of open, soft-bottom areas and patches of coralline algal nodules formed by Lithophyllum and Lithothamnium. The nodules are sparse and very patchy in the northern part of the study area, but increase in density southward, approaching 100% coverage along portions of Transect D and culminating in a fused pavement or crust along the southernmost transect (Transect E). Associated with the nodules are species of calcified algae (the cryptonemialids Peyssonnelia rubra and P. simulans, as well as the green alga Halimeda), and, in the southern portion of the area, leafy green algae (Anadyomene menziesii). Sparse populations of sessile epifauna such as sponges, azooxanthellate gorgonians, hard corals, and crinoids also are present in these nodule areas.

The 60- to 80-m depth range on Transect E is characterized by a unique assemblage of plate corals (Agaricia spp.) and dense growths of Anadyomene menziesii occurring on a substratum consisting of a fused coralline algal nodule pavement. Biotic coverage in this area ranges from 64% to 90%, the highest values seen on the shelf. Most of the cover is due to algae (Anadyomene and Peyssonnelia), which show little seasonal variation in abundance at this depth.

Most of the outer shelf is covered by a thick sand veneer. Scattered outcrops occur throughout the area, but most are concentrated along two partially buried, north-trending reef features described by Holmes (1981). The inner reef occurs in a water depth of about 150 m and is visible in the form of isolated, steep-walled outcroppings (referred to as prominences), protruding up to 3 m above the surrounding thick sand on the northern end of Transect L and the western end of Transect C. The outer reef occurs at the shelf break; low-relief outcrops were seen between 190- and 200-m depths on the outer ends of Transects C, D, and E.

Because of the water depth and attendant low light levels on the outer shelf, algae are not major elements of the epibiota. The dominant sessile epibiota are crinoids, antipatharians, non-zooxanthellate gorgonians and hard corals, and small, hexactinellid (glass) sponges. The crinoids occur on emergent rock as well as on layers of coarse shell rubble in soft-bottom areas.

Distribution of Individual Groups

The following discussion reviews the distribution of groups of conspicuous sessile epifauna on the southwest Florida shelf. The focus is on hard corals, gorgonians, sponges, and crinoids. Additional information about other sessile epifauna is presented in the final reports from Year 2 (Woodward Clyde Consultants and Continental Shelf

Associates, Inc., 1985), Year 3 (Continental Shelf Associates, Inc., 1987), and Year 5 (Danek and Lewbel, 1986).

Scleractinian Corals

A large variety of hard corals was collected during the 5 years of southwest Florida shelf sampling. Most of the species collected on the inner and middle shelf contain symbiotic zooxanthellae and presumably derive a portion of their nutrition from photosynthesis. However, there is little reef-building activity (light-enhanced calcification), with the exception of the deep Agaricia reef found in the vicinity of Station 29. Accordingly, these corals are referred to as zooxanthellate rather than hermatypic (Schuhmacher and Zibrowius, 1985).

Hard corals, although abundant at most of the live-bottom stations, were not major cover contributors. The exception was at Station 29, where Agaricia accounted for 6 to 12% coverage (probably an underestimate because leafy algae obscured corals in many photographs).

Table 3.7-2 lists 53 scleractinian species that were collected at one or more of the southwest Florida shelf stations during Years 1 through 5. The list is very similar to those presented by Jaap (1984) for reefs in the Florida Keys, where approximately 65 scleractinian species are found. Of 51 species of zooxanthellate species listed by Bright et al. (1984) as occurring on Caribbean reefs, 26 have been collected on the southwest Florida shelf. However, major hermatypic (reef-building) species such as Montastrea annularis, Acropora palmata, A. cervicornis, Diploria strigosa, D. labyrinthiformis, and Colpophyllia natans have not been collected on the southwest Florida shelf. Many of the more common corals on the inner and middle shelf are hardy, tolerant species that are often found in some of the less favorable, fringing environments in Caribbean and south Florida coral reef systems (Jaap, 1984).

Table 3.7-2. Occurrences of scleractinian corals in dredge and quadrat samples from live-bottom stations.

Species	Station: 13-19 m					20-32 m					44-58 m					62-77 m					129-159 m			
	44	52	51	45	47	13	19	1	7	15	21	3	27	9	17	10	11	23	29	30	36	32	35	38
Siderastrea siderea	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Porites porites	*	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dichocoenia stellaris	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Porites branneri	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solenastrea hyades	*	*	*	*	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Isophyllia sinuosa	.	.	*	*	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladocora arbuscula	*	*	.	*	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Siderastrea radians	*	*	*	*	*	*	.	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.
Stephanocoenia michelinii	.	.	*	*	.	*	.	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Porites porites divaricata	.	.	.	*	.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Isophyllia multiflora	.	.	.	*	.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mussa angulosa	.	.	.	*	.	*	.	.	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Cladocora debilis	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solenastrea bournoni	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Oculina robusta	*	.	.	.	.	.	.	.	*	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.
Favia gravida	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhizosmilia maculata	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scolymia lacera	.	*	.	*	.	*	.	.	*	*	*	*	.	.	.	.	.	.	*	.	.	.	.	.
Manicina areolata	*	.	.	*	.	.	*	*	*	*	.	.	*	.	.	.	.	.	*	*	.	.	.	.
Oculina varicosa	.	.	.	.	.	.	.	.	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Agaricia lamarcki	.	.	.	*	.	.	.	.	.	*	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Astrangia solitaria	.	.	.	.	.	.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Balanophyllia wellsi	.	.	.	.	.	.	.	.	*	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.
Phyllangia americana	*	*	*	*	*	*	.	*	*	*	*	.	*	.	.	.	.	.	.	.	*	.	*	.
Madracis decactis	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Oculina tenella	.	.	.	.	.	.	.	.	.	.	*	*	*	*	*	.	.	.	.	.	.	.	.	.
Agaricia fragilis fragilis	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	*	.	.	.	.	.
Madracis formosa	.	.	.	.	.	.	.	.	*	*	.	.	.	.	.	.	.	*	*	*	.	.	.	.
Agaricia fragilis	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	*	*	.	.	.	.	.

Table 3.7-2. (Cont.).

Species	Station 13-19 m 44	52	51	45	47	20-32 m 13	19	1	7	15	44-58 m 21	3	27	9	17	62-77 m 10	11	23	29	30	129-159 m 36	32	35	38
Oculina diffusa	*	.	.	.	.	.	.	.	*	*	*	*	.	.	.	.	.	.	.	.	.	.	*	.
Madracis mirabilis	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	*	*	*	.	.	.	.
Agaricia agaricites	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Agaricia agaricites agaricites	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Porites astreoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Montastrea cavernosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Agaricia agaricites purpurea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Madracis brueggemanni	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	.	.	.	.
Agaricia fragilis contracta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	.	.	.
Leptoseris (Helioseris) cucullata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Dendrophyllia cornucopia	.	.	.	.	.	.	.	.	*	.	.	*	.	.	.	.	.	.	.	.	*	*	.	.
Madracis asperula	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*	*	*	*	*	.	*	.	*	*
Guynia annulata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	*
Madracis myriaster	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	*	*
Oxysmilia rotundifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.
Anomocora fecunda	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	.
Flabellum fragile	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	.
Deltocyathus calcar	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.
Trochocyathus rawsonii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.
Caryophyllia horologium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	*
Paracyathus pulchellus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*	*
Javania cailleti	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*	*
Coenosmilia arbuscula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	*
Madrepora carolina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	*
Caryophyllia berteriana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*

*Indicates species occurred in at least one dredge or quadrat sample at the listed station.

Distinct coral zonation patterns are evident. There is a well-defined inner shelf grouping consisting of corals such as Solenastrea hyades, Siderastrea radians, Cladocora arbuscula, Phyllangia americana, Stephanocoenia michelinii, and Scolymia lacera. These corals were common at one or more stations in depths less than 40 to 50 m. All of these species, with the exception of Phyllangia americana, contain symbiotic zooxanthellae (Cairns, 1977 and 1978) and may be light limited in their distribution. Phyllangia americana was not limited to the inner shelf; it was also collected at two outer shelf stations (Station 32--depth 137 m; Station 35--depth 159 m). Most of the inner shelf species are also fairly tolerant of exposure to suspended solids and temporary (several days) burial (Rice, 1984). Hubbard and Pocock (1972) reported that Manicina areolata and Isophyllia sinousa, two additional species found on the inner and middle shelf, can right themselves after being overturned in sediment.

Few coral species were collected at the 44- to 58-m stations, probably due to declining light levels and limited availability of suitable substratum for zooxanthellate species able to grow under low light (e.g., agariciids). Oculina tenella, a species lacking symbiotic zooxanthellae, occurred most consistently in this depth range.

In the 62- to 77-m depth range, only one species (Madracis asperula, which does not contain symbiotic zooxanthellae) was collected at Stations 10 and 11, where the substratum consisted of sparse algal nodules over sand. Three other Madracis species, M. brueggemanni, M. formosa, and M. mirabilis, were associated with the three southern stations in this depth range, where the substratum consisted of dense algal nodules (Station 23) or an algal nodule pavement (Stations 29 and 30). Station 29 possessed the largest and most distinctive coral assemblage, consisting of 19 species, including a number of deep-reef corals. Species found primarily or exclusively at this station included the agariciids Agaricia agaricites, A. fragilis, A. lamarcki, and Leptoseris cucullata, as well as Montastrea cavernosa, Porites astreoides, and Madracis decactis. Only one of the agariciids was collected at Station 30, which also was characterized by the algal nodule pavement but at a greater water depth than Station 29 (76 m versus 62 m).

The predominance of agariciids at Station 29 probably reflects the influence of both light levels and substratum type. The plate-like growth form of Agaricia helps increase light capture and allows the corals to grow at depths greater than those inhabited by most other zooxanthellate species. Decreasing light availability probably defines the lower depth limit of the agariciid reef growth and helps to explain the relatively low abundance of Agaricia at Station 30 in comparison to Station 29. Also, the absence of unconsolidated sediments at Station 29 is an important factor, because Agaricia is a poor sediment remover (Hubbard and Pocock, 1972). In Caribbean and south Florida reefs, Agaricia is often found in locations where the potential for accumulation of sediment on coral surfaces is minimal, such as vertical surfaces and undersides of ledges (Hubbard and Pocock, 1972; Van den Hoek et al., 1978; Jaap, 1984).

The outer shelf is characterized by a suite of azooxanthellate forms, primarily species in the families Caryophylliidae and Flabellidae. Paracyathus pulchellus, Caryophyllia berteriana, C. horologium, Javania cailleti, Flabellum fragile, Trochocyathus rawsonii, and Deltocyathus calcar all are solitary. Paracyathus pulchellus was cited as a common deepwater species in MAFLA samples from all areas of the west Florida shelf (Hopkins, 1979). Caryophyllia horologium, previously reported to a depth of 91 m in the Hourglass samples, may occur attached to the hard substratum or as a free surface dweller, along with T. rawsonii and D. calcar (Cairns, 1977). Nearly all of the species that were common on the outer shelf occurred exclusively there, with the major exception of Madracis asperula (minimum depth 54 m, Station 27).

Two stations are omitted from Table 3.7-2: Station 39, located in a water depth of 152 m and sampled by rock dredge only, and Station 55, located in a water depth of 27 m near the Dry Tortugas (not on any of the cross-shelf transects). Only two corals (Caryophyllia horologium and Paracyathus pulchellus) were collected at Station 39; both are typical outer shelf forms. In contrast, Station 55 harbored a diversity of hard corals, including one species (Meandrina meandrites) not found at any of the other stations (though believed to occur more widely). Station 55 was second to Station 29 in the number of coral species collected (15 versus 19), and several deep-reef species were found only at these two stations (Montastrea cavernosa, Leptoseris cucullata, and Madracis decactis).

Octocorals

The subclass Octocorallia (Alcyonaria) includes sessile invertebrates such as sea fans, sea whips, sea plumes, and sea pens. Most are associated with reef environments. These organisms typically feed on zooplankton and particulate organic matter (Lasker, 1981), but most shallow water species possess symbiotic zooxanthellae and derive some portion of their nutrition from photosynthesis. A general reference for octocorals of the tropical and subtropical western Atlantic is Bayer (1961); information concerning the distribution of octocorals in the Gulf of Mexico is summarized by Giammona (1978).

Along the mainland coast of southwest Florida, the octocorals are most abundant in shallow water depths (<20 m). Smith (1976) reported that gorgonian densities generally are much higher at patch reefs in water depths less than 18 m than at deeper reefs. Counts of gorgonians made during Years 4 and 5 television surveys at several stations show a pattern of declining relative abundance with increasing water depth (Figure 3.7-3). Gorgonian densities were maximal (16 colonies per square meter) at Station 45 (17 m) and decreased sharply seaward of the 19- to 20-m isobath; the increase on the outer shelf reflects an increased

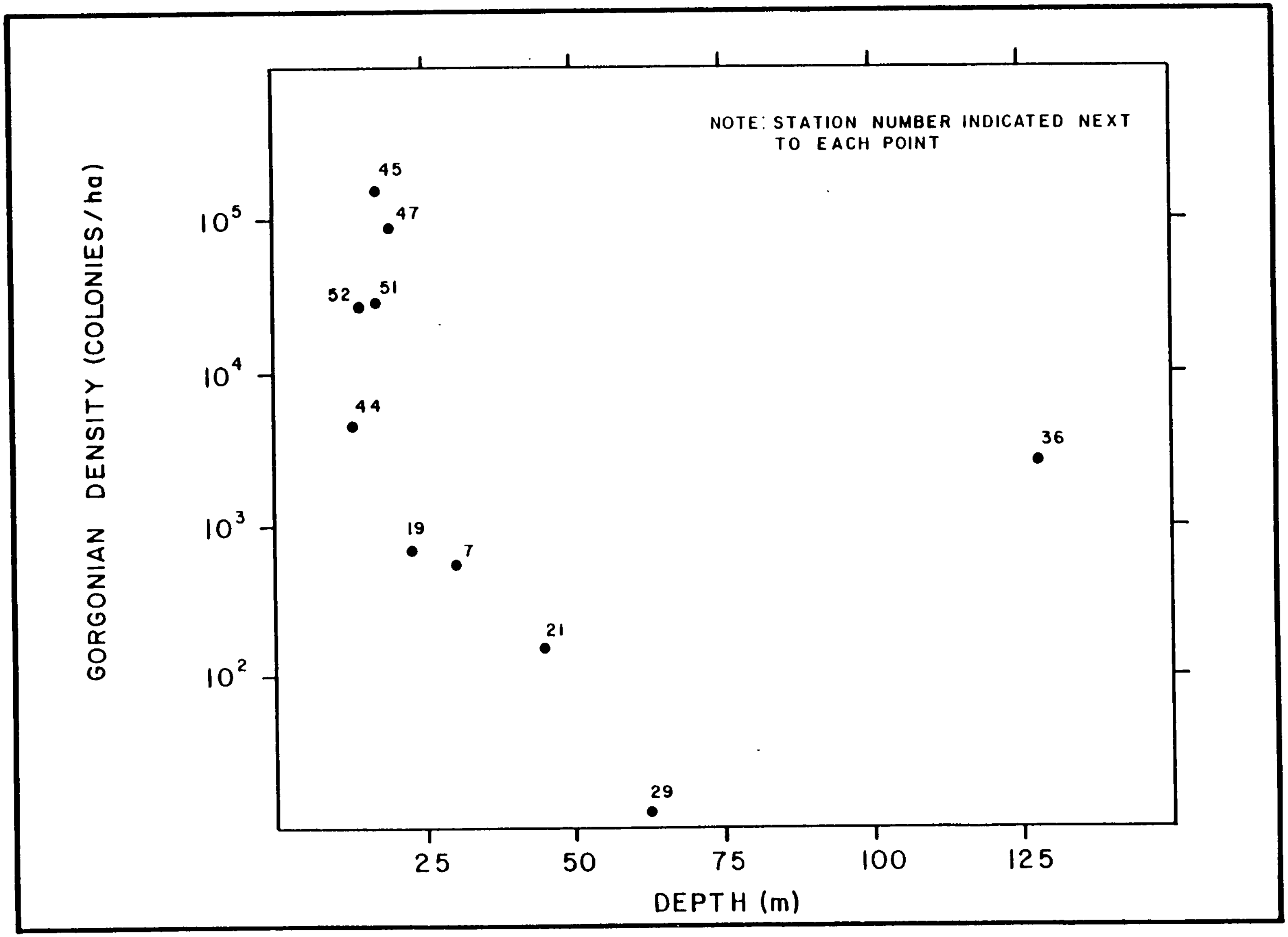


Figure 3.7-3 Relationship between water depth and gorgonian abundance, estimated visually using underwater television.

abundance of groups such as the ellisellids, which lack zooxanthellae. Photographic cover estimates from Years 1 through 3 show a similar pattern, with maximal gorgonian cover (24%) also observed at Station 45. The highest nearshore densities are in the low end of the range of values reported by Goldberg (1973) for lush gorgonian beds on patch reefs off the southeast Florida coast.

Table 3.7-3 shows the station occurrence patterns of the 70 species of octocorals collected at stations along the five east-west transects in the study area. The stations are grouped into depth ranges to illustrate zonation.

A large group of species is associated with stations in water depths of 22 m (Station 19) or less. Particularly characteristic species are *Pterogorgia guadalupensis*, *Pseudopterogorgia acerosa*, *Muricea elongata*, *M. laxa*, *Plexaurella fusifera*, and *Eunicea calyculata*. Many of the same nearshore gorgonian species were collected at Station 55 also, which is not included in the table. Station 55 is located near the Dry Tortugas in a water depth of 27 m. Several additional gorgonians such as *E. palmeri*, *E. laciniata*, *E. clavigera*, *E. pinta*, *Plexaura homomalla*, *Pterogorgia citrina*, and *Pterogorgia anceps* were collected exclusively at this station.

All of the nearshore gorgonian species harbor symbiotic zooxanthellae and derive at least part of their nutrition from photosynthesis. Consequently, decreasing light availability with increasing water depth probably is a major factor responsible for their limitation to shallow water depths (Goldberg, 1973). However, some shallow water species grow well when transplanted to deeper water, suggesting that effects of light levels on zonation may be due to larval preference or differential larval survival rather than adult survival patterns (Goldberg, 1970). Light levels are affected by water clarity as well as depth *per se*, as shown by the occurrence of large numbers of zooxanthellate gorgonians at 27 m at

Table 3.7-3. Occurrences of octocorals in dredge and quadrat samples from live-bottom stations.

Species	Station 13-19 m					20-32 m					44-58 m					62-77 m					127-159 m			
	44	52	51	45	47	13	19	1	7	15	21	3	27	9	17	10	11	23	29	30	36	32	35	38
Eunicea sp. cf. asperula	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leptogorgia virgulata	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudoplexaura fusifera	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunicea tourneforti	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carejoa riisei	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Muricea laxa	*	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plexaurella pumila	.	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunicea cf. laciniata	*	*	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunicea asperula	*	*	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plexaurella fusca	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudoplexaura wagenaari	*	*	*	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Muricea elongata	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plexaurella nutans	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plexaurella fusifera	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudoplexaura porosa	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudopterogorgia americana	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leptogorgia setacea	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunicea fusca	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Muricea pinnata	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunicea sp. cf. tourneforti	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudopterogorgia rigida	*	.	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pterogorgia guadalupensis	*	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudopterogorgia acerosa	*	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudoplexaura flagellosa	.	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunicea knighti	.	*	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lophogorgia hebes	*	*	.	.	.	*	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plexaurella dichotoma	.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunicea calyculata calyculata	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lophogorgia punicea	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 3.7-3. (Cont.)

Species	Station 13-19 m					20-32 m					44-58 m					62-77 m					127-159 m			
	44	52	51	45	47	13	19	1	7	15	21	3	27	9	17	10	11	23	29	30	36	32	35	38
Lophogorgia barbadensis	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eunicea calyculata	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Lophogorgia cardinalis	.	.	.	.	*	*	*	.	.	*	.	*	*	*	*	.	*	.	.	.	.	.	.	.
Leptogorgia medusae	.	*	.	.	.	.	.	.	.	.	.	*	.	.	.	.	*	.	.	.	.	.	.	.
Swiftia costa	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.
Virgularia presbytes	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.
Telesto fruticulosa	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.
Leptogorgia euryale	.	.	.	.	.	.	.	.	.	.	.	*	.	.	*	.	.	.	.	.	.	.	.	.
Diodogorgia nodulifera	.	.	.	.	.	.	.	.	*	.	.	*	.	.	.	.	.	.	*	*	.	.	.	.
Telesto sanguinea	.	.	.	.	.	.	.	.	*	.	.	*	*	.	.	*	*	.	.	.	.	.	.	.
Leptogorgia stheno	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	.	.	*	.	.	.	.	.	.
Keratoisis flexibilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Lignella richardi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.
Telesto corallina	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	*	.	.	.	.	.	.	.
Ellisella atlantica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*	*	.	*	.	.	.	.
Eunicea calyculata coronata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.
Nicella schmitti	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	.	.	.
Thesea plana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.
Telesto operculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	*	.	.	.	.
Bellonella tenuis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.
Ellisella elongata	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	*	.	.	.	*	.	.	.
Nidalia occidentalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	*	.	.	.
Scleracis guadalupensis	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	*	*	.	.	*	*
Thesea parviflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	.	.	*	.	*	.
Nicella guadalupensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*	.	*	.	*	*
Ellisella barbadensis	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	*	.	.	.	*	.	*	*
Caliacis nutans	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	*	.
Scleracis petrosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	*	*
Placogorgia rudis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.
Siphonogorgia agassizii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	*	.	*	*

Table 3.7-3. (Cont.).

Species	Station																							
	13-19 m					20-32 m					44-58 m					62-77 m					127-159 m			
	44	52	51	45	47	13	19	1	7	15	21	3	27	9	17	10	11	23	29	30	36	32	35	38
Thesea citrina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	*	*
Thesea grandiflora rugulusa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	.
Ellisella funiculina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	*
Placogorgia tenuis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	*
Thesea grandiflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*	*
Placogorgia mirabilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	*
Nicella cf. *granifera*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	*
Nicella americana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.
Bebryce grandis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.
Thesea hebes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*
Thesea guadalupensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*
Villogorgia nigrescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*

*Indicates species occurred in at least one dredge or quadrat sample from the listed station.

Station 55. Away from the mainland coast with its associated turbid waters, the gorgonians apparently are able to extend into greater depths.

Zonation patterns on the middle and outer shelf are not as well defined. Octocoral densities are much lower than in the nearshore zone, and the species lack zooxanthellae. Examples of widely distributed middle shelf species are Lophogorgia cardinalis (19 to 77 m), Diodogorgia nodulifera (30 to 76 m), and Telesto sanguinea (30 to 77 m). Common middle to outer shelf species include Ellisella barbadensis (50 to 159 m), Scleracis guadalupensis (62 to 159 m), and Siphonogorgia agassizi (77 to 159 m). Species apparently restricted to the outer shelf include Thesea grandiflora, Placogorgia mirabilis, and Nicella cf. granifera.

Sponges

Sponges are colonial invertebrates that occur widely in hard-bottom habitats, including Caribbean reefs and the Florida reef tract (Schmahl, 1983). The southwest Florida shelf harbors a diversity of sponges that collectively accounts for a large portion of the epifaunal biomass in most locations, especially on the inner and middle shelf. All sponges are suspension feeders, and many also apparently contain symbiotic blue-green algae (cyanobacteria), which serve the same function as the dinoflagellate zooxanthellae of the corals (Wilkinson, 1983).

There are four classes of sponges. Most of the species collected on the shelf belong to the Demospongea, which contain siliceous spicules and/or organic spongin fibers. This group includes the common commercial sponges (sheepswool sponge, Hippospongia lachne, and various species of Spongia) (Walton Smith, 1954), boring sponges (e.g., Cliona), and some of the most conspicuous species such as Spheciospongia vesparium (loggerhead sponge) and Ircinia campana (vase sponge). Class Calcarea is represented by only four genera in the southwest Florida shelf collections (Clathrina, Leucetta, Leucoselenia, and Aphroceras). Sponges in this group contain calcareous spicules. A third group, the Hexactinellida, contains only deepwater forms (glass sponges) that contain siliceous spicules. Two species (Aulocystis zittelii and Dactylocalyx pumiceus) were identified from the southwest Florida shelf collections, along with specimens from two other genera (Hexactinella and Eurete). Many of the outer shelf specimens were not identifiable to genus or species. The fourth class, Sclerospongiae, is not represented in the southwest Florida shelf collections.

Sponge cover ranged from 0 to 23.4% of the total bottom area viewed in still photographs from the southwest Florida shelf stations. Values were typically less than 10%, except at Stations 15 (12.5 to 23.4%) and 21 (9.0 to 13.9%). Sponge biomass, estimated at five nearshore stations during Year 3, ranged from 446 to 3,098 g/m^2 (wet weight) and accounted for 58% of total epifaunal biomass (>70% at some stations) (Continental Shelf Associates, Inc., 1987).

Table 3.7-4 lists 75 sponge species collected by dredge at two or more stations during Years 1 through 3 of southwest Florida shelf studies. Eighteen additional species were present at only one station and are not listed. Not included in the table are the many specimens identified only to genus or higher levels; additional species undoubtedly are present in this group. The largest numbers of sponge species were collected at Stations 15 and 21 and four stations of the nearshore group (Stations 44, 45, 51, and 52). The smallest numbers of species were collected at the outer shelf stations and Station 9 (56 m).

Well-defined zonation patterns are not evident in the data. Several species, such as Euryspongia rosea, Thalysias juniperina, and Hemectyon pearsei, were restricted to the inner shelf (≤20 m). Most of the remaining species were present at several stations on the inner to middle shelf (to 60 or 70 m). Examples of widely distributed species in this category are Cinachyra alloclada, Geodia gibberosa, Haliclona compressa, Ircinia campana, and Placospongia melobesioides. Few species were

Table 3.7-4. Occurrences of sponges in dredge samples from live-bottom stations.

Species	Station 13-19 m					20-32 m					44-58 m					62-77 m					129-159 m			
	44	52	51	45	47	13	19	1	7	15	21	3	27	9	17	10	11	23	29	30	36	32	35	38
Spongia tubulifera	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thalysias juniperina	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hemectyon pearsei	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tethya seychellensis	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ulosa ?hispida	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tethya crypta	*	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nepheliospongiidae sp. A	*	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Myriastra kallitetilla	*	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Timea mixta	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Euryspongia rosea	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhizochalina oleracea	*	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Siphonodictyon sp. A	.	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Epipolasis lithophaga	*	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ptilocaulis ?spiculifer	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pandaros acanthifolium	*	*	.	.	*	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Axinella bookhouti	*	*	*	*	*	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Haliclona viridis	.	*	*	*	*	.	*	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cinachyra kuekenthali	*	*	*	*	.	.	.	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Homaxinella rudis	.	.	.	.	.	*	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Igernella notabilis	*	*	*	*	*	.	*	.	.	.	*	.	.	.	*	.	.	.	.	.	.	.	.	.
Homaxinella waltonsmithi	*	*	*	*	*	*	*	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.
Cliona delitrix	.	.	*	*	.	*	.	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Hippospongia lachne	.	.	*	*	.	.	*	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Chondrilla nucula	*	*	*	*	.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	*	.	.	.	.
Ircinia campana	*	*	*	*	.	*	.	.	.	*	*	*	.	.	.	.	.	.	*	.	.	.	.	.
Spheciospongia vesparium	*	*	*	*	*	*	*	.	*	*	*	*	*	.	.	.	.	.	*	.	.	.	.	.
Halichondria ?magniconulosa	.	.	.	.	.	.	*	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Spinosella vaginalis v. armigera	.	.	.	.	.	.	*	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudaxinella lunaecharta	*	*	*	*	.	*	.	*	*	*	*	*	.	.	.	.	.	.	*	*	.	.	.	.
Oxeostilon burtoni	.	*	.	.	*	*	*	*	*	*	*	*	.	.	.	.	*	.	.	.	.	.	.	.
Aiolochroia crassa	*	*	*	*	*	*	*	*	.	*	*	*	*	.	*	*	.	.	*	.	.	.	.	.

Table 3.7-4. (Cont.).

Species	Station																							
	13-19 m					20-32 m					44-58 m					62-77 m					129-159 m			
	44	52	51	45	47	13	19	1	7	15	21	3	27	9	17	10	11	23	29	30	36	32	35	38
Haliclona compressa	*	*	*	*	*	*	*	.	.	*	*	.	.	.	*	.	.	*	*	*	.	.	.	.
Ircinia felix	*	*	*	*	*	*	.	.	.	*	*	*	*	.	.	*	*	.	.	.	.	.	.	.
Anthosigmella varians	*	*	*	*	*	*	*	.	*	*	*	*	*	.	*	*	.	*	.	.	.	.	.	.
Geodia gibberosa	*	*	*	*	*	*	*	.	.	*	*	*	.	.	.	*	*	.	*	.	.	.	.	.
Aplysina fistularis v. fulva	*	*	*	*	*	*	*	.	.	*	*	*	*	.	*	*	.	.	*	.	.	.	.	.
Pseudaxinella rosacea	.	.	.	.	.	.	.	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Axinella polycapella	*	.	.	*	*	*	.	*	*	*	.	*	.	*	.	.	.	.	*	*	.	.	.	.
Niphates erecta	*	*	*	*	*	*	.	.	.	*	*	*	*	.	.	.	.	*	*	*	.	.	.	.
Cinachyra alloclada	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	.	*	*	.	.	.	.
Cliona celata	.	.	.	.	.	*	*	.	*	*	.	.	*	.	.	.	.	.	.	*	.	.	.	.
Iotrochota birotulata	.	.	.	.	.	.	.	*	*	*	*	*	.	.	*	.	.	.	.	.	.	.	.	.
Higginsia strigilata	*	.	.	*	.	.	.	*	*	.	.	*	.	.	.	.	*	*	.	.	.	.	.	.
Placospongia melobesioides	*	*	*	*	.	*	*	*	*	*	*	*	*	.	*	*	*	*	*	*	.	.	.	.
Microciona prolifera	.	.	.	.	.	.	.	*	*	*	*	*	.	.	.	.	*	.	.	.	.	.	.	.
Anthosigmella varians v. incrustans	.	.	.	.	.	.	.	.	*	*	*	*	.	.	*	.	.	.	.	.	.	.	.	.
Siphonodictyon siphonum	.	.	.	.	.	*	.	.	.	*	*	*	*	.	*	.	.	.	.	.	.	.	.	.
Neofibularia nolitangere	.	*	*	*	.	.	.	.	.	*	*	.	*	.	*	*	*	*	*	.	.	.	.	.
Spirastrella coccinea	.	.	.	.	.	*	.	.	*	*	*	*	*	.	*	*	.	.	*	.	.	.	.	.
Aplysina lacunosa	.	.	.	.	.	.	.	.	.	*	*	.	.	.	.	.	.	.	*	.	.	.	.	.
Hyattella intestinalis	.	*	*	*	.	.	.	.	.	*	*	.	.	.	*	*	*	*	.	*	.	.	.	.
Halichondria melanadocia	.	.	.	.	.	.	.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.
Phakellia folium	.	*	*	.	.	.	.	*	*	*	*	*	.	.	.	*	.	*	.	.	*	.	.	.
Lissodendoryx isodictyalis	.	*	.	.	.	.	.	*	.	.	*	*	*	.	*	*	.	.	*	.	.	.	.	.
Spinosella plicifera	.	.	.	.	.	.	.	.	.	*	*	*	*	.	.	.	.	.	*	.	.	.	.	.
Aplysina fistularis	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.
Ircinia strobilina	*	*	*	*	*	*	.	.	*	*	*	*	*	.	*	*	*	*	*	*	*	*	.	.
Tethya actinia	.	.	.	.	.	.	.	.	.	*	*	*	*	*	.	.	.	.	.	*	.	.	.	.
Coelosphaera fistula	.	.	.	.	.	.	.	.	.	.	*	.	*	.	*	.	.	.	.	.	.	.	.	.
Scolopes megastra	.	.	.	.	.	.	.	.	.	*	*	.	.	.	.	.	*	.	*	.	.	.	.	.

Table 3.7-4. (Cont.).

	Station																							
	13-19 m					20-32 m					44-58 m					62-77 m					129-159 m			
Species	44	52	51	45	47	13	19	1	7	15	21	3	27	9	17	10	11	23	29	30	36	32	35	38
Pellina ?carbonaria	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	*	.	.	.	.
Leucetta ?floridana	.	.	.	.	.	.	*	.	.	.	*	*	*	.	.	.	*	.	*	*	.	.	.	.
Erylus trisphaera	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	*	.	.	.	.	.
Dysidea fragilis	.	.	.	.	.	.	.	*	.	.	.	.	.	.	*	*	.	*	*	.	.	.	.	.
Teichaxinella morchella	.	.	.	.	.	*	.	.	*	.	*	*	.	.	.	*	*	*	.	.	*	.	.	.
Erylus formosus	.	.	.	.	.	.	.	.	.	.	*	.	.	.	*	*	*	.	.	*	.	.	.	.
Geodia neptuni	*	.	.	.	.	.	.	.	.	.	.	*	*	.	*	*	*	*	*	*	.	*	.	.
Cliona schmidti	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	*	*	.	.	.	.
Xestospongia subtriangularis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	.	.	.	.
Teichaxinella shoemakeri	.	.	.	.	.	.	.	.	*	.	*	*	.	.	.	*	*	*	.	*	.	*	.	.
Laxosuberites coerulea	.	.	*	.	.	.	.	.	.	.	*	.	.	.	.	.	.	*	.	*	.	.	.	*
Myriastra ?crassispicula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	.	.	.	.	.	.
Stylocordyla ?longissima	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	*	*	*	*
Pachastrella ?monilifera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*

*Indicates species occurred in at least one dredge sample from the listed station. Only species occurring at two or more stations are listed.

present on the outer shelf; Stylocordia (?)longissima and Pachastrella (?)monilifera were common, and two hexactinellids, Dactylocalyx pumiceus and Aulocystis zittelii, also were collected at one station (not shown in the table). Other hexactinellids were collected but not identified to genus or species. Of the common inner-middle shelf species, only Ircinia strobilina occurred on the outer shelf, although not at the deepest stations.

Crinoids

Comatulid crinoids (feather stars) are conspicuous elements of the outer shelf epifauna. Feather stars are discretely motile rather than sessile; the organisms can swim, and they attach by means of their basal cirri to various substrata, such as rock, shell, and other animals. Nutrients are derived via suspension feeding.

Common species on the southwest Florida shelf are Comactinia meridionalis, Crinometra brevipinna, Leptonemaster venustus, and Neocomatella pulchella. Comactinia meridionalis was collected at Stations 29 (62 m) and 30 (76 m), as well as on the outer shelf; the other species occurred only at the four outer shelf stations (127 to 159 m). The crinoids were associated with exposed hard bottom as well as areas of coarse shell rubble (especially at Station 36).

Quantitative data on crinoid abundance are available from Years 4 and 5 television surveys at Station 36 (depth: 127 m). The substratum at this station consisted of very coarse sand and shell rubble. The average crinoid density was 3 individuals per square meter (Danek and Lewbel, 1986). Leptonemaster venustus was the most abundant crinoid in dredge samples collected from this station during Year 2 (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1985).

3.7.3 DISCUSSION

Five years of dredge, trawl, and photographic sampling on the southwest Florida shelf have shown that the area supports a very diverse sessile epifauna. Likely contributing factors are the large area of the shelf, the range of water depths and substratum types represented, the generally favorable temperature regime for tropical and subtropical species, and the proximity to sources of colonizing reef biota.

Zonation patterns of the groups discussed in the preceding sections are similar in that all appear related primarily to water depth. However, there are differences in the patterns of abundance and species composition among groups. For the octocorals, the major breakpoint in species composition and abundance appears to be at the 20-m isobath (or slightly deeper in the clear waters near the Dry Tortugas). Octocoral species with middle and/or outer shelf affinities are present, but these groupings are not as distinct as the one seen on the inner shelf. For scleractinian corals, the major breakpoint appears to be at approximately 40 to 50 m, the seaward depth limit for many of the zooxanthellate species collected. There is a deeper, transitional zone containing several azooxanthellate species, as well as (in certain areas) zooxanthellate species capable of growing under conditions of low-light intensity (e.g., agariicids). Finally, the outer shelf is characterized by a suite of corals, including both solitary and colonial forms, that do not contain zooxanthellae. For the sponges, the major breakpoints appear to be at about the 20-m isobath (several species were restricted to shallower water depths) and the 60- to 70-m isobath (most species were restricted to shallower water depths). Crinoids, the other group discussed, occur primarily on the outer shelf.

The apparent importance of water depth as a master variable controlling zonation patterns of the major faunal groups undoubtedly reflects the influence of correlated environmental variables such as temperature, light, and substratum type. Zonation patterns that appear related to factors other than water depth alone (e.g., the occurrence of Agaricia in the vicinity of Station 29, but not at other locations in this depth range) probably reflect non-bathymetric variations in these underlying controlling factors.

Temperatures on most of the shelf are usually suitable for tropical species to flourish. Recording thermographs deployed at selected stations during Years 4 and 5 showed that temperatures were greater than 18°C most of the time, except at one station on the outer shelf (Station 36) (Danek and Lewbel, 1986). Inner shelf temperatures are more seasonally variable than middle- and outer-shelf temperatures, however, and occasional cold fronts may kill large numbers of tropical invertebrates and fishes in shallow water (Bullock and Smith, 1979; Bohnsack, 1983). Temperatures on the outer shelf may also be too low at times for tropical species due to upwelling of cold water from the continental slope. The middle shelf probably is the most favorable for development of tropical assemblages (Miller and Richards, 1979).

Light is another important influence on the composition of sessile epifaunal communities. As noted previously, many of the corals and sponges present on the shelf contain symbiotic algae and depend, in part, upon photosynthesis to meet their nutritional requirements. Illumination decreases with increasing water depth, with the 1% (of surface incident) light level occurring at approximately 65 to 70 m on the southwest Florida shelf (Woodward Clyde Consultants and Skidaway Institute of Oceanography, 1983). Therefore, species that depend upon symbiotic zooxanthellae are restricted to the inner and middle shelf, with various taxa showing different bathymetric ranges depending on their adaptations to the light regime. Water column turbidity also affects the amount of light reaching the benthos, and nearshore areas are subject to episodic resuspension events that severely cloud the water. Nearshore species must be able to tolerate intermittent turbidity.

For sessile epifauna, the availability of suitable hard substratum for attachment is often a limiting factor. On the southwest Florida shelf, this is particularly important because there is very little exposed hard bottom and most is low relief (<1 m). Most areas of hard bottom are covered by a thin sand veneer, but the underlying rock must occasionally be exposed in order for larvae to attach and grow sufficiently to not be dislodged or buried when the area is covered again by sand. Where the sand veneer is thin and the potential for sediment movement is high, exposure and colonization of the hard bottom must be relatively frequent, and extensive growths of sessile epibiota would be expected. This appears to be true both on a local scale (epifaunal biomass and cover are greater at stations where the veneer is thick than where it is thin) and on a regional scale [live bottom associated with sand-covered hard bottom is most common on the inner shelf (<20 m) where the sand veneer is generally thin and the potential for sediment movement by surface waves is high].

Latitudinal differences in substratum type help to explain why Agaricia predominates in the vicinity of Station 29 but not at other stations in this depth range. The algal nodule pavement present in the southwest corner of the shelf only (65- to 80-m depth range) provides a favorable environment for growth of Agaricia, which does not tolerate sedimentation or scour (Hubbard and Pocock, 1972). Why the pavement develops in this area and not farther north is unknown, but temperature, nutrients, and hydrodynamics are probable major influences. The density of algal nodules generally increases from north to south in this depth range, possibly reflecting slightly higher temperatures and higher near-bottom nutrient levels toward the south (due to upwelling-induced doming of nutrient isopleths near the shelf break, which is steeper in the southern part of the study area). Also, nodules require particular hydrodynamic conditions for their formation. The incipient nodules form on bits of shell debris or other nuclei, and periodic rolling of the growths is necessary for the formation of spheroid or ovoid shapes (Bosellini and

Ginsburg, 1971). Rolling may be accomplished by surface waves during storms (not a major influence at these depths) or even by movement of sand waves, as suggested by McMaster and Conover (1966). Slightly more quiescent hydrodynamic conditions usually associated with increasing water depth can result in increasingly flattened or amoeboid growth, or ultimately, a flattened pavement.

3.8 MOTILE EPIFAUNA

3.8.1 INTRODUCTION

This section describes motile epifauna (large, free-living benthic invertebrates) censused during Years 1 through 5 of the Southwest Florida Shelf Ecosystems Program. As the program evolved, so did the methods used to study the distribution of these organisms. During Years 1 through 3, motile epifaunal species were collected primarily by dredging and trawling and surveyed qualitatively with underwater television. Epifauna was also harvested and photographed in quadrats by divers at some shallow stations. During Years 4 and 5, dredging and underwater television continued to be used, but epifauna collected with the trawl was considered incidental to the fish catch and discarded. Quadrat sampling was discontinued.

Both the triangular dredge and the trawl yielded high-resolution taxonomic data that was considered most appropriate to analyze only for presence or absence. To obtain density estimates, videotapes taken during Years 4 and 5 during site-specific underwater television surveys were examined. Additional information on epifauna was also available in the 35-mm still photographic data from Years 1 and 2. The density figures given in subsequent sections are derived exclusively from Years 4 and 5 underwater television data, since underwater television surveying covered a much larger sampling area than did any other technique.

Although dredge-and-trawl samples could be identified to species in the laboratory, many individuals seen in videotapes or still photographs could not be identified to species because small morphological details were not visible. Names were assigned to animals seen photographically whenever possible. Names were given at the species level only if collected specimens from the same location closely resembled those in photographic images and if they could not be confused visually with any other species collected there or nearby. Otherwise, the individuals were identified at a higher taxonomic level. The smaller an individual, the more difficult it was to identify visually. In practical terms, anything smaller than a grapefruit rarely could be classified visually beyond the family level.

The overview provided is confined to forms large enough to be seen and identified easily in videotapes, such as asteroids (sea stars), regular and irregular echinoids (sea urchins, sand dollars, and sea pussies), holothurians (sea cucumbers), gastropods (conchs), and decapods (lobsters, large crabs). The information is based primarily upon dredge, trawl, and videotape data, fused conceptually and interpreted in the context of some of the relevant literature. In the interests of brevity, only the largest, most abundant taxa are included. Details on less abundant or smaller motile epifauna are available in the program's various annual reports.

The Year 3 and Year 5 annual reports were most useful and least confusing for that purpose. The Year 1 final report contained significant errors, and most of the data were completely re-analyzed in the Year 2 final report. The Year 3 final report further refined the information in the Year 1 and Year 2 reports and summarized and integrated the combined data set from Years 1, 2, and 3. For similar reasons, the Year 5 final report re-analyzed most of the data from Year 4 and summarized both the Year 4 and Year 5 data.

At the onset of the 5-year sampling program, stations were arbitrarily divided into two categories (soft bottom versus live bottom), and each category was sampled biologically with different methods, although some techniques were used at both kinds of stations. For example, grab samplers were used at soft-bottom stations, but dredges were not. While this may have been a logical division of effort, the lack of quantitative television data and dredge data from the soft-bottom stations limited their inclusion in this discussion. As a result, the discussion pertains mainly to live-bottom stations. Paradoxically, most of the taxa discussed are soft-bottom forms, since large, motile invertebrates are easier to see and collect on sand than on hard substrates.

At live-bottom stations, a comprehensive picture of the epibiota was assembled though the use of various gear types. Most of these stations were a mosaic of unconsolidated sediment, gorgonian beds, corals, sponges, and other benthic features used to define the live bottom. Many species of motile epifauna found at these stations were present also at soft-bottom stations, as evidenced by trawl data from both sets of stations.

For convenience, the discussion is organized along taxonomic lines. A brief summary by general habitat type is also provided at the end of the section.

3.8.2 MAJOR TAXA

Asteroids

Asteroids were very frequently encountered on the southwest Florida continental shelf. The overall mean density of asteroids at the 12 live-bottom stations surveyed during Years 4 and 5 was 8.1 individuals per hectare. This is certainly an underestimate of their true density--perhaps by orders of magnitude--due to the habit of many species to partially or completely bury themselves in sediment.

Asteroids were common at every station except Station 29 (an *Agaricia* Plate Coral Assemblage site 64 m deep) and ranged in density up to 52.3 asteroids per hectare (at Station 44, a sandy site with scattered gorgonian beds, 13 m deep). Many species had wide depth ranges, implying that factors other than the availability of suitable unconsolidated substrate probably do not control their distributions on much of the shelf. Furthermore, asteroids (especially those found on sand) tend to be generalistic predators, capable of accepting various prey. Their catholic diets undoubtedly contribute to their cosmopolitan distributions. The most frequently encountered forms were members of the genera *Astropecten*, *Echinaster*, and *Luidia*.

Astropecten is sometimes called the sand star, because it is almost always found on or buried in sandy or shelly bottoms, where it feeds primarily on small molluscs (Downey, 1973; Kaplan, 1982). Kaplan (1982) also reported that Astropecten can feed on detritus, although this is unlikely to be an important feeding mode on most of the shelf where sediments tend to be very coarse. Of the 20 different asteroids taken with the triangular dredge during Years 4 and 5, there were five species of Astropecten, including Astropecten duplicatus, A. articulatus, A. comptus, A. americanus, and A. nitidus, all in water from 13 to 47 m deep. An unidentified Astropecten was collected with trawls from 14 different stations during Years 1 and 2, and eight asteroids (including Astropecten duplicatus and A. articulatus) were taken by dredging during Years 1 and 2. The only density record for Astropecten from this program is from the television data for Station 47: 0.3 individuals per hectare, species not identified.

Several species of Echinaster were collected during Years 1 through 5 by dredging and trawling. Echinaster (= Verrillaster) spinulosus and E. modestus spanned wide depth ranges: 13 to 32 m, and 13 to 74 m, respectively. E. sentus was collected by dredging and trawling during Year 3 at several stations 13 m deep and has been characterized as most commonly associated with coral debris, whereas E. spinulosus is more typical of soft bottoms (Kaplan 1982).

Luidia has also been described as a shallow water genus, confined to sand or sand/mud bottoms where they feed on small molluscs and other echinoderms (Downey, 1973). Luidia alternata, the limp sea star, was collected by dredging and trawling during Years 1 through 5 at stations ranging from 13 to 47 m deep. It would not have been expected to be visible in television transects due to its habit of lying in sand, partially buried (Kaplan, 1982). Luidia clathrata was collected during Year 3 in 13 m of water. Luidia barbadensis was collected only at Station 23, which is 74 m deep and has a bottom consisting of algal nodules and sand patches.

The reticulated sea star, Oreaster reticulatus, was also a prominent inhabitant of sandy areas. Oreaster is a typical inhabitant of sand flats and sea grass beds and is widely distributed in warm waters from Cape Hatteras and Bermuda to Brazil and the Cape Verde Islands (Colin, 1978). The largest of the sea stars in the region, Oreaster, has a distinctive appearance and cannot be mistaken for any other species.

Although Oreaster is found sometimes feeding among seagrasses, it apparently does not digest them, but, rather, everts its stomach around them and digests micro-organisms, fine filamentous algae, and detritus associated with them. It is also capable of everting its stomach against sandy substrates and feeding on detritus particles. The availability of fine-particulate organic material in the substrate is of primary importance in determining the suitability of a substratum type (Scheibling, 1980a). Oreaster is more common in sparsely covered areas, and adults actually avoid areas of dense growth of turtle grass, Thalassia testudinum, since the grass restricts its movement (Scheibling, 1980b).

Oreaster was seen in television transects at five stations during Years 4 and 5, in densities up to 28 individuals per hectare. These densities are probably fairly correct, since Oreaster does not burrow. Oreaster was collected by dredging and trawling at several stations during Years 1 through 5, at depth from 13 to 47 m, and was observed moving along the substrate several times in time-lapse camera records from Station 55 (27 m deep). Still-camera photographs from Year 2 also included a shot of Oreaster on coarse sand at Station 20 (22.5 m deep).

A number of asteroids were collected by dredging only at the deeper stations during Years 4 and 5. Species such as Narcissia trigonaria, Linckia nodosa, Henricia antillarum, Tosia parva, Rosaster alexandri, Pectinaster gracilis, and Sclerasterias contorta were taken at Stations 23 and 36 (74 and 125 m depth, respectively). Downey (1973) confirmed their status as deeper water forms, reporting a depth range for Narcissia trigonaria of 37 to 137 m; Henricia antillarum, 320 to 713 m; Linkia nodosa, 113 to 217 m; Tosia parva, 30 to 597 m; Rosaster alexandri, 60 to 443 m; Pectinaster gracilis, 128 to 548 m; and Sclerasterias contorta, 20 to 344 m. They were not particularly abundant as a group, averaging from 0.5 to 2 individuals per hectare in television transects at Stations 23 and 36.

Echinoids

Most of the irregular echinoids examined in this program were burrowing, soft-bottom forms. Dredging and trawling produced many clypeastroid sand dollars or cake urchins, such as Clypeaster subdepressus, C. rosaceus (the common West Indian sea biscuit), Encope michelini, and E. aberrans; spatangoid heart urchins such as Meoma ventricosa (the sea pussy), and Echinolampas depressa. Overall density for these burrowing species was 23.4 individuals per hectare, based on underwater television data from Years 4 and 5. Echinoids were most abundant in shallow water. For instance, at Station 44 (13 m deep), their average density was 620 individuals per hectare. Due to the cryptic habits of most of these species, these densities are certainly underestimates.

Clypeastroids and spatangoids are all sand dwellers. Many members of this group span considerable depth ranges, both on the southwest Florida shelf and elsewhere. For example, Clypeaster subdepressus has a reported range of 5 to 210 m, and Meoma ventricosa of 2 to 200 m (Serafy, 1979). Their widespread distribution is probably a result of the comparative lack of specificity of their diets. Burrowing forms such as Meoma ingest large quantities of sediment, from which they extract nutrients; sand dollars such as Clypeaster are suspension, deposit, or ciliary-mucus feeders that selectively remove small particles from the water and surficial sediment layers (Hyman, 1955). It is not surprising, therefore, that unidentified mellitid sand dollars (a general term for various sand dollars that could not be identified in videotapes) were identified at stations spanning the entire depth range of the Years 4 and 5 studies (13 to 125 m).

Burrowing echinoids are a very important source of bioturbation in soft sediment on the shelf and could influence the fate and persistence of any contaminants deposited on sand in their vicinity. Their tracks were conspicuous features on the bottom. At Station 7 (32 m deep), burrowing echinoids were visible as moving mounds of sand in time-lapse camera records. They left trails 10 to 15 cm wide and up to 5 m long per night. They were active only at night, confirming that their true densities were underestimated in daytime underwater television surveys.

The abundance of echinaceans (regular sea urchins) was very low in underwater television samples (<0.1 per hectare), and they could not be identified to species on videotapes, although they were common in dredge-and-trawl hauls, especially those that included reef corals.

Several echinaceans collected during this program are associated with coral reefs. Perhaps the most obvious example is the long-spined sea urchin, Diadema antillarum. Diadema is a generalized herbivore, with a dietary preference for turtle grass (Thalassia testudinum) and small algae usually found growing on coral reefs, such as Herposiphonia secunda (Ogden et al., 1973). Diadema has been reported from "all kinds of marine communities," even reaching depths of 400 m (Weil et al., 1984; Avent et al., 1977).

Diadema can grow to at least 40 cm in diameter (spine, tip-to-tip) and often returns to the same crevice or general area during the daytime (Braverman and Konigsberg, 1973; Shy and Wu, 1973). Its necessity for shelter is almost certainly a response to predation (Carpenter, 1984). At least 15 species of fishes, several gastropods, and spiny lobsters (Panulirus argus) eat Diadema (Colin, 1978; Randall et al., 1964; Weil et al., 1984). Diadema was collected at few stations during this program (2 out of 12 stations during Years 4 and 5). Its overall density in underwater television transects was very low (<0.1 individuals per hectare), and it was not observed even at Station 29, despite its frequent appearance in dredge-and-trawl collections there in Years 1 and 2.

This observation serves to highlight the importance of comparing visual or video surveying to specimen collections. On the basis of the coral and algal species lists, Diadema would have been expected to be common at more stations. However, videotapes revealed that the hard substrate at most stations was too low in relief to provide adequate shelter for Diadema in the daytime. Station 29 is an Agaricia plate coral environment, which offers many nooks and crannies where Diadema can hide.

An alternative (and simpler) explanation for the dearth of Diadema may also be true. For the past 3 years, Diadema in the Caribbean has suffered from a disease of unknown origin that has caused mortalities of nearly 100% on many islands (Hughes et al. 1985; Lesios et al., 1984). It is possible that Diadema was much more abundant on the Florida shelf prior to 1983, when the disease first started to spread throughout the Caribbean. Quantitative video surveying did not begin until late 1983, when Diadema had already experienced heavy losses throughout the Caribbean.

Many other urchins collected by dredging do not require shelter within coral reefs and are frequently found on unconsolidated substrates. Since urchins are primarily herbivores and depend mainly on attached or drift algae for food, they would be expected to be less abundant on sandflats and other large areas of unconsolidated substrate than on or near exposed hard substrate. Representative species collected by dredging included Arbacia punctulata, Eucidaris tribuloides, Lytechinus variegatus, L. euerces, L. callipeplus, Stylocidaris lineata; S. lineata, and Coelopleurus floridanus.

The brown rock urchin, Arbacia punctulata; the pencil urchin, Eucidaris tribuloides; and the green sea urchin, Lytechinus variegatus, were collected often in dredge samples. Arbacia punctulata has very broad habitat requirements; it is reported from rocky and sandy bottoms as far north as Cape Cod (Kaplan, 1982).

Although Eucidaris is most common on reefs, where it often feeds on limestone invaded by the boring sponge, Cliona (Serafy, 1979), it is not necessarily confined to those reefs and has a reported depth range of 0 to 800 m. It and Lytechinus variegatus are abundant also on sand and in seagrass beds, such as those in shallower portions of the study area (Kaplan, 1982; Serafy, 1979). Lytechinus is primarily a herbivore. It occasionally experiences population explosions in seagrass beds and has completely denuded some turtlegrass (Thalassia testudinum) areas in Florida (Serafy, 1979).

Holothurians

There are many species of holothurians on the southwest Florida shelf. Miller and Pawson (1984) described 16 species collected during the Hourglass cruises, in depths from 6 to 73 m on the northern side of the Years 1 through 5 study area. All of the species taken in this program (e.g., Thyonella gemmata, T. pervicax, and Isostichopus badionotus) were identified also in samples from the Hourglass cruises.

Holothurians had an overall density in underwater television samples from Years 4 and 5 of 2.1 individuals per hectare. They were common at most shallow water stations, but were not seen at any stations deeper than Station 29 (64 m).

Most holothurians are deposit feeders that typically sweep the surface of or ingest unconsolidated substrates, digesting the organic matter and ejecting large amounts of sediment as fecal material.
Holothurians are frequently associated with hard substrates, since sessile organisms generate a considerable amount of organic matter in

their vicinities. For example, many relatively fragile sea cucumbers such as the synaptids (e.g., Euapta lappa) live in crevices under rocks adjacent to soft substrate, over which they extend and feed at night. However, more robust forms are most common on sand and mud.

The most widespread holothurian collected by dredging and trawling on the shelf during Years 1 through 5 was Isostichopus badionotus, the three-rowed or chocolate chip sea cucumber, collected in depths ranging from 13 to 24 m. Miller and Pawson (1984) indicated that it can range to 55 m, but its depth preference on the central Florida shelf is about 18 m. Where present, Isostichopus achieved densities from 0.3 to 3.9 individuals per hectare. This large sea cucumber (to 45 cm long) is likely to be responsible for a considerable amount of bioturbation. Kaplan (1982) reported that Isostichopus fills its gut with sand and empties it several times a day. Other sea cucumbers also may have similar patterns of large-scale ingestion, since the organic material that can be extracted by digestion from calcareous sand is probably fairly low.

Holothurians such as Isostichopus may be quite vulnerable to exposure to benthic contamination due to their relatively sedentary habits and their eating habits. Any contamination reaching the sediment could be ingested with sand. Contaminants could possibly be packaged in fecal material and ejected in more cohesive or concentrated form or absorbed by the gut during the passage of large volumes of sediment. Isostichopus may re-ingest its own fecal material (Miller and Pawson, 1984), providing another potential opportunity for extraction or concentration of contaminants.

Crinoids and Ophiuroids

Comatulid crinoids are perhaps not appropriate for inclusion in this section, since their mobility is quite limited. However, their very high densities at deeper stations along the southern transects (e.g., almost 30,000 per hectare at Station 36) and diversity (e.g., Comactinia meridionalis, Neocomatella pulchella, Leptonemaster venustus, and Crinometra brevipinna) make them important, characteristic outer shelf organisms. Being suspension feeders, they would be potentially vulnerable to contamination by suspended particulate and colloidal pollutants. Ophiuroids were extremely abundant and diverse in dredge samples. At least 30 species were collected, some at many stations. For example, Ophiothrix angulata appeared in dredges at 10 of the 12 Years 4 and 5 live-bottom stations. However, they were too small to view in videotapes, and no density estimates are available for the southwest Florida shelf.

Gastropods

Gastropods are extremely diverse on the southwest Florida shelf. During Year 1, almost 200 taxa of prosobranch gastropods were collected, including many relict species ("living fossils," Petuch, 1983). During Year 3, 65 species were collected at five stations, all in 13 m of water. During Years 4 and 5, 64 species of gastropods were identified from 12 stations, including the rare abalone, Haliotis pourtalesii. The gastropod fauna of the shelf is sufficiently diverse to permit the clear definition of zones lying roughly parallel to depth contours (Lyons, 1979).

Nearly all of the gastropods collected by dredging and trawling in this program were too small to see and identify on videotape. Many of the smaller gastropods were predatory forms such as Conus spp. and Oliva spp., which would often be partially or wholly buried in sediment. Many other gastropods were sometimes associated or collected with sponges and other sessile epibiota, such as Diodora spp. and Cypraea spp., and many muricids. The larger forms could be picked out of samples on deck, but many smaller species were discovered only later when preserved samples were sorted.

The only gastropods for which density estimates could be made from underwater television transects were conchs, Strombus spp. They were not particularly abundant throughout the study area, but did achieve high local densities occasionally (e.g., 12.2 per hectare at Station 44, 13 m deep). Conchs were sometimes seen on sandy bottoms, but could not be identified to species in underwater television transects. Trawls and dredges during Years 1 through 5 collected queen conchs, *Strombus gigas*, and fighting conchs, *S. pugilis*, at stations from 13 to 27 m deep; Florida fighting conchs, *S. alatus*, from 13 to 32 m deep; and milk conchs, *Strombus costatus* from 13 to 47 m deep. These depth ranges exceed those described by Opresko *et al*. (1976). However, Brownell and Stevely (1981) noted that queen conchs may be found as deep as 76 m, although they are usually in water 30 m deep or less. The restriction is thought to be related to their dietary requirements.

Conchs are herbivores, grazing on algae and seagrasses. As a result, conchs are most abundant in the vicinity of seagrass beds, coral reefs, or other sources of nutrition. Most plants are found in shallow water, and their depth distribution in this program mirrored that of most conchs. For example, the average number of plant taxa identified during Years 4 and 5 from dredge samples taken in depths of 13 to 47 m was 15.6 per station. By comparison, deeper stations averaged only 5 plant taxa per station.

Conchs may be important in bioturbation within the study area. Tracks were often seen in sandy locations, and some of these are thought to have been caused by conch movement. Queen conchs may cover 50 to 100 m/day (Hesse, 1979). When not involved in inshore/offshore seasonal migrations, queen conchs exhibit homing behavior and tend to remain within circumscribed areas. Larger conchs have larger home ranges and produce bigger furrows.

Conchs may also be particularly sensitive to localized benthic contamination, since they sometimes remain in one area for long periods of time. The home range of small conchs may be only a few hundred square meters, and queen conchs of all sizes may bury themselves in sand during stormy weather or during periods of dormancy. These periods of dormancy may last up to 6 weeks. Furthermore, while buried, conchs would not be visible on television. Estimates of their abundance based upon underwater television data may be erroneously low, especially during the winter, when storms are most frequent.

Crabs

Many brachyuran and anomuran crabs were collected by dredging and trawling during the 5-year program. In the first year alone, almost 270 taxa of crabs were included in the species list. Many small crabs were also present in harvested quadrats taken during Year 3. Most of the small crabs were xanthids, majiids, petrolisthids, porcellanids, and pagurids (e.g., Stenorhynchus seticornis, Mithrax spp., Dromidia antillensis, Macrocoeloma spp., Paguristes spp., and Pagurus spp.) associated with larger sessile epibiota such as corals and sponges. When masses of sponges were brought on deck, hundreds of tiny crabs often fell out of them. Stenorhynchus was collected at 23 of the 24 Years 1 through 3 stations by dredging, for example.

The only crabs large enough to be recognized reliably in underwater television samples from Years 4 and 5 were calappids (box crabs) and portunids (swimming crabs). They were uncommon in videotapes, seen only at two stations, where their densities were less than 1 per hectare. However, it is very likely that their true abundances in the study area were substantially higher than the video data would suggest.

Both calappids and portunids often partially or completely bury themselves in sediment (Williams, 1984), probably as a response to predation by fishes. While buried, they cannot be observed with underwater television cameras. Nonetheless, they are capable of rapid movement and might be expected to move rapidly from localized sources of irritation such as pollutants or mechanical disturbance.

Dredge and trawl samples during Years 1 through 5 revealed a diverse assortment of portunids, including Portunus gibbesii, P. depressifrons, P. spinimanus, P. anceps, P. floridanus., an unidentified species, P. ordwayi, and P. spinicarpus. All but the last two were collected in water less than 32 m deep. Portunus ordwayi had a depth range that extended to 74 m and P. spinicarpus to 125 m.

The portunids are opportunistic scavengers and predators, capable of catching small fish and invertebrates or grazing on benthic organisms. Several of them are typical shallow water inhabitants, such as P. depressifrons, usually found on sandy bottoms between 0 and 29 m, and P. anceps, most abundant on or near sandy shores in depths of 0 to 20 m; however, both these species can be found occasionally in much deeper water (e.g., 93 m and 103 m, respectively) according to Williams (1984). Portunus gibbsii, P. spinimanus, and P. spinicarpus appear to favor deeper offshore waters (Felder, 1973). However, portunids have very wide depth ranges reported in the literature (e.g., Portunus gibbesii, 0 to 393 m; P. floridanus, 9 to 640 m; P. spinimanus, 0 to 393 m; P. ordwayi, 0 to 366 m; and P. spinicarpus, 9 to 550 m).

Box crabs taken in trawls and dredges included Calappa sulcata, C. flammea, and C. angusta. C. angusta was collected as deep as 125 m, whereas the maximum depth for C. flammea was 47 m and for C. sulcata, 24 m. Wide depth ranges have been reported for all these species (Williams, 1984; Felder, 1973). Calappa flammea, in particular, spends much time buried beneath the sand with only its eyes projecting (Kaplan, 1982).

The stone crab, Menippe mercenaria, was not collected offshore during this program. Although Menippe has been collected as deep as 51 m (Williams, 1984), it prefers shallow water, and larger individuals are often found burrowing in mud flats, harbors, and other tidal locations. The area inshore of the sampling sites for this program--especially in Florida Bay--includes many suitable habitats for Menippe and has been harvested commercially for years (Bert et al., 1978). Menippe juveniles have been reported to prefer deeper water than do adults (Kaplan, 1982) and may be more likely to be at risk than the adults with regard to possible impacts by offshore development.

Another large crab which was not observed on underwater television during Years 4 or 5, but which was collected in dredges and trawls and noted in still photographs, was the giant decorator crab, Stenocionops furcata. Stenocionops was collected by dredging at stations ranging from 20 to 47 m deep, and photographed at 146 m during Year 2. Stenocionops has been previously recorded in the Gulf of Mexico at depths of over 100 m (Felder, 1973) and elsewhere to 227 m on various bottom types (Williams, 1984).

Large paguridian hermit crabs were seen relatively often on soft bottoms in underwater television transects. These crabs were usually living in Strombus shells. Their densities were probably somewhat underestimated during video surveys, because unless crab legs were seen projecting from shells, the shells were recorded as gastropods. Even so, the overall density of large hermit crabs (0.4 per hectare) was similar to that of conchs (0.5 per hectare). They were recorded at depths from 13 to 74 m in video transects and frequently collected by dredging and trawling in depths from 13 to 125 m.

Hermit crabs have broad habitat requirements; many species collected in this program have reported depth ranges from the surface to hundreds of meters and have diets that include benthic algae and detritus, as well as infaunal and epifaunal invertebrates (Williams, 1984). Individuals carrying conchs or other large gastropod shells were generally restricted to fairly flat terrain such as sand flats and seagrass beds. Although hermit crabs could not be identified visually, dredge-and-trawl samples included several very large species that are often found in large gastropod shells, such as Dardanus fucosus, the bar-eyed hermit crab,

D. venosus, the star-eyed hermit crab, and Petrochirus diogenes, the red hermit crab.

Lobsters

Both palinurid (spiny) and scyllarid (slipper or shovelnose) lobsters are found on the southwest Florida shelf, although they were fairly scarce in samples collected in the study area during Years 1 through 5. This is hardly surprising, since lobsters are caught most effectively in traps rather than with dredges or trawls. They were viewed occasionally on underwater television and in time-lapse camera frames. Due to their cryptic behavior, lobster densities in the study area were probably much higher than the samples from this program would suggest.

Palinurids in the area include the spiny lobster, Panulirus argus, and the spotted spiny lobster, Panulirus guttatus. Panulirus argus spawns primarily in the spring in Florida (Gregory et al., 1982) and may undergo mass migrations to and from deep water in the fall, apparently triggered by falling water temperatures (Kanciruk and Herrnkind, 1978). Panulirus guttatus is sometimes more common in shallow water in Florida than is P. argus. It spawns mainly in June in Florida, and its reported depth range (2 to 24 m) is less than that of P. argus (0 to 90 m).

Both species of Panulirus are common primarily near coral reefs or other relief that can provide large holes for shelter during the daytime (Colin, 1978). Smaller individuals are sometimes numerous in seagrass beds and along shorelines. Spiny lobsters are more prone to be seen in the open during the daytime than are spotted spiny lobsters. Panulirus argus was identified in underwater television surveys at Stations 21 and 23 (47 and 74 m deep, respectively), but with very low overall density (less than 0.1 individual per hectare).

Five species of scyllarids (Scyllus chacei, S. americanus, S. faxoni, Syllarides nodifer, and Scyllarides aequinoctialis) were taken in dredges or trawls during Years 1 through 5 of this program, mostly at stations between 13 and 47 m deep. The overall density of scyllarids seen with underwater television during Years 4 and 5 was very low--less than 0.1 individual per hectare--but these surveys took place during the daytime when scyllarids are inactive. Scyllarids do not require the large holes that palinurids do, since they are flattened and more easily camouflaged in crevices and depressions. They are frequently found on irregular bottoms of sponges, coralline algae, shell hash, and rocky outcrops (Lyons, 1970).

Lobsters are probably active at night in order to reduce their exposure to predators. Predators on adult scyllarids include many fishes found on the shelf, including red groupers, Epinephelus morio; gag groupers, Mycteroperca microlepis; dusky flounders, Syacium papillosum; cubbyus, Equetus acuminatus; scorpionfish, Scorpaena brasiliensis; snakefish, Trachinocephalus myops; and several other less common forms.

3.8.3 SUMMARY

Dividing the southwest Florida shelf into benthic habitat types, biotic assemblages, or zones is probably necessary for conceptual purposes. Most areas consist of a mosaic of different habitat types. In the Year 3 report, Phillips divided the live bottom into seven differentiable types of assemblages. In addition, there are clearly defined depth differences for most sessile fauna. However, many of the animals mentioned previously may be found at most locations, no matter what benthic biotic designation appears to be most appropriate. The reason for this is the majority of large, motile epifaunal species are sand dwellers.

Calcareous sand is the single universal benthic habitat type on the shelf. Thick or thin layers of sand can be found at every location examined, even where high-relief, hard-bottom, algal nodules, or Agaricia beds are prevalent. Most live-bottom communities on the shelf consist of various species of long-lived sessile invertebrates or plants anchored to hard substrate and projecting through a thin layer of sand.

Consequently, only two benthic habitat types are defined in the subsequent subsections: high- and low-relief bottoms. Most of the motile invertebrates that have been described are confined to, or most abundant on, sand, whether or not it is adjacent to coral, limestone outcrops, etc. For a few of the larger motile invertebrates, such as lobsters and some sea urchins, the shelter and food that high-relief substrates can provide is certainly important. However, many of these motile invertebrates are closely associated with the surrounding sand, also.

High-Relief Bottom

High-relief bottom refers to areas of coral and limestone outcrops projecting upward from the surrounding bottom and generally permanently exposed or free from sand burial. High-relief bottom provides large holes, overhangs, and crevices where fish and large, motile epifauna can find shelter, as well as substrate for long-lived sessile epibiota such as corals, gorgonians, and sponges.

Patches of high-relief bottom may be found at many of the Years 1 through 5 live-bottom and soft-bottom stations, including the Agaricia Plate Coral Assemblage on Transect E and the outer shelf prominences Live-Bottom Assemblage on Transect L.

Large, motile epifaunal organisms most frequently found on or near high-relief bottom include palinurid and scyllarid lobsters (Panulirus argus, P. guttatus, Scyllarus spp., and Scyllarides spp.), brachyuran crabs (Stenocionops furcata and many other smaller species), and sea urchins (Diadema antillarum, Arbacia punctulata, and Eucidaris tribuloides). Many of these species are more abundant in shallow water (e.g., less than 60 m deep), due to partially or wholly herbivorous diets and the greater availability of plants in shallow water.

Low-Relief Bottom

Low-relief bottom refers to areas of partially buried limestone, coral or algal debris, and sandy substrates. Low-relief bottom can be found at nearly every study site from Years 1 through 5. Seagrass beds are included in the definition. In fact, on a percentage-cover basis, most of the shelf can be defined as low-relief bottom.

Large, motile epifauna likely to be encountered frequently on low-relief bottom include many asteroids (Astropecten spp., Oreaster reticulatus) confined to sandy patches or seagrass beds, as well as sea stars such as Echinaster and Luidia that may be found either on sand or consolidated substrates. Most asteroids have broad depth requirements due to the opportunistic, predatory diet and are found throughout most of the shelf. Some species of asteroids are most abundant or confined to water deeper than 60 m, such as Henricia antillarum, Narcissia trigonaria, Pectinaster gracilis, and Sclerasterias contorta. Habitats in deeper water that harbored many asteroids included the Middle Shelf Algal Nodule Assemblage on Transect E and sand.

Echinoids typical of low-relief bottom include many irregular burrowing species such as Clypeaster spp., Meoma ventricosa, and Encope spp. that are found only in sand. Regular (echinacean) echinoids include those mentioned as common on high-relief bottom and other species, such as Lytechinus spp., that are also at home in seagrass beds, sand flats, and other low-relief areas. Most urchins have very wide depth distributions (with some exceptions such as the deepwater forms, e.g., Echinolampas depressa, Stylocidaris spp.). The majority of urchins collected off southwest Florida are primarily herbivorous, but are not necessarily confined to hard substrates; drift algae and smaller plants growing on stable sand can also provide nutrition.

Large holothurians are abundant in low-relief areas of the shelf. Most of them (e.g., Isostichopus badionotus) ingest sand and extract organics and are found in locations of unconsolidated sediment over a wide depth range.

Portunid and calappid crabs are also found primarily in sandy areas, where they can burrow and cover themselves. Large hermit crabs (Paguristes spp., Pagurus spp., and Dardanus spp.) are found on soft bottoms and in seagrass beds. Hermit crabs, portunids, and calappids have wide depth ranges, probably as a result of their broad dietary requirements. Stone crabs, Menippe mercenaria, are common only inshore of the study area.

Gastropods such as conchs (Strombus spp.) are also confined to soft bottoms and seagrass beds. Since they are herbivores, they are especially abundant in water less than 40 m deep.

3.9 FISHES

3.9.1 INTRODUCTION

Only a few large-scale studies of the demersal fishes of the west Florida shelf have been conducted. The most comprehensive recent overview of demersal species was done by Darcy and Gutherz (1984), who trawled at 338 stations from the Dry Tortugas to Cape San Blas in depths ranging from 9 to 193 m. Approximately one half of the stations were located within the area surveyed by the Southwest Florida Shelf Ecosystems Program conducted by MMS; therefore, these results are particularly germane to this program.

Species most frequently collected by Darcy and Gutherz were the sandperch, Diplectrum formosum; the dusky flounder, Syacium papillosum; the planehead filefish, Monacanthus hispidus; the scrawled cowfish, Lactophrys quadricornis; the bank sea bass, Centropristis ocyurus; the sand diver, Synodus intermedius; the inshore lizardfish, Synodus foetens; the tomtate, Haemulon aurolineatum; the pigfish, Orthopristis chrysoptera; and the pinfish, Lagodon rhomboides. All but the last two species were common in samples from the Southwest Florida Shelf Ecosystems Program area, where they would not have been expected to be predominant due to their preferences for more nearshore environments or seagrass and foliose algal beds (Darcy, 1983a, 1985).

An introduction to further information on areas adjacent to the MMS study area and on the ecology of species found within the MMS study area is provided by Darovec, 1983; Emery, 1973; Jaap, 1984; Longley and Hildebrand, 1941; Moe and Martin, 1965; MRRI, 1982; Ross, 1983; Schomer and Drew, 1982; Smith, 1976; Smith et al., 1975; Starck, 1968; Topp and Hoff, 1972; and Thresher, 1980. Many of these references are based on the Hourglass program (Joyce and Williams, 1969), which surveyed an area immediately north and adjacent to the MMS study area and on other work by the State of Florida in the Florida Middle Grounds.

The following section summarizes the results of fish studies conducted during Years 1 through 5, which to a large extent repeat those of Darcy and Gutherz and the Hourglass program. The material in this section is derived primarily from the Year 3 and Year 5 final reports, in which revised and condensed data from Years 1 and 2 and Years 4 and 5 (respectively) may be found, as described in Section 3.8.1 (Motile Epifauna, Introduction). Due to space limitations, emphasis is placed on numerically dominant species. It is organized by gear type and followed by a short summary by general habitat type.

During Years 1 through 5, fishes were collected by trawling and dredging at designated live-bottom stations and (during Years 1 and 2) at soft-bottom stations. On each visit to a station, one trawl haul was taken. During all 5 years, three replicated dredge hauls were taken at live-bottom stations. Fishes brought up with the dredge were retained and identified during Years 1 through 3, but considered incidental to the benthic invertebrate and plant catch during Years 4 and 5 and discarded.

During Years 4 and 5, extensive underwater television surveys were conducted at 12 live-bottom stations. Fishes collected in trawls were utilized as voucher specimens to facilitate identification of species seen on videotapes. Not all fishes seen on videotapes were collected by trawling, and vice versa, but between the two sampling methods, a broad cross section of the fish community was obtained. A similar approach was used during Year 2, when divers surveyed some of the shallower live-bottom stations and conducted visual counts of fishes for comparison to trawl-and-dredge data.

The trawl was most effective for fishes close to the bottom in relatively unobstructed areas. The underwater television camera censused fishes over a wider range of habitats, such as higher in the water column or in rough terrain. However, the television camera missed many cryptic forms that were collected with the trawl, such as flatfishes and lizard fishes partially buried in the sand. Underwater television surveys covered very large areas (from 14,735 m^2 to 67,341 m^2 at each station) and, therefore, were useful for quantitative estimation of fish densities (Boland and Lewbel, 1986), whereas the unreplicated trawl data were more appropriate for estimates of relative abundances or presence/absence.

Additional information about fish behavior and activity was obtained by time-lapse cameras placed at selected live-bottom stations during Years 4 and 5. Gut content and reproductive condition analyses were also conducted on selected species taken by trawling in Years 4 and 5.

3.9.2 DREDGE COLLECTIONS

Fishes taken with the dredge during Years 1 through 3 were usually small, slower-moving, or cryptic species. Even though the dredge was not designed as a fish sampling device, a surprising variety of fishes (192 taxa) was obtained. Most of the fishes were taken with the trawl also at the same stations, and many were observed by divers.

Fishes most frequently dredged were the fringed filefish, Monacanthus ciliatus; the barbfish, Scorpaena brasiliensis; and the leopard toadfish, Opsanus pardus, each collected at 12 or more of the 24 live-bottom stations surveyed in Years 1 through 3. Further information about fishes taken in the dredge may be found in the Year 3 final report, Section 5.5.2, Dredge and Trawl Collections.

3.9.3 DIVER SURVEYS

Most of the fishes observed by divers at shallow (13 to 19 m deep) live-bottom stations were classified by Continental Shelf Associates (1986b) as primary or secondary reef dwellers (per Starck, 1968). Many were species not often collected by trawling or dredging, due to their size, behavior, or ability to avoid capture.

Examples of larger species observed by divers and infrequently (or never) taken in collections included the great barracuda, Sphyraena barracuda; various snappers (e.g., the mutton snapper, Lutjanus analis; the mahogany snapper, L. mahogani; the gray snapper, L. griseus; and the yellowtail snapper, Ocyurus chrysurus); jacks (the greater amberjack, Seriola dumerili; the blue runner, Caranx crysos; the crevalle jack, C. hippos; and the yellow jack, C. bartholomaei); and groupers (the gag, Mycteroperca microlepis).

Most of these fishes are fast-swimming, visual predators capable of avoiding slow-moving nets, especially during the daytime when most trawling took place. Surveying for them with nets is usually ineffective, but many of them, especially the jacks, are attracted to divers or show no fear of them. The fishes sometimes will circle divers at close range, where they can be identified reliably.

Quite a few small or cryptic reef fishes, which might either slip through a net or avoid capture by hiding in crevices, also were recorded by divers (e.g., the tiger goby, Gobiosoma macrodon); damselfishes [e.g.,the beaugregory, Pomacentrus (= Stegastes) leucostictus; the threespot damselfish, P. planifrons]; the Gulf toadfish, Opsanus beta; and wrasses (the slippery dick, Halichoeres bivittatus; the clown wrasse, H. maculipinna; and the rainbow wrasse, H. pictus). Presence/absence lists of species observed by divers may be found in the Year 3 final report, Section 5.3.6, Live-Bottom Stations, Fish Counts.

3.9.4 TRAWL COLLECTIONS

Most of the fishes collected by trawling were widely distributed species, usually found over unconsolidated substrate, or secondary reef dwellers found near reefs only occasionally. This reflected both the nature of otter trawls, which were designed for use on soft bottoms and are most effective there, and the high proportion of soft bottom at most stations in the study area. The relative dominance in trawl samples of fishes that heavily utilize soft bottoms is an accurate reflection of the demersal fish community on the southwest Florida shelf.

During Year 3, 51 fishes were collected by trawling at live-bottom stations ranging from 13 to 19 m deep. Of these, only 20 species were primary reef dwellers. The remainder were secondary reef dwellers or sand-bottom dwellers (see Table 5.37 in the Year 3 final report).

A few stations (notably, deeper sites with Agaricia plate coral or coralline algal nodule substrates, such as Stations 23 and 36) had ichthyofaunas that included a high proportion of primary and secondary reef dwellers. It is also likely that many fishes at these stations were missed by trawling and dredging, since these substrates contain many holes in which fishes can hide. Had it been possible for divers to survey the deeper stations, it is possible that the species list would have been much longer.

Trawl collections from stations which had gorgonian beds, large sponges, or other prominent benthic features as well as soft bottom were usually highly diverse. Primary and secondary reef dwellers (such as apogonids and lutjanids) were often taken in the same hauls with synodontids and other sand dwellers, tangled in the net with large benthic organisms.

Live-Bottom Stations

Based on frequency of occurrence, the most common fishes overall taken by trawling during Years 1 through 3 on the shelf were the fringed filefish, Monacanthus ciliatus; the sand diver, Synodus intermedius; the tattler, Serranus phoebe; the offshore lizardfish, Synodus poeyi; and the dusky flounder, Syacium papillosum. Each of these species was collected at a large number of stations. Overall, 192 taxa of fishes were identified from live-bottom stations; the range was from 13 to 55 fishes per station.

Cluster analysis of Year 1 through 3 trawl data for fishes grouped live-bottom stations into two main groups, with each group lying roughly parallel to shore: an inner shelf group of stations less than 44 m deep and a middle-to-outer shelf group of stations lying seaward of 50 m (see and a middle-to-outer shelf group of stations lying seaward of 50 m (see Figure 3.9-1). Within each of these groups, inverse cluster analysis elucidated sets of fishes commonly found together.

The white grunt, Haemulon plumieri; the hogfish, Lachnolaimus maximus; and the orange filefish, Aluterus schoepfi, were typical of the innershelf stations, especially in water depths less than 20 m. The jackknife-fish, Equetus lanceolatus; the tomtate, Haemulon aurolineatum; and the scrawled cowfish, Lactophrys quadricornis were representative of stations to depths of 44 m.

Within the middle-to-outer shelf stations, three characteristic subgroups of fishes were present. One subgroup was found at stations which ranged in depth from 62 to 76 m and had bottoms of algal nodules and/or Agaricia plate corals. A second subgroup was present from 50 to 77 m deep at all other midshelf stations which had sandy bottoms with patches of gorgonians, sponges, plants, and corals. A third subgroup was present at deeper stations (127 to 159 m) that had primarily sandy bottoms. Several other species (e.g., Monacanthus ciliatus and Synodus intermedius) clustered together and were ubiquitous throughout the study area.

Stations that had agariciid plate corals or nodule bottoms sheltered an assortment of fishes usually associated with tropical coral reefs, including various damselfishes (e.g., the blue chromis, Chromis cyaneus; the bicolor damselfish, Pomacentrus partitus; and the purple reeffish, Chromis scotti), wrasses (the spotfin hogfish, Bodianus pulchellus, and the creole wrasse, Clepticus parrai), trumpetfish, Aulostomus maculatus; hawkfish, Amblycirrhitus pinos; balloonfish, Diodon holacanthus; the rock beauty, Holacanthus tricolor; and the greenblotch parrotfish, Sparisoma atomarium. Several smaller serranids were also present, such as the orangeback bass, Serranus annularis, and the chalk bass, S. tortugarum.

At other live-bottom stations between 50 m and 77 m, the blackedge moray, Gymnothorax nigromarginatus; the anglefin whiff, Citharichthys

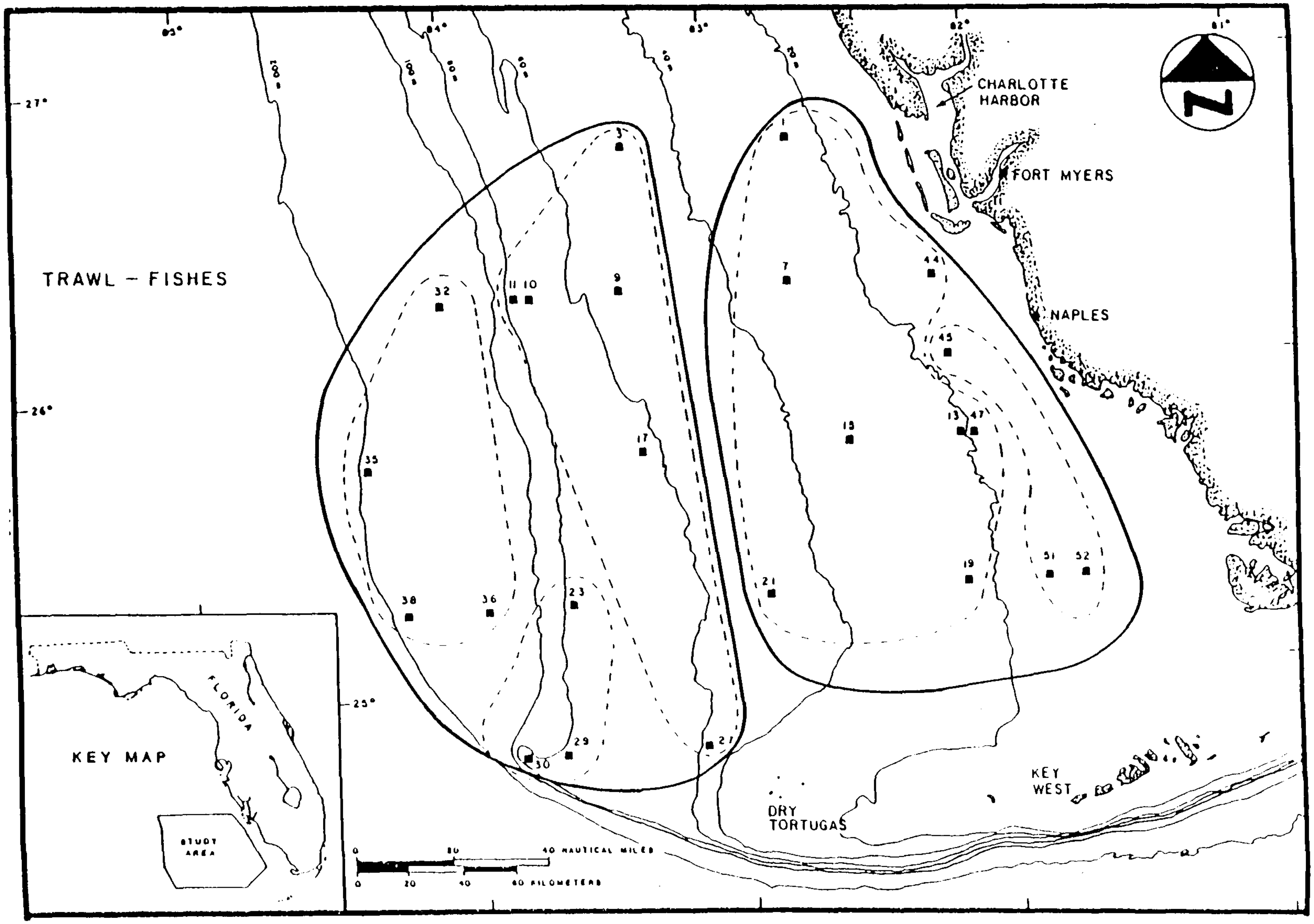


Figure 3.9-1 Station groupings from cluster analysis of trawl data for fishes only.

gymnorhinus; the longfin scorpionfish, Scorpaena agassizi; and the bank sea bass, Centropristis ocyurus, were characteristic species. Offshore lizardfish, Synodus poeyi; the pancake batfish, Halieutichthys aculeatus; the tattler, Serranus phoebe; and the saddle bass, Serranus notospilus, were common at middle shelf stations, although they were frequently collected at deeper stations, also. Most of these stations had substrates of calcareous sand, patches of coralline algal nodules and algal rubble, and occasional rock outcrops.

Seaward of the 100-m depth contour, characteristic fishes included the deepbody boarfish, Antigonia capros; the roughtongue bass, Holanthias martinicensis; and the streamer searobin, Bellator egretta. Most of these deeper stations had sandy, coarse substrates, often with coralline rubble.

During Years 4 and 5, trawling continued at 12 live-bottom stations; 166 taxa of fishes were identified in samples. Since sampling effort was not equal at all stations, no statistically valid conclusions can be reached about diversity differences with depth, but there were no obvious inshore/offshore trends either in terms of numbers of species or fish densities. Fish were present at high densities at shallow stations (e.g., Station 52, 13 m deep, 71.1 individuals per hectare), intermediate depth stations (e.g., Station 7, 32 m deep, 36.5 individuals per hectare); and at deep stations (e.g., Station 36, 125 m deep, 117.2 individuals per hectare).

As during Years 1 through 3, a mixture of primary and secondary reef dwellers was collected, as well as species found on sand bottoms. Overall, fishes with the highest frequencies of occurrence were the sand diver, Synodus intermedius; the scrawled cowfish, Lactophrys quadricornis; the red grouper, Epinephelus morio; the white grunt, Haemulon plumieri; the tomtate, Haemulon aurolineatum; the sand perch, Diplectrum formosum; the fringed filefish, Monacanthus ciliatus; the blackedge moray, Gymnothorax nigromarginatus; the lane snapper, Lutjanus synagris; the jackknife-fish, Equetus lanceolatus; the dusky flounder, Syacium papillosum; the bandtail puffer, Sphoeroides spengleri; the inshore lizardfish, Synodus foetens; and the flathead filefish, Monacanthus hispidus.

Although the saddle bass, Serranus notospilus (incorrectly identified in the Years 4 and 5 reports as Serranus atrobranchus), was not present at many stations, it and the tattler, Serranus phoebe, had the highest overall mean densities of any species collected with the trawl. These small serranids were extremely abundant in collections from Stations 23 (depth 74 m) and 36 (125 m).

Cluster analysis of Years 4 and 5 trawl hauls produced four main groups of stations (see Figure 3.9-2): two lying within the 27-m depth contour, one spanning the depth range from 32 to 125 m (though with shallow and deeper subgroups), and a fourth including only Station 29 (64 m, Agaricia plate coral bottom). The two shallower groups of stations were dominated by grunts (Haemulon plumieri, and H. aurolineatum), red groupers (Epinephelus morio), many species of reef-associated fishes such as porgies (Calamus spp.), and various lutjanids.

The group of stations spanning 32- to 125-m depths were dominated by various synodontids, especially Synodus poeyi (the offshore lizardfish), and Saurida brasiliensis (the largescale lizardfish). Hauls from Station 29 suggested high densities of pomacentrids such as the purple reeffish (Chromis scotti) and the yellowtail reeffish (Chromis enchrysurus), but many other small species also were collected, along with coral rubble.

The clustering results were similar to those obtained by visual examination of depth-range graphics (see Figure 3.9-3), which show the depth range within which each species was collected by trawling. The depth ranges shown do not indicate that a species was present at every site or depth within that range, but imply that it could be found if suitable substrate and hydrographic conditions were present. Three

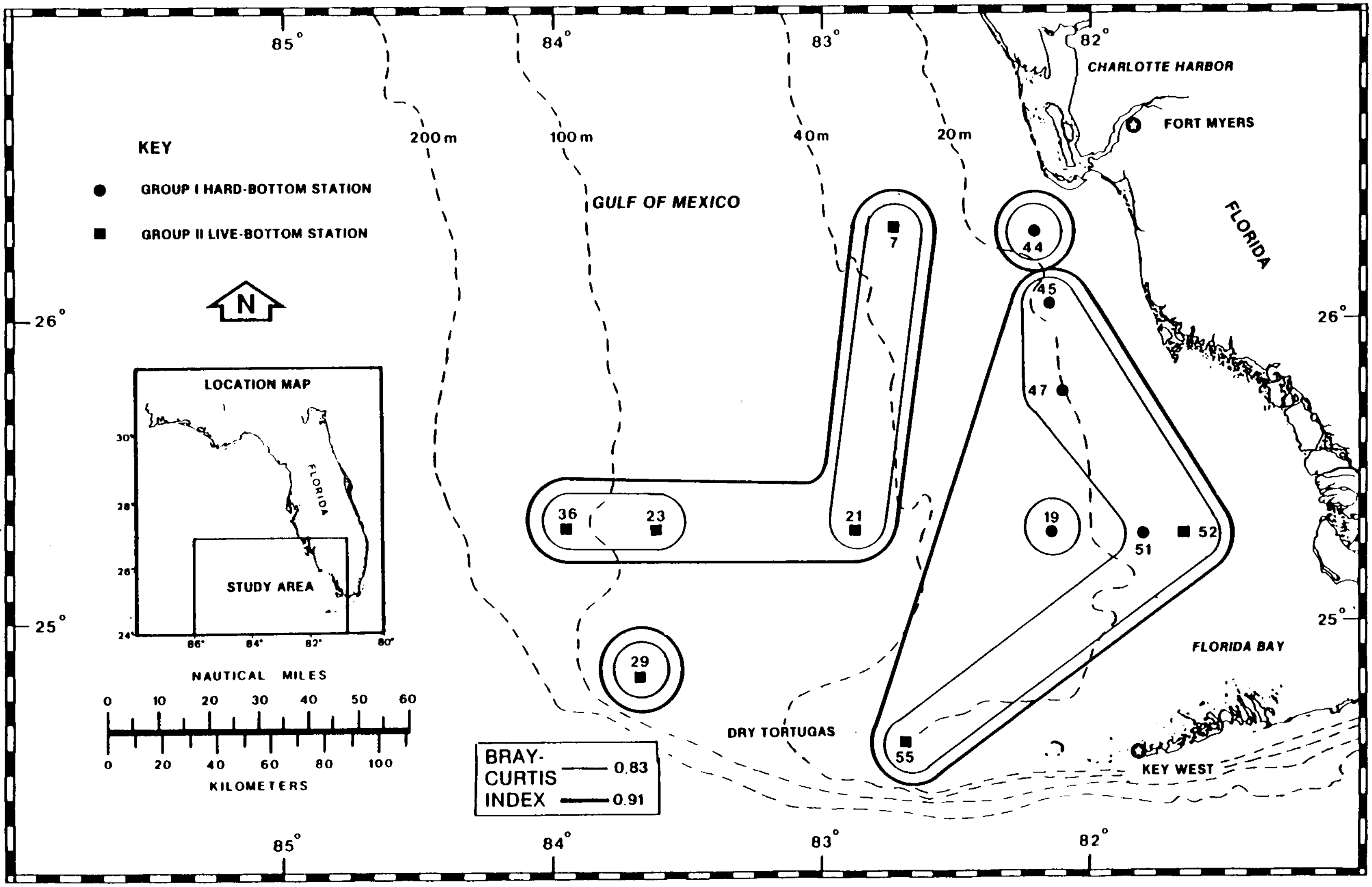


Figure 3.9-2 Results of cluster analyses of trawl data using Bray-Curtis Index of Dissimilarity to group stations at two levels.

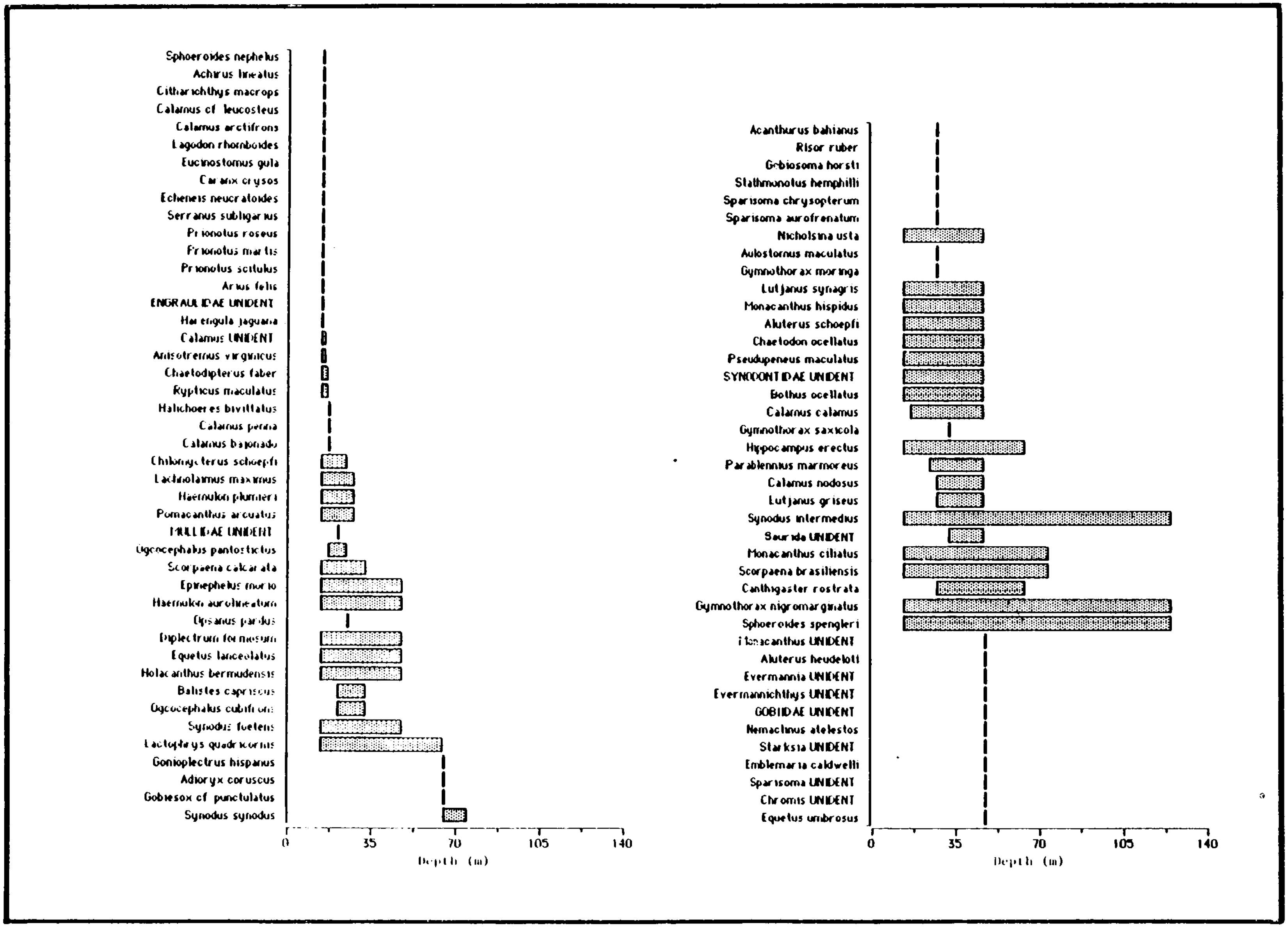


Figure 3.9-3 Depth ranges for fishes collected by trawling for all stations and all cruises.

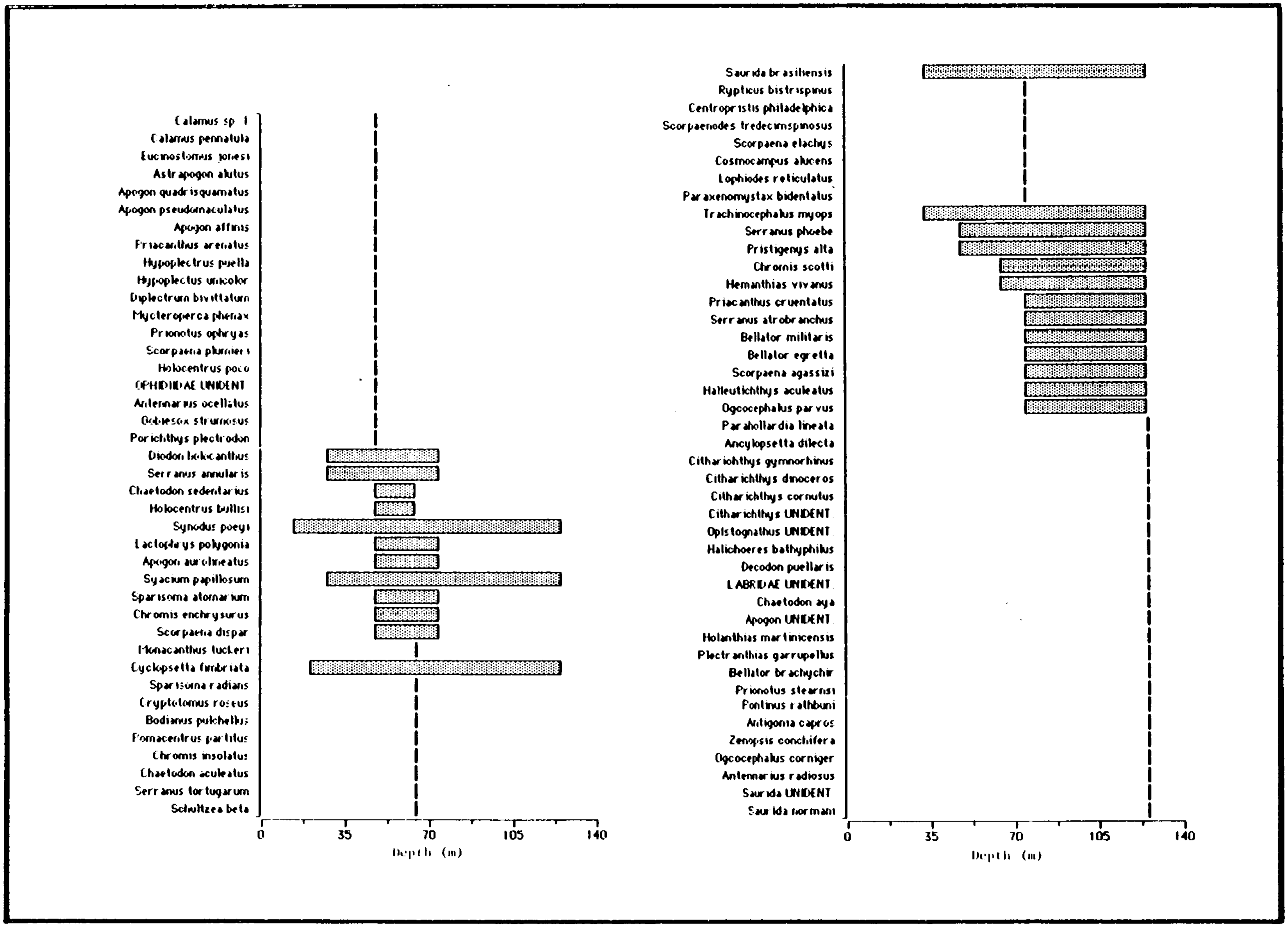


Figure 3.9-3 (Cont.).

fairly distinct groups of species could be delineated from depth-range graphics, as well as a set of ubiquitous species.

Species present throughout the study area over a wide depth range included Synodus intermedius; Synodus poeyi; Saurida brasiliensis; the blackedge moray, Gymnothorax nigromarginatus; the dusky flounder, Syacium papillosum; the spotfin flounder, Cyclopsetta fimbriata; the snakefish, Trachinocephalus myops; and the bandtail puffer, Sphoeroides spengleri.

Fishes taken primarily in the shallow depth range (from 13 to 47 m) included primary reef-dwellers such as grunts (Haemulon plumieri and Haemulon aurolineatum), porgies (Calamus spp.), blue and gray angelfishes (Holacanthus bermudensis and Pomacentrus arcuatus), and sand dwellers such as searobins (Prionotus spp.). Fishes occupying stations between 47 m and 74 m deep included various chaetodontids (e.g., the reef butterflyfish, Chaetodon sedentarius; and the longsnout butterflyfish, Chaetodon aculeatus) and the yellowtail reeffish, Chromis enchrysurus. A third group present primarily in deeper water (74 to 125 m) included smaller serranids (Serranus notospilus and S. phoebe) and damselfishes (Chromis scotti).

Soft-Bottom Stations

Patterns of distribution of fishes collected by trawling at soft-bottom stations during Years 1 through 3 were fairly similar to those at live-bottom stations, underscoring the mosaic of benthic habitat types present at many locations on the shelf. The similarities between the collections from soft- and live-bottom stations may be interpreted to mean that there were fewer differences between the two categories of stations than originally anticipated, at least from the standpoint of species composition of fishes.

The dusky flounder, Syacium papillosum; the fringed filefish, Monacanthus ciliatus; the pancake batfish, Halieutichthys aculeatus; and the barbfish, Scorpaena brasiliensis, were the most widely distributed species in trawl samples from soft-bottom stations in terms of numbers of frequency of occurrence. Many species taken at soft-bottom stations spanned a wide range of depths, probably as a result of the relative homogeneity of unconsolidated substrates across the shelf. During Years 4 and 5, trawling was discontinued at soft-bottom stations.

Species Accounts

Eight species collected with the trawl were examined for gut contents, reproductive condition, and length and weight frequency distributions during Years 4 and 5: the tattler, Serranus phoebe; the saddle bass, Serranus notospilus (incorrectly identified in the Years 4 and 5 final reports as a closely related species also reported in the area, Serranus atrobranchus); the white grunt, Haemulon plumieri; the tomtate, Haemulon aurolineatum; the red grouper, Epinephelus morio; the lane snapper, Lutjanus synagris; the sand diver, Synodus intermedius; and the scrawled cowfish, Lactophrys quadricornis. Further details may be found in the Year 5 final report, Section 3.2.2, Species Accounts. A brief summary of findings regarding diets and reproductive condition is provided.

All of the serranids are predators (Thresher, 1980). Gut contents analysis for Serranus phoebe revealed a diet based on shrimp-like decapods and other unidentified crustaceans, followed by copepods. Robins and Starck (1961) conducted gut analyses on this species, finding that most of the material in the guts consisted of crustacean remains, primarily shrimp and crabs. All of the tattlers collected at Station 21 (64 m deep) were immature, but specimens from Stations 23 (74 m) and 36 (125 m) included individuals with ripening or mature gonads (especially in the fall), suggesting a possible offshore movement to spawn. This is consistent with the report of Robins and Starck (1961), who commented that S. phoebe is most abundant from 55 to 182 m, although juveniles have been taken in much shallower water.

Unidentified decapods and copepods appeared to be the most important dietary items for Serranus notospilus on the southwest Florida shelf. A few reproductively mature individuals were found at Station 23, but larger and more mature saddle bass were collected in deeper water at Station 36, especially during winter. The species is reported from South America to Florida; most records are from about 73 to 165 m (Robins and Starck, 1961), suggesting that the saddle bass collected in this study were near the upper edge of their preferred depth distribution.

Haemulon plumieri and Haemulon aurolineatum are distributed widely throughout the Caribbean, along the South American coast, and as far north as the central eastern United States coast. Most of the literature for both species describes them as common at shallower than 50 m (Darcy, 1983b), where they occupy a wide variety of habitats, especially where hard substrate adjoins sand bottoms, seagrass beds, or other open areas. Both feed primarily at night, usually over sand flats, alcyonarian patches, or seagrass beds (Hobson, 1973; Meyer and Schultz, 1985; Randall, 1967).

Haemulon plumieri has been described as a generalized carnivore on benthic invertebrates (Darcy, 1983b). White grunts collected in this program ate primarily polychaetes and amphipods. Cycling of nutrients between the soft-bottom and live-bottom areas by white grunts may be an important biological process in the maintenance of photosynthetic scleractinians and octocorals on the shelf. White grunts deposit large amounts of nitrogen, phosphorus, and organic carbon as feces on or near corals while resting during the day (Meyer and Schultz, 1985). Sexually mature white grunts were collected primarily in the late fall, when spawning appeared to take place. Darcy (1983b), describing work by Munro et al. (1973), reported that spawning of grunts may take place when water temperatures drop.

Haemulon aurolineatum, also a benthic generalist, contained primarily polychaetes and shrimp-like decapods. These results were similar to those of Sedberry (1985), who reported that guts removed from tomtates in the South Atlantic Bight contained a higher volume of polychaetes and amphipods than any other dietary component, although there were about 120 species of prey utilized. There were too few tomtate gonads analyzed to characterize their reproductive patterns in this study.

Epinephelus morio is reported to feed primarily on invertebrates (Moe, 1969; Randall, 1967). Red grouper stomachs usually contained almost nothing, due to eversion upon trawl ascent. Those few specimens suitable for gut content analyses contained only crustaceans, primarily brachyuran crabs. Three-fourths of the red groupers examined in this study had inactive gonads, although some ripening and mature specimens were collected in winter, spring, and summer.

Lutjanus synagris is a nocturnal bottom feeder which migrates at night from reef areas to nearby grass flats and sandy zones (Manooch, 1984). Lane snappers collected in this study contained primarily small crustaceans--in particular, shrimp-like decapods and small crabs. Too few lane snappers were taken to characterize their reproductive patterns.

Synodus intermedius is a demersal carnivore (Randall, 1967; Thresher, 1980) which rests on the bottom and darts upward to seize prey. Sand diver stomachs contained mostly fishes--in particular, other lizardfishes. Gonad sample size was inadequate to characterize reproductive condition.

Lactophrys quadricornis has been reported to feed on polychaetes, sponges, tunicates, shrimps, amphipods, and other invertebrates; it often eats by "excavation," squirting water downward onto sand and then sucking out exposed invertebrates (Randall, 1967; Thresher, 1980). In this study, the most important prey items were amphipods and polychaetes. There was a good deal of sand, shell fragments, and plants inside scrawled cowfish guts. Gonad sample size was inadequate to characterize reproductive patterns.

3.9.5 UNDERWATER TELEVISION RESULTS

Underwater television proved the most effective fish-surveying tool used in this program for determining densities and distribution patterns for visible species. Fishes seen in videotapes could be identified in most cases to the species level, especially when compared to voucher specimens collected with the trawl.

The depth ranges of fishes censused with underwater television were usually broader than they appeared to be, based on trawl collections. For example, during Years 4 and 5, the reef butterflyfish, *Chaetodon sedentarius*, was observed in videotapes from stations ranging from 13 to 125 m in depth, whereas trawling captured *Chaetodon sedentarius* only at stations between 47 and 64 m deep. These results further highlighted the importance of using more than one gear type per station for fish surveying.

Underwater television samples included 116 identifiable fish taxa. The fishes with the highest frequency of occurrence (see Table 3.9-1) were primary and secondary reef dwellers such as the red grouper, *Epinephelus morio*; unidentified porgies, *Calamus* spp.; *Chaetodon sedentarius*; the scrawled cowfish, *Lactophrys quadricornis*; the lane snapper, *Lutjanus synagris*; the gray angelfish, *Pomacanthus arcuatus*; the white grunt, *Haemulon plumieri*; and the tomtate, *Haemulon aurolineatum*. These results were similar to those obtained at the same stations during Years 4 and 5 with the trawl, although the most frequently trawled fish (the sand diver, *Synodus intermedius*, collected at 10 stations) was observed only with the television camera at five stations.

Other common species (e.g., the dusky flounder, *Syacium papillosum*, and the blackedge moray, *Gymnothorax nigromarginatus*) were not seen in videotapes, nor were the fringed and planehead filefishes, *Monacanthus ciliatus* and *M. hispidus*. The discrepancy between the results can be partially attributed to the problems of observing partially buried or light-colored fishes against a sand bottom on black-and-white television.

Table 3.9-1. Fishes observed with underwater television at five or more stations.

Taxon	No. of Stations
Epinephelus morio	10
Calamus sp.	10
Chaetodon sedentarius	9
Lactophrys quadricornis	8
Lutjanus synagris	8
Pomacanthus arcuatus	8
Haemulon plumieri	8
Haemulon aurolineatum	8
Equetus lanceolatus	7
Caranx crysos	7
Diplectrum sp.	7
Epinephelus/Mycteroperca sp.	7
Serranus sp.	6
Holacanthus bermudensis	6
Synodus intermedius	5
Decapterus punctatus	5
Seriola dumerili	5
Lachnolaimus maximus	5
Balistes capriscus	5

In addition, specimens of filefishes collected by trawling were very small and would have been very difficult to see on television.

However, several very common species were observed on television at many stations, but almost never taken in trawls, such as the hogfish, Lachnolaimus maximus; the amberjack, Seriola dumerili; the blue runner, Caranx crysos; and the round scad, Decapterus punctatus. These fish are large and fast enough to avoid most active fishing gear.

Underwater television surveys provided information both on relative and absolute densities for fishes. Overall, the most abundant fishes were the yellowtail reeffish, Chromis enchrysurus (124 per hectare); Decapterus punctatus (118 per hectare) and unidentified congeners (24 per hectare); serranids of the genus Hemanthias (46 per hectare) and other unidentified anthinids (22 per hectare); Haemulon plumieri (43 per hectare); the purple reeffish, Chromis scotti; the boga, Inermia vittata (16 per hectare); Epinephelus morio, the jackknife-fish (Equetus lanceolatus) and the tattler (Serranus phoebe) (all 5 per hectare); and Chaetodon sedentarius (4 per hectare).

For the majority of species, these densities reflected extremely high abundances at several stations, rather than high mean densities at many stations. For example, Chromis enchrysurus was abundant at only three stations (Stations 21, 29, and 23; depths 47, 64, and 74 m, respectively), where its densities were 114, 518, and 221 individuals per hectare, respectively. Decapterus punctatus was present at low densities at several stations, but extremely abundant (911.7 per hectare) only at Station 23. Hemanthias was reported only from Station 29, at a very high density (294.9 per hectare). Even Haemulon plumieri (present at eight stations from 13 to 32 m deep) was highly abundant (36.9 per hectare, 248.2 per hectare, and 278.4 per hectare at only three of these stations (Stations 19, 51, and 52, respectively).

Cluster analysis on underwater television data for fishes produced three groups of stations (see Figure 3.9-4). This pattern is believed to represent the actual distribution of numerically dominant species more accurately than the cluster analysis, based on trawl data for three reasons. First, the underwater television effectively covered a much larger sampling area per station than did any other gear type. Second, species censused both with trawl and television usually showed a wider range of distribution in television samples. In other words, trawls were more likely to miss species other than cryptic sand dwellers. Third, cluster analyses based on trawl density estimates were derived from pooled, unreplicated samples and thus would be expected to be less precise and less accurate than estimates of density from replicated video censuses.

The shallowest set of stations (13- to 32-m depths) in the videotape cluster analysis was dominated by typical reef-associated species such as snappers (e.g., the lane snapper, Lutjanus synagris, and the gray snapper, L. griseus), grunts (the porkfish, Anisotremus virginicus; the white grunt, Haemulon plumieri; and the tomtate, Haemulon aurolineatum), and balistids (Monacanthus spp, Aluterus spp., and Cantherines spp.).

The second group of stations included Stations 21 (47 m deep), 29 (64 m), and 23 (74 m). Numerically dominant fishes in this cluster of stations included many small serranids (Serranus phoebe and Hemanthias spp.), bigeyes (Pristigenys alta and Priacanthus spp.), scad (Decapterus), damselfishes (Chromis scotti, C. enchrysurus, and Pomacentrus partitus), emmelichthyids (Inermia vittata), and squirrelfishes (Holocentrus spp.). The blue goby, Ioglossus calliurus, was also common at Station 21.

Station 36 (125 m) was the only member of the deepest cluster. Its ichthyofauna was dominated by small anthinids, the bank butterflyfish (Chaetodon aya), the offshore lizardfish (Synodus poeyi), and various synodontids (Trachinocephalus, Synodus spp.).

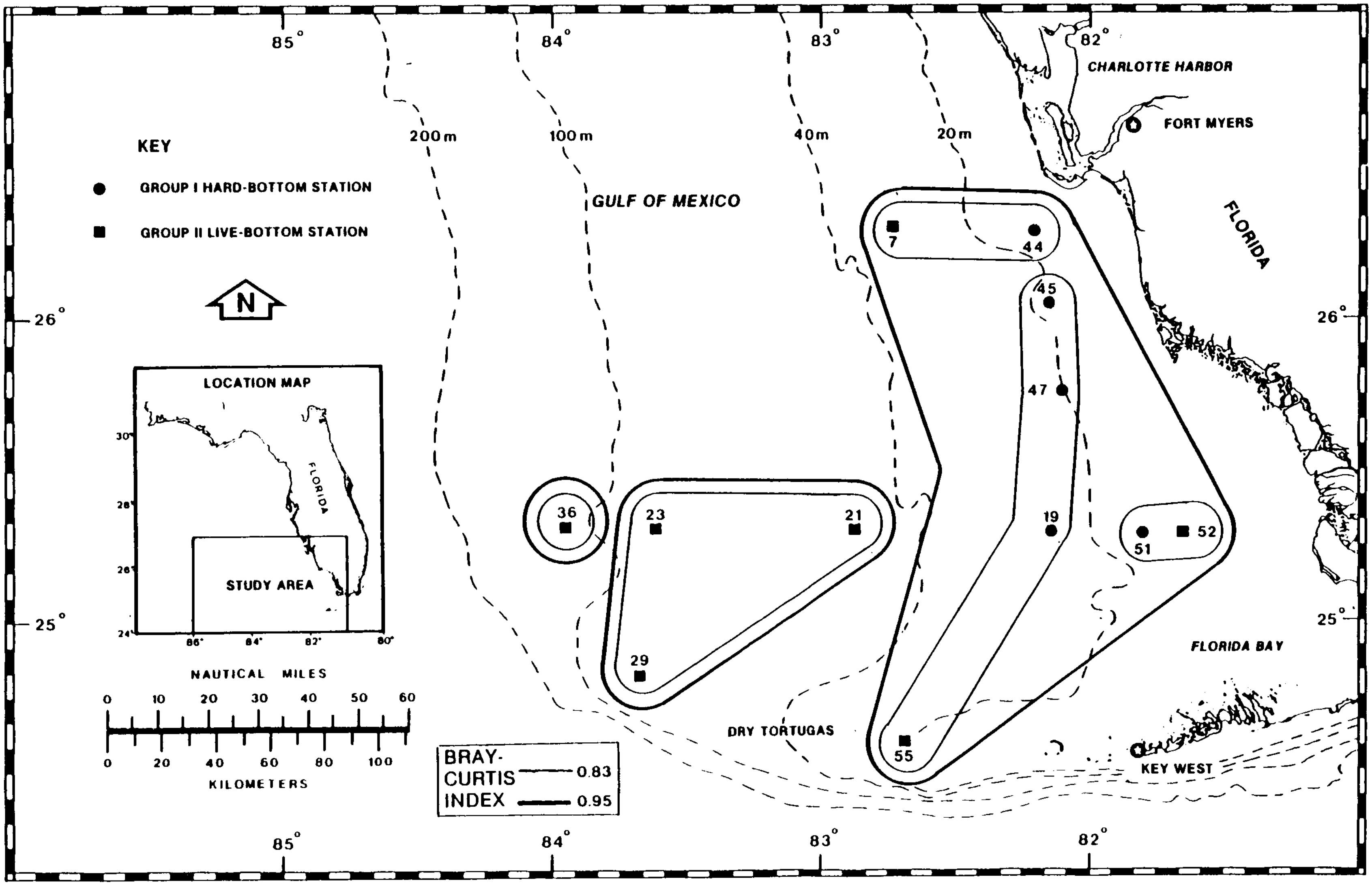


Figure 3.9-4 Results of cluster analyses of underwater television data for fishes using Bray-Curtis Index of Dissimilarity to group stations at two levels.

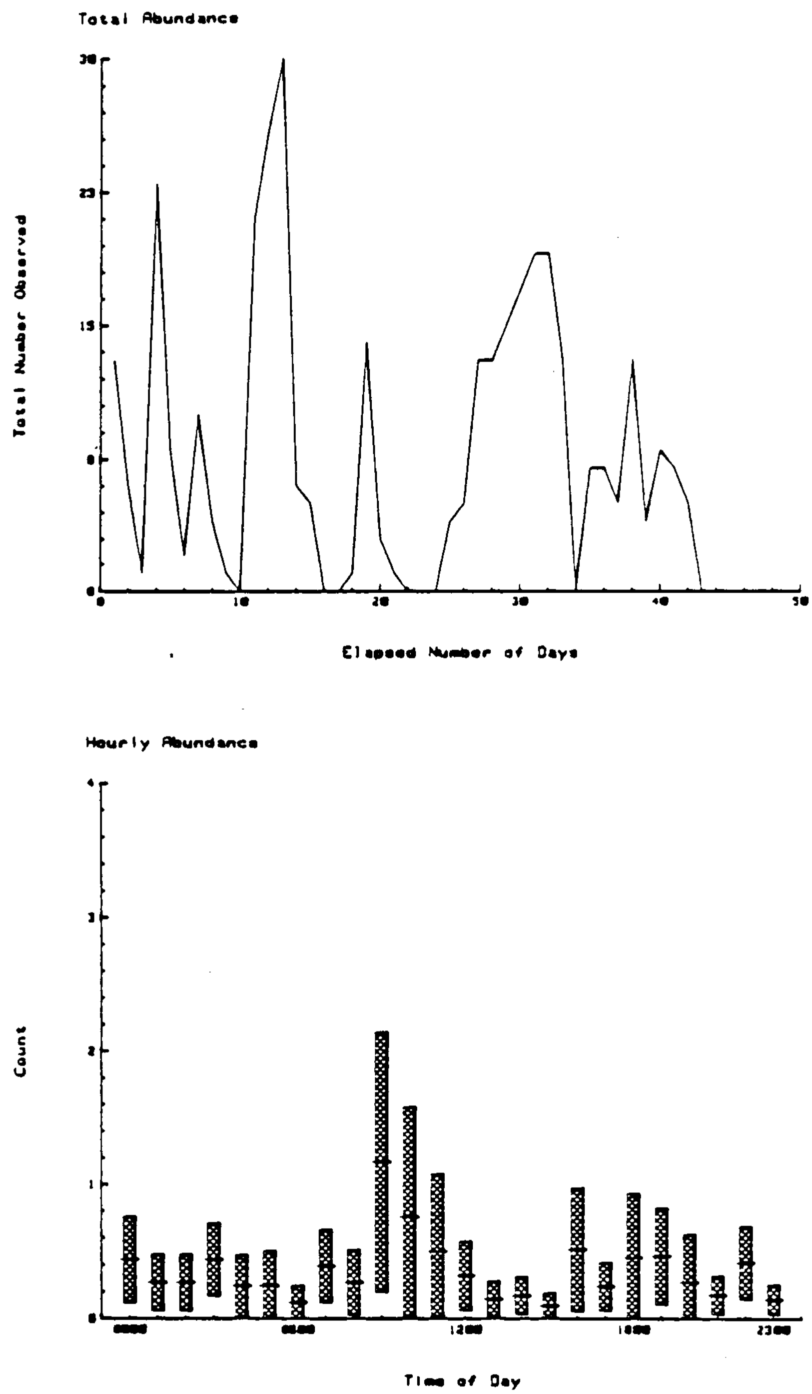
3.9.6 TIME-LAPSE CAMERA RESULTS

Time-lapse cameras were placed on the bottom at various stations during Years 4 and 5. The cameras were fastened to large pyramidal arrays which offered shelter and orientation aids to various fishes (see Section 2.1.3, In Situ Array, in the Year 5 final report). The time-lapse cameras provided information about fish behavior, diurnal activity patterns, and residency or attendance around these benthic structures. A brief summary of fishes most frequently observed follows. For further details, refer to Section 4.1.2, Benthic Community Distribution and Structure, in the Year 4 final report, and Section 3.2.1, Station Descriptions, in the Year 5 final report.

Station 52 (13 m deep) was a low-relief, flat area with patches of sponges, algae, and dense stands of gorgonians projecting from underlying hard substrate through carbonate sand. Time-lapse cameras were installed at Station 52 throughout Years 4 and 5, and more film was successfully exposed there than at any other station.

At Station 52, the most common fishes seen were the white grunt, *Haemulon plumieri*; the tomtate, *H. aurolineatum*; the gray snapper, *Lutjanus griseus*; the jewfish, *Epinephelus itajara*; the porkfish, *Anisotremus virginicus* (especially juveniles); the red grouper, *Epinephelus morio*; the Atlantic spadefish, *Chaetodipterus faber*; the sheepshead, *Archosargus probatocephalus*; the nurse shark, *Ginglymostoma cirratum*; and various unidentified smaller fishes. Many fish arrived at the array within a few days of installation (see Figure 3.9-5). There was some evidence of succession; for example, shortly after installation, white grunts were most abundant, and gray snappers were uncommon; several months later, gray snappers replaced white grunts as the most frequently observed fish (see Table 4.1-14 in the Year 4 Final Report).

Most of the sightings of fishes at Station 52--and, for that matter, at many other stations--appear to have been repeated observations of the same individual(s), and, therefore, indicate at least semipermanent



NOTE: VALUES PLOTTED AS MEAN ± TWO STANDARD ERRORS ABOUT THE MEAN.

Figure 3.9-5 Total and hourly abundance for all fishes from time-lapse camera records for Station 52, beginning December 1983.

residency. This is most likely true for snappers and grunts and is known for the jewfish and nurse shark, which were distinctively marked and could be seen resting in the same location within the array over a period of days or weeks. Other species, such as the Atlantic spadefish, took up temporary residency for a few days and then disappeared from the vicinity.

Pronounced diurnal periodicity was observed for species such as snappers and grunts (see Figure 3.9-6), which typically rest near reefs or other benthic relief during part of the day, and forage in sandy areas and seagrass beds during the night.

Large fish may also be responsible for a considerable amount of sediment resuspension and bioturbation at selected locations on the shelf. Nurse sharks, jewfish, groupers, and other species that spent a great deal of time at the array were the probable cause of an observed removal of sand beneath the array, as well as damage to the array's instrumentation.

Station 44 (depth 13 m) was similar to Station 52 in terms of topography and large epifaunal organisms. Time-lapse cameras were in place during much of Year 5, though various difficulties severely limited the amount of usable data. The only fishes frequently observed were sand perch or dwarf sand perch, Diplectrum bivittatum or D. formosum (which could not be separated visually); juvenile tomtate (tentative identification); jackknife-fish, Equetus lanceolatus; and Epinephelus itajara. Sand perch have been reported to prefer areas around natural and artificial reefs (Darcy, 1985b) and might have been attracted to the array rather than incidental photographic subjects.

Station 55 (depth 27 m) was a sandy site with very high densities of gorgonians and low-lying sponges and corals. Time-lapse cameras operated there during most of Year 5 in an area of deep sand over carbonate rock. The most common fishes seen there by the cameras were grunts and snappers (e.g., Haemulon aurolineatum; the gray snapper, Lutjanus griseus;

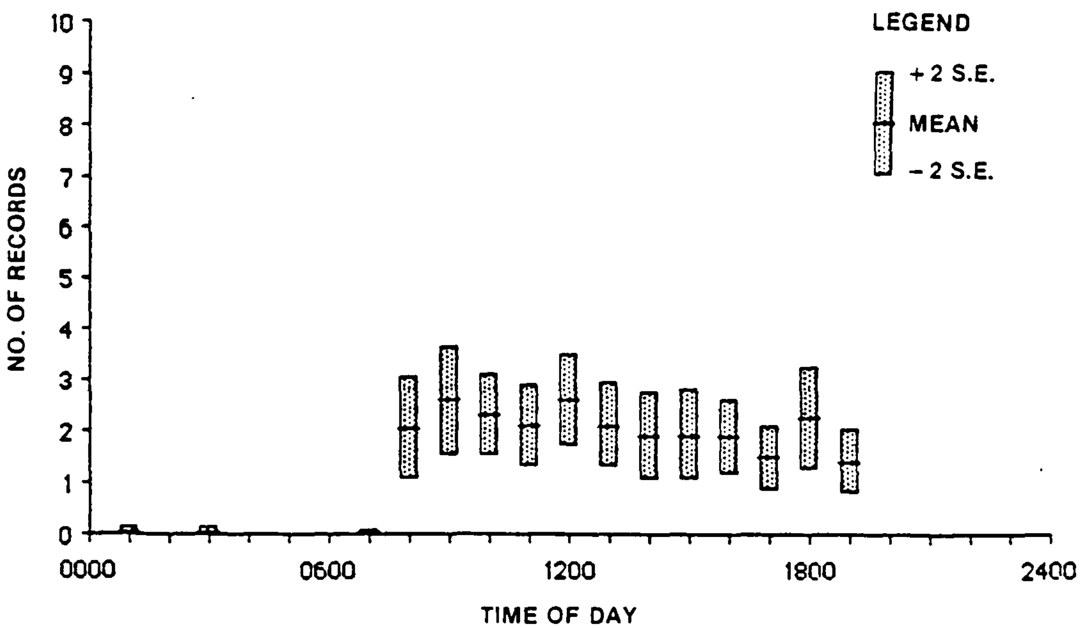


Figure 3.9-6 Activity pattern for *Lutjanus griseus* at Station 52 from time-lapse camera, December 6, 1984 - January 8, 1985.

Haemulon plumieri; and the porkfish, Anisotremus virginicus) forming resting aggregations during daylight; Epinephelus morio (daylight hours); bermudensis; and Epinephelus itajara. Jewfish attendance decreased near dawn and dusk, perhaps as a result of feeding activities (Randall, 1967). Spotted goatfish, Mulloidichthys maculatus, were also observed feeding in the sand near the camera frame, creating a large plume of suspended sediment.

Station 7 (depth 32 m) was a sandy area with occasional rock outcrops and calcareous rubble and patches of gorgonians, sponges, and algae. Time-lapse cameras were present for much of Year 5. The fishes most frequently recorded were the planehead filefish, Moncanthus hispidus; the orange filefish, Aluterus schoepfi; and the bandtail puffer, Sphoeroides spengleri. These species were seen only at night and sometimes remained at or returned to the same fixed locations for long periods of time. Diplectrum spp.; the Atlantic spadefish, Chaetodipterus faber (most commonly seen just before dawn); and the blue angelfish, Holacanthus bermudensis; were often recorded at Station 7.

After the initial period following installation, other species were often seen at the array at Station 7. They included the greater amberjack, Seriola dumerili (primarily at dusk, in the middle of the night, and just after sunrise) and Lutjanus synagris (seen every hour of the day, but most common during daylight). Atlantic spadefish became much more common after the array had been in place for some months, as did the gray snapper, Lutjanus griseus (all hours, with a major gap before dawn); Haemulon aurolineatum (most common during daylight hours); and various small, unidentified lutjanids and scads.

Station 21 (depth 47 m) was fairly sandy, with ripple marks and clear evidence of bioturbation in the sediment, and occasional patches of algae and sponges. Time-lapse cameras recorded data from the latter part of Year 4 through Year 5. Many of the fishes seen by the camera were too small to identify. Other species frequently seen included Epinephelus itajara (present around the clock); the spotfin butterflyfish, Chaetodon ocellatus (in the evenings); and various unidentified groupers, probably genus Mycteroperca.

The deepest time-lapse camera installation was at Station 23 (74-m depth) on a substrate of coralline algal nodules. Time-lapse equipment was present during the first part of Year 5. The most frequently observed species were damselfishes such as the yellowtail reeffish (Chromis enchrysurus) and the purple reeffish (Chromis scotti), which were seen primarily during daylight hours. Other species recorded from time to time included the gray angelfish, Pomacanthus arcuatus; unidentified squirrelfishes (Holocentrus spp.); and Chaetodon ocellatus.

3.9.7 SUMMARY BY GENERAL HABITAT TYPE

There have been a variety of schemes proposed to divide or categorize the benthic habitats of the southwest Florida shelf. Most of them have focused upon major topographic features, suites, or assemblages of characteristic epifaunal organisms. For example, the Year 3 final report from this program attempted to integrate a set of visually designated assemblages with the results of cluster analyses, in order to produce a new, proposed zonation scheme for the shelf. This scheme is used in a brief description of fish by habitat type and depth range.

Continental Shelf Associates' inner shelf zone included depths roughly from 10 to 45 m, with a division into two subzones (I and II) corresponding to stations on either side of a biotic break at approximately 20 m. Cluster analyses for fishes surveyed with the underwater television camera during Years 4 and 5 were reasonably consistent with those major divisions, in that stations inshore of 32 m were in a separate cluster from those seaward of 47 m, and another break was seen between 74 m and 124 m, corresponding with Continental Shelf Associates' split between the middle shelf (to 100 m) and the outer shelf (deeper than 100 m). Exact agreement would not be expected, of course, since Continental Shelf Associates' zones took into account benthic organisms, whereas the cluster analysis described previously is based only on data for fishes.

A faunal breakpoint was also visible in the depth range graphics for both trawl and videotaped fish data from Years 4 and 5 between Station 21 (47 m) and the next deepest station, Station 29 (64 m deep), with many species extending as far as (but not beyond) Station 21. Characteristic fishes in the inner shelf zone included many primary reef-dwellers such as grunts and snappers, which feed on adjacent soft substrate, as well as others such as apogonids and chaetodontids that are much more closely tied to larger sessile epifauna and hard substrate for both shelter and food (Lasker, 1985).

Within the inner shelf zone, considerable variability was present between different habitat types. Fishes associated with coral reefs--some of which are numerical dominants in this zone--are known for fine-scale partitioning of habitat utilization (cf. Alevizon et al., 1985). Some species within this zone showed preferences for the shallowest stations (13 to 20 m), while others such as Lutjanus synagris, Haemulon plumieri, and H. aurolineatum ranged across the zone. Others were more common toward the outer edge of the inner shelf zone, such as the blue goby, Ioglossus calliurus.

Continental Shelf Associates' middle shelf zone spanned depths from 45 to 100 m and was divided into two sections: Middle Shelf I (45 to 60 m), and Middle Shelf II (60 to 100 m). Fishes typical of Middle Shelf I communities included the bank sea bass, Centropristis ocyurus; the horned whiff, Citharichthys gymnorhinus; various priacanthids (Pristigenys alta, Priacanthus spp.); and chaetodontids. By comparison, dominant species collected by Darcy and Gutherz (1984) in depths from 36 to 93 m were the cownose ray, Rhinoptera bonasus (not collected or observed during the MMS studies); the pinfish, Lagodon rhomboides; and Haemulon aurolineatum.

Continental Shelf Associates' Middle Shelf II was a special category for algal nodule and algal pavements (some bearing Agariciid plate corals). Areas between 60 m and 100 m without algal nodules or pavements were not defined by the scheme. Fishes found primarily in the Middle Shelf II zone included many damselfishes such as Chromis enchrysurus, Chromis scotti, and Chromis insolatus; anthinids and other serranids (Serranus notospilus, S. phoebe, S. annularis, S. tortugarum); the boga, Inermia vittata; and the greenblotch parrotfish, Sparisoma atomarium.

It is likely that many more species and individuals occupy areas of nonconsolidated algal rubble and Agaricia than consolidated algal pavements, due to the greater availability of suitable refuges within nodules and living and dead coral debris (viz. Shulman, 1984); however, neither trawl, dredge, nor television camera is ideal for surveying this complex habitat, and it is probable that many species of small fishes escaped collection or observation in the Middle Shelf II environment.

Continental Shelf Associates' outer shelf zone spanned from 100 to 200 m. Characteristic fishes from this zone included the tattler, Serranus phoebe, and other small serranids such as the roughtongue bass, Holanthias martinicensis; the offshore lizardfish, Synodus poevi; searobins (e.g., the shortwing searobin, Prionotis stearnsi; the shortfin searobin, Bellator brachychir; and the streamer searobin, Bellator egretta); batfishes (Ogcocephalus corniger, Halieutichthys aculeatus); and the bank butterflyfish, Chaetodon aya.

Many fishes had depth ranges that extend across these zones. Examples of ubiquitous species included Monacanthus ciliatus, Synodus intermedius, Syacium papillosum, Gymnothorax nigromarginatus, Equetus lanceolatus, Epinephelus morio, Lactophrys quadricornis, Pomacanthus arcuatus, and Chaetodon sedentarius.

Despite the apparent simplicity provided by this summary, it is vital not to infer that fishes are necessarily confined to one habitat type or another and keep in mind that the Continental Shelf Associate's scheme is most pertinent for benthic organisms. Nearly all schemes of zonation are, of necessity, oversimplifications, especially for motile species collected near zonal boundaries.

Fishes are capable of moving rapidly between habitat types, especially upon the approach of biological sampling equipment. The apparent boundaries of such zones are not absolute barriers, but may be regarded as regions of rapidly changing abundances and/or probabilities of occurrence, especially for larger species. As Alevizon et al. (1985) pointed out, "larger reef fishes do not appear to be so specialized... that specific 'sites' will be predictably reoccupied by... the same species." In other words, many fish are notoriously unreliable indicator species.

Furthermore, many attempts to schematically portray the fish communities of the shelf on a base map for this report were intuitively unsatisfying, and, therefore, unsuccessful. As soon as a zonal boundary was drawn on the map (using one cluster analysis or another), a new reference from the literature or data record from this program would come to light, invariably requiring that boundary to be shifted. This was particularly true for the most abundant species in the area, the sand dwellers, such as synodontids and various flatfishes. Consequently, no such schematic diagram appears in this volume.

Three conclusions can be drawn from this endeavor:

1. To make a simple map of fish distribution on the southwest Florida shelf would require unrealistic oversimplification and unwarranted obfuscation of data;
2. The shelf is, from the standpoint of most fishes, a single, accessible zone within which there are preferred habitats distributed in a mosaic fashion; and
3. Zones or boundaries are much more relevant to sessile, benthic organisms than to highly motile species such as fishes.

Fishes of the southwest Florida shelf arbitrarily are divided into three categories (primary reef dwellers, secondary reef dwellers, and non-reef dwellers), which may be sufficient to describe the distribution of most fishes on the shelf.

The size, type, and relief of gorgonian patches, sponge assemblages, or other benthic relief may be the most important factors in determining the species composition of primary and secondary reef dwellers. Most of the patch reefs, gorgonian beds, and other benthic features of the shelf are relatively small and low, isolated from one another by wide stretches of sand. The size of patch reefs is directly related to the diversity and stability of the fish communities associated with them (Gladfelter et al., 1980). For large species, in particular, they may serve as more of a landmark than a source of shelter (Ogden and Ebersole, 1981).

Nonetheless, some patterns of fish distribution were clearly visible, with various species preferring inshore areas and others preferring offshore regions of the shelf. For most of the inshore species, their distribution probably reflects the distribution of large epibiota (sponges, gorgonian beds) providing benthic relief on an otherwise relatively flat, featureless shelf. Fishes preferring very shallow water may also be restricted by dietary requirements for nearby shallow water plant communities, rather than by physical or physiological depth limitations.

Many of the deeper species were small forms such as serranids and damselfishes. Their distribution pattern may be tied to the availability of holes for shelter. Many of the species found in agariciid plate coral and algal nodule environments in deeper portions of the shelf are known from shallower depths in more fully developed coral reef areas, pointing out the importance of hiding places from larger predators such as lizardfishes, which abound on the sandy shelf.

3.10 FISHERIES/SOCIOECONOMICS

3.10.1 OVERVIEW OF RECREATIONAL AND COMMERCIAL FISHERIES

Saltwater fishing activities, both commercial and recreational, are essential for the social and economic welfare of the citizens in southwest Florida, an area known for its marine resources. The diversity of aquatic habitats found off southwest Florida provides food and shelter for various invertebrates and fishes that directly or indirectly relate to commercial and recreational fisheries. Across the broad continental shelf are soft-bottom areas, seagrass meadows, and scattered hard-bottom areas that attract assemblages of fishes and invertebrates, including important fishery species. The adjacent coastal areas lined with mangroves, salt marshes, and sandy beaches provide nursery and permanent residence to many economically important species of fish and shellfish. These species are exploited by tourist and resident recreational anglers and commercial fishermen.

Recreational Fisheries

Recreational fishing is a substantial component of Florida's economy, and both residents and tourists participate. Bell et al. (1982), investigating the economic impact of recreational fisheries in Florida, estimated that fisheries resources used for saltwater recreational fishing in Florida had an asset value exceeding $27 billion. Approximately $5 billion were directly or indirectly generated by tourist and resident saltwater recreational anglers. Approximately $1.4 billion in revenues generated 124,000 jobs. Furthermore, tourist and resident anglers generated almost $150 million in state taxes for Florida. Recreational fishing by tourists yielded $763 million in direct net income to the state during 1980.

On a regional basis, Bell et al. (1982) estimated that more than 625,000 resident and tourist saltwater anglers in southwest Florida spent almost 10 million man-days fishing during the 1980-1981 season. The southwestern region of Florida (not including Monroe County) contained 21.3% of all resident saltwater anglers in the state and, at 24 fishing days per angler, was most active of the five state regions investigated. This region also reported the highest retiree angler participation in the state (23.7%), reflecting the size of the local retirement community. Similarly, most tourist saltwater recreational anglers in southwest Florida were retired. Numbers, efforts, and expenditures of tourist and resident recreational anglers in the southwest Florida region are listed in Table 3.10-1.

In estimating the distribution of fishing effort for the southwest Florida region, Bell et al. (1982) found that approximately 84% of the fishing days were spent on surf, shore, pier, jetty, or bridge fishing, and the remaining 16% of the fishing days were spent on charter, party, or private boats. Fishing effort by boaters in the southwest Florida region occurred primarily within 3 mi of shore. Recreational boat registrations for the southwestern Florida counties are listed in Table 3.10-2. Private vessels, party boats, charter boats, and guide boats are important to recreational for-hire fisheries of the area. In the Florida Keys, which were not included in the previous estimates of fishing effort, there were 86 charter boats and 24 party boats operating during 1984, whereas 215 charter boats and 41 party boats operated on the west coast of Florida during 1984 (Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council, 1985). The primary ports are Fort Myers, Marathon, and Key West (U.S. Department of the Interior MMS, 1984). Party boats fish primarily over offshore hard-bottom areas, wrecks, or artificial reefs for amberjack, barracuda, groupers, snappers, grunts, porgies, and sea basses. In addition, charter and party boats operating out of Key West frequently make trips to the Dry Tortugas to fish for grouper and snapper. Blue-water charter fishing for billfishes, dolphin, tunas, and wahoo occurs mostly along the east coast of the Florida Keys where Gulf Stream waters pass closest the shore. The most sought-after inshore species in the Ten Thousand Island area include spotted sea trout, red drum, gray snapper, tarpon, and snook. Kinch and O'Harra (1976) reported that guided charter boats were more successful than private boats in that area.

Table 3.10-1. Estimated total number of resident and tourist saltwater anglers, expenditures, and days in southwest Florida (not including Monroe County) from 1980 to 1981.*

	Residents	Tourists	Total
Number of Anglers	250,380	374,820	625,200
Annual Expenditures	$118,148,348	$109,176,455	$227,324,803
Total Days	6,000,146	3,982,172	9,982,318
Expenditures/Day	$19.69	$27.42	$22.77**
Annual Expenditures/ Angler	$471.88	$291.27	$363.60**
Days/Angler	24	11	16**

*Data from Bell et al. (1982).
**Weighted average of tourist and resident values (weighted by number of anglers).

Table 3.10-2. Boat registrations and saltwater products licenses issued in southwest Florida coastal counties, 1984 to 1985.*

County	Boat Registrations		Salt Water Products Licenses
	Commercial	Recreational	
Charlotte	521	9,281	287
Lee	1,701	21,898	1,097
Collier	969	11,612	415
Monroe	3,621	11,856	2,698

*Data supplied by Florida Department of Natural Resources, Tallahassee, Florida.

Commercial Fisheries

Florida's marine commercial fishery, although not as valuable as the recreational fishery, was ranked fifth nationally in value of dockside landings ($171,073,000) in 1985, and ninth in terms of poundage (182,577,000) (National Marine Fisheries Service, 1986a). The seafood industry of Florida is best described as producing multiple species with higher per-pound market prices than larger volume, single species fisheries of other states (Cato, 1985). This description certainly applies to the fisheries of the study area, particularly Monroe County, where valuable species such as pink shrimp, spiny lobster, stone crab, and snapper are caught. Fish and shellfish landings from Collier, Charlotte, Lee, and Monroe Counties (G. Davenport, personal communication) are depicted in Figures 3.10-1 and 3.10-2. Monroe County leads the four counties in volume and value of fish and shellfish landings, and Lee County is ranked second. As a port, Key West (Monroe County) ranked 43rd nationally in terms of pounds landed; also, Key West ranked 14th and Fort Myers (Lee County) ranked 27th nationally in terms of dollar value of the catch (National Marine Fisheries Service, 1986a).

Fishing effort by the commercial sector in a particular area is often estimated by counting the number of commercially registered vessels in the area. Also, the number of saltwater products licenses (required of anyone selling seafood products in the State of Florida) issued by county may be a relative indicator of commercial fishing activity in those counties. Table 3.10-2 indicates that, for the 1984-1985 period, the numbers of saltwater products licenses and commercial boat registrations were highest in Monroe County, followed by Lee, Collier, and Charlotte Counties.

3.10.2 SPECIES PROFILES

Recreationally and commercially important species of fish and shellfish in the southwest Florida region are profiled in the following paragraphs.

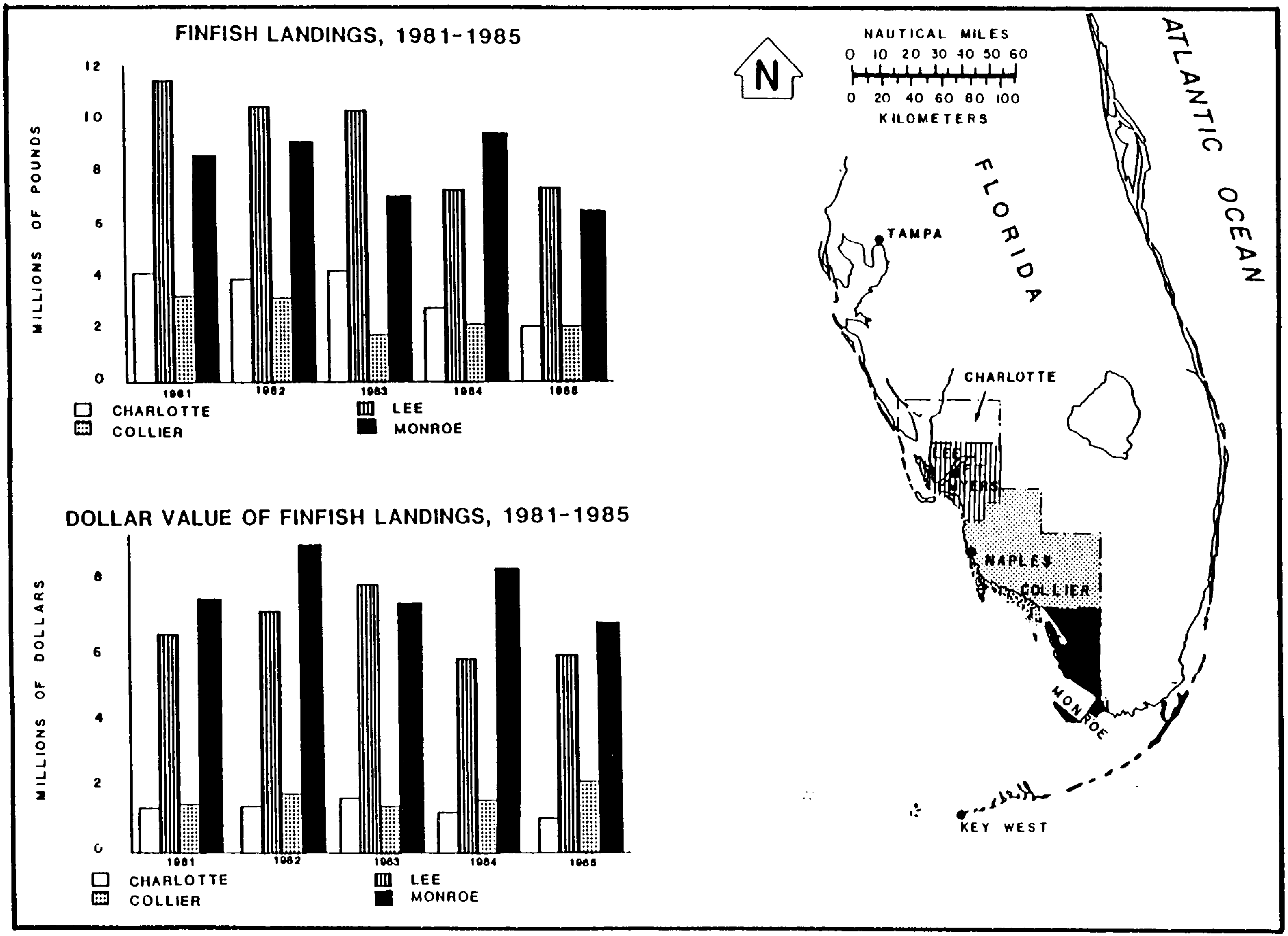


Figure 3.10-1 Commercial finfish landings from coastal counties of southwest Florida.

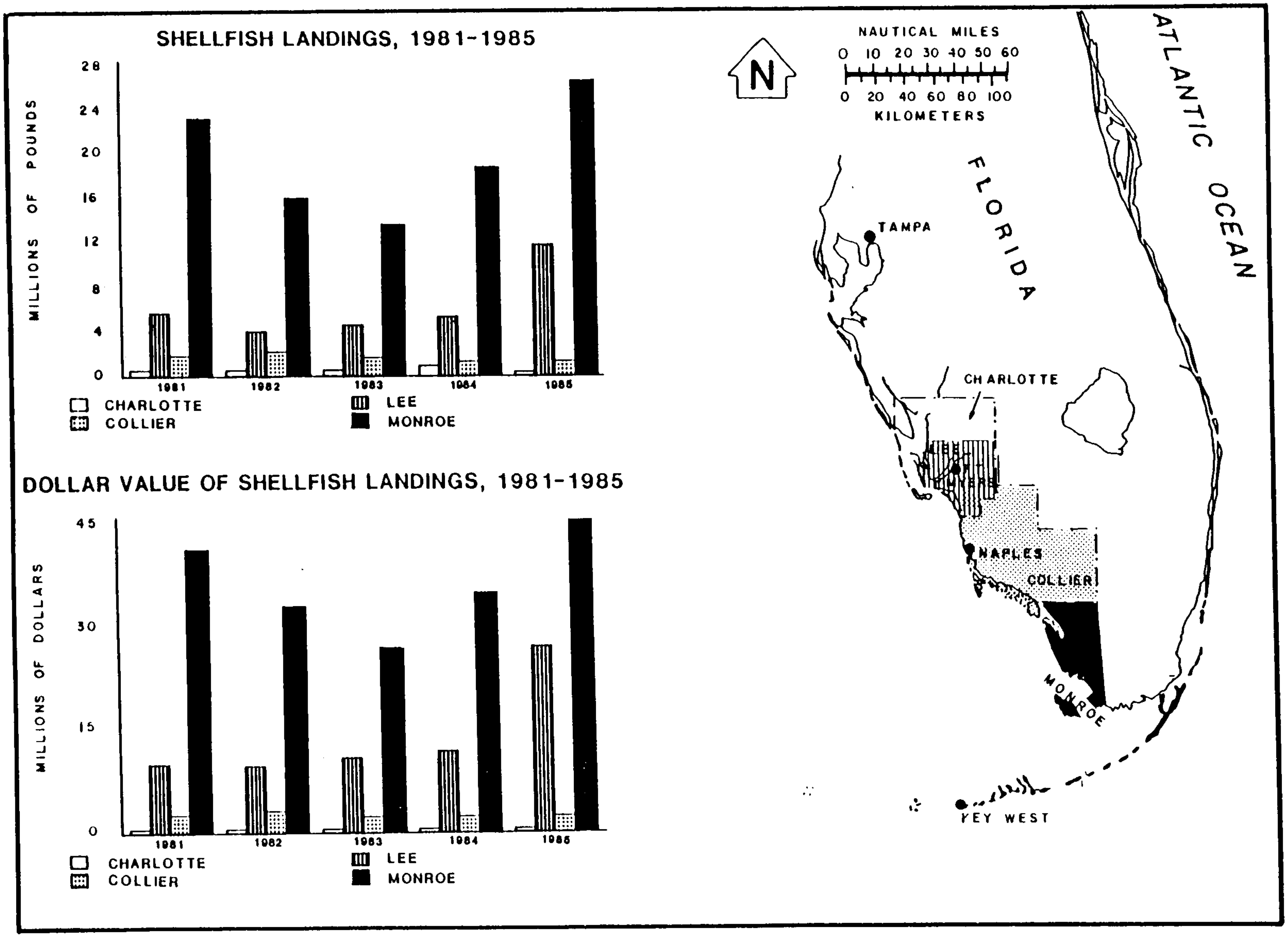


Figure 3.10-2 Commercial shellfish landings from coastal counties of southwest Florida.

Finfishes sought by recreational and commercial anglers in southwest Florida may be broadly grouped as inshore fishes, coastal pelagic fishes, and reef fishes for general discussion. Other groups such as offshore pelagics (e.g., billfish, dolphin, and tuna) certainly occur in the area, but they will not be discussed because they are not as important to the regional fisheries as the aforementioned groups.

In addition to the county landings cited previously, catch statistics are also recorded by statistical reporting grids (G. Davenport, personal communication; see also MMS, 1984). Statistical reporting Grids 1 through 4 cover much of the study area (shown on figures cited in the following paragraph). Catch data from each grid from 1979 to 1983 were provided by G. Davenport of NMFS in Miami. Data compiled from each grid as 5-year averages were used to characterize the study area in terms of the commercial catch of each of the groups discussed in the subsequent paragraphs.

Inshore Fishes

Inshore species important to fisheries of the study area include red drum, spotted sea trout, snook, striped or black mullet, tarpon, pompano, black drum, and sheepshead. Many of these species spawn in coastal or occasionally oceanic waters, but early-life history stages are dependent on inshore/estuarine areas for survival and growth. With the exception of the sea trout and mullet, these species are sought primarily by recreational anglers. Red drum have recently been declared a gamefish by the State of Florida. Recreational catch statistics are not available on a regional basis; therefore, only commercial catches from NMFS reporting grids are discussed. Figure 3.10-3 shows the magnitude and locations of commercial catches of inshore species from NMFS Grids 1 through 4 in the study area. Pompano, black drum, and sheepshead are not as commercially important as the other inshore species and are omitted from the following discussion.

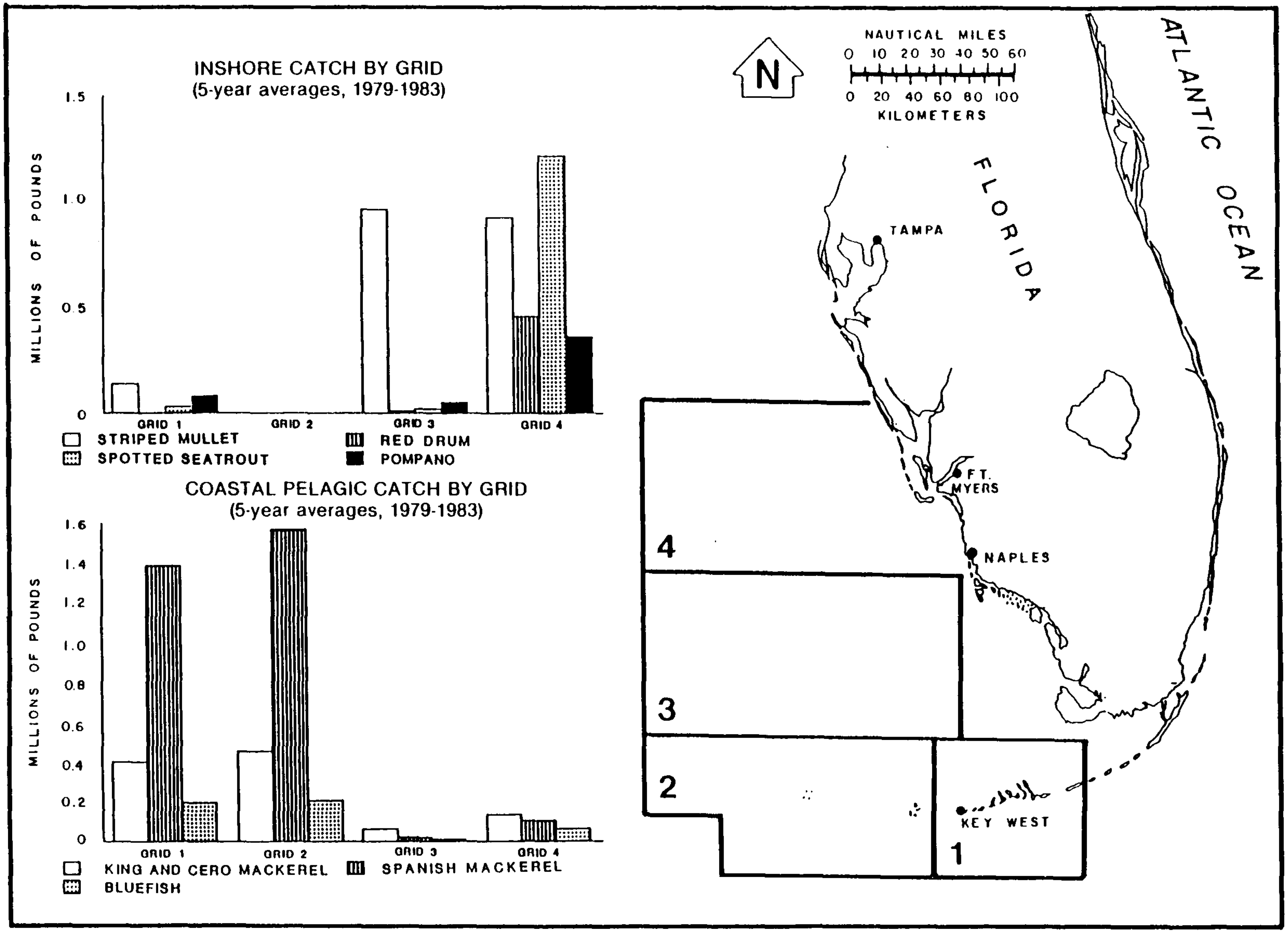


Figure 3.10-3 Commercial catch of inshore and coastal pelagic fishes within NMFS statistical grids.

Red Drum (Sciaenops ocellatus)

Red drum or redfish are found in inshore areas, usually around oyster bars and mangrove shorelines. Spawning occurs in coastal waters from mid-August to November, with peaks during September and October when adults form large aggregations (Reagan, 1985). Young are found in low-salinity waters, usually over seagrass meadows, where they reside for 6 to 8 months. Collins and Finucane (1984) collected red drum larvae during August and November from inshore waters of the Everglades National Park. Adults forage on crabs, shrimps, and benthic fishes. In the study area, red drum are distributed from Fort Myers south into northern Florida Bay. Commercial fishermen use seines, gill nets, and pound nets to capture this species. During 1979 through 1983, red drum were caught primarily in NMFS Grid 4 (Figure 3.10-3). The popularity of red drum as a target species of the charter boats operating in and around Everglades National Park and the Ten Thousand Island area has increased in recent years. Several management measures are being explored, including changing red drum status to a game fish (thereby halting all commercial harvesting) and releasing hatchery-reared young.

Spotted Sea Trout (Cynoscion nebulosus)

Spotted sea trout are known to inhabit inshore seagrass habitats during their entire life cycle (Lassuy, 1983). Spawning occurs in channels or deeper areas adjacent to seagrass meadows from April through July (Tabb, 1966). There is an ontogenetic shift in diet from zooplankton and microinvertebrates in juveniles to fishes and macroinvertebrates in subadults and adults (Darnell, 1961). Spotted sea trout are sought by commercial and recreational anglers throughout the inshore waters of the study area. Commercial catches were highest in the northern part of the study area in NMFS Grid 4 (Figure 3.10-3), where catches are made using gillnets, trammel nets, and pound nets. Bell et al. (1982) found spotted sea trout to be ranked second in the state in terms of recreational catch. Kinch and O'Harra (1976) found spotted sea trout to be the major species caught by recreational anglers in the Ten Thousand Island area of Collier County; 81% of the catch was recorded from November to May. In

1985, spotted sea trout represented 10% of the total Gulf of Mexico recreational catch (NMFS, 1986b).

Snook (Centropomus undecimalis)

Four species of snook occur in southern Florida waters (Rivas, 1986); however, only the common snook (C. undecimalis) is sought by recreational anglers. Snook inhabit inshore waters of southwest Florida during all phases of their life cycle. Spawning occurs from June through August, when mature adults aggregate in passes, inlets, and coastal waters (Seaman and Collins, 1983). Early postlarval and juveniles display an affinity for low-salinity waters and are found in creeks, ditches, and similar habitats (Gilmore et al., 1983). Adult snook feed on fishes, shrimps, and swimming crabs, whereas juveniles consume zooplankton and other microcrustaceans (Gilmore et al., 1983).

In 1957, fear of overexploitation prompted a ban on the sale of snook in Florida, thus ending all commercial harvest. Since that time, its popularity as a gamefish has increased substantially, and fishing pressure has grown with the number of recreational anglers. Strict management by the Florida Department of Natural Resources includes size limits, bag limits, and, most recently, a closed summer season (June, July, and August) implemented in 1982. Despite these management measures, recreational catches of snook have been declining in recent years along Florida's southwest coast; habitat loss and the alteration of freshwater input into the Everglades (with resulting reductions in suitable nursery areas) may be more serious than fishing pressure in contributing to reduced catches (Seaman and Collins, 1983).

Striped or Black Mullet (Mugil cephalus)

Several mullet species occur in the southwest Florida area, but the striped or black mullet is the primary target of commercial net fishermen. This species travels in small pods or vast schools, primarily over shallow sand flats within bays and lagoons of the study area. Spawning generally occurs in offshore waters from October to February, with a peak during November and December (Collins, 1985). The young move inshore to bays and estuaries, where they reside for 6 to 8 months. Adults graze on benthic algae and detritus. Juveniles are fed upon by inshore predators such as snook, redfish, jacks, and sea trout. Striped mullet constitute a major portion of the commercial finfish landings in Lee and Collier Counties. Fishermen use gillnets to capture mullet, which are sold for food and bait. Most of the striped mullet caught from the study area were reported from the mainland coastal areas, NMFS Grids 3 and 4 (see Figure 3.10-3). Silver or white mullet (Mugil curema) also appear in commercial catches but are not as abundant as striped mullet.

Tarpon (Megalops atlanticus)
The tarpon is a popular gamefish revered by marine recreational anglers worldwide. The Florida Keys are famous for tarpon fishing opportunities. Tarpon are wide ranging as adults, and their migratory nature would generally place them into the coastal pelagic category, but here they will be considered an inshore species because most fishing efforts are restricted to shallow, inshore waters. Larval collections from offshore waters of the study area indicate spawning must occur in this area (Smith, 1980). Leptocephalus larvae migrate inshore and settle in low-salinity habitats, usually mangrove creeks or shallow lagoons. A related species, the bonefish (Albula vulpes), is also an esteemed gamefish that reaches peak abundance in the Florida Keys. Bonefish live on the shallow sand and seagrass flats of the Florida Keys and Florida Bay and forage for molluscs and crustaceans (Bruger, 1974).

Coastal Pelagic Fishes

Coastal pelagic species are migratory fishes that traverse coastal and inner shelf (neritic) waters during their life spans. Typical coastal pelagics encountered on the southwest Florida shelf include Spanish, cero, and king mackerels; bluefish; little tunny; and cobia. These species are important fishery resources to both recreational and commercial fishermen, but, economically, the Spanish and king mackerels are the most important.

Spanish Mackerel (Scomberomorus maculatus)
Seasonal migrations in the eastern Gulf of Mexico occur in fall when schools migrate south along the coast from near Cape San Blas (Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council, 1985). Traveling in schools of similar-sized individuals, Spanish mackerel will often enter lagoons or bays during their migrations. Spawning of females 2 years of age or more occurs from April until September (Powell, 1975). Although actual spawning grounds are unknown, larval collections suggest that spawning occurs on the west Florida shelf (Dwinell and Futch, 1973; Houde et al., 1979; McEacheren et al., 1980).

Spanish mackerel are important to both recreational and commercial interests in southwest Florida. During 1979 through 1983, the highest Spanish mackerel catches were made in NMFS Grids 1 and 2 (including the Florida Keys and the Dry Tortugas) using purse seines, gillnets, and hook and line (Figure 3.10-3). Peak catches were reported in 1982, when almost two million pounds were caught in Grid 1. Catch quotas for commercial hook and line, net, and recreational fishermen have been proposed (Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council, 1985).

King Mackerel (Scomberomorus cavalla)
This coastal pelagic is one of the most economically important fish to commercial and recreational fishermen. King mackerel travel in large schools that, like those of Spanish mackerel, are segregated by size. Tagging studies have provided researchers with evidence of an Atlantic king mackerel population and a Gulf of Mexico king mackerel population. The Gulf stock apparently circumnavigates the Florida peninsula during a winter migration from the lower east coast of Florida into the Gulf of Mexico (Gulf of Mexico Fishery Management Council and South Atlantic

Fishery Management Council, 1985; Sutherland and Fable, 1980). According to the proposed migration route, the Gulf king mackerel stock traverses the shelf waters of the study area during spring and fall. King mackerel are attracted to natural or artificial structures that exhibit some relief, especially if there is an abundant supply of bait fishes. Spring and summer are primary spawning seasons, but spawning areas are not known for the eastern Gulf of Mexico (Beaumariage, 1973). King mackerel feed on a variety of fishes and invertebrates, preferring clupeids (Saloman and Naughton, 1983).

In terms of commercial catch, NMFS Grids 1 and 2 (southern part of the study area) yielded the most pounds over the 1979-to-1983 period (Figure 3.10-3). Commercial fishermen catch king mackerel by trolling, handline, and run-around gillnet. The recreational catch, although not well known, is thought to exceed the commercial catch. Stock assessments from 1983 indicate that Gulf king mackerel were overfished and the stock was declining (Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council, 1985). Initial management measures include Federal catch quotas for net and hook-and-line users and closed seasons for Federal waters. The closely related cero mackerel also occurs in the waters of the Florida Keys and is included with the king mackerel catch.

Reef Fishes

Reef fishes or hard-bottom fishes most exploited in recreational and sport fisheries include larger predatory species (e.g., snappers, groupers, grunts, porgies, barracudas, and jacks). Smaller reef-associated species, including angelfishes, butterflyfishes, damselfishes, gobies, jawfishes, and small sea basses, are sought by recreational and commercial aquarists for ornamental purposes, but collecting activities are restricted largely to areas in Monroe County where the Florida reef tract occurs close to shore. Scattered hard-bottom or live-bottom areas exist on the shelf throughout the study area in water depths of 5 to 200 m. Such areas, as well as artificial reefs, attract various assemblages of reef fishes depending on environmental factors and chance.

Using electronic navigational equipment such as Loran C, fishermen easily find and fish particular structured areas, usually for snappers and groupers. This often results in overfishing and eventual stock depletion. Reef fishes are the most important group to the charter boat industry of west Florida (Gulf of Mexico Fishery Management Council, 1981). The most sought-after reef species, snappers and groupers, are known to grow slowly and mature late; therefore, intense fishing pressure can have serious effects on the stocks by depressing the average size of adults in heavily fished areas. Other reef species, e.g., amberjack (Seriola dumerili), jacks (Caranx spp.), grunts (Haemulon spp.) and great barracuda (Sphyraena barracuda), are captured by commercial and recreational fishermen and are becoming increasingly important fishery resources as snapper and grouper stocks decline.

Snappers (Lutjanus spp., Ocyurus chrysurus, and Rhomboplites aurorubens)

Several snapper species occur in the study area, including red (L. campechanus), gray (L. griseus), lane (L. synagris), mutton (L. analis), cubera (L. cyanopterus), and dog (L. jocu) snappers. Most species are typically found near high-relief, hard-bottom areas, where they swim in small groups or schools by day. At night, these schools disperse to feed over adjacent sandy areas or seagrass meadows (Starck and Davis, 1966). The vermilion (Rhomboplites aurorubens) and yellowtail (Ocyurus chrysurus) snappers are both found associated with hard bottom, but are mid-water foragers. Gray snappers are wide ranging in terms of environmental tolerance, existing from inshore estuarine waters to offshore reefs. In the Florida Keys, spawning takes place on offshore reefs from June to August, and larvae settle in inshore habitats, particularly seagrass meadows (Starck, 1971). Adult red snapper occur in deeper waters (30 to 65 m); spawning apparently occurs at inner-shelf areas from June to October (Futch and Bruger, 1976). Juvenile red snapper are found in inner shelf waters over level bottoms. Yellowtail, mutton, and lane snappers have prolonged spawning seasons with spring-summer peaks, and the young usually are found in seagrass beds (Bortone and Williams, 1986). Houde et al. (1979) collected lutjanid larvae in the study area year round, but peak abundances occurred during summer months.

Red snapper catches from the Gulf of Mexico have been declining since 1965 despite increased fishing effort (Gulf of Mexico Fishery Management Council, 1981). During 1979 through 1983, yellowtail dominated the snapper catch in the Florida Keys, and consequently NMFS Grids 1 and 2 displayed peak catches of this species (see Figure 3.10-4). Gray snapper was the dominant species in the commercial catch from the four grids. Additionally, gray snapper was one of the top five most sought-after recreational fish in the Ten Thousand Islands area of Florida (Kinch and O'Harra, 1976). Snappers are caught using handlines, electric reels, bottom longlines, stab nets, and fish traps (Gulf of Mexico Fishery Management Council, 1981).

Groupers (Epinephelus spp. and Mycteroperca spp.)

Groupers rank with snappers as the most sought-after reef fishes by both commercial and recreational anglers in the eastern Gulf of Mexico. Groupers characteristically inhabit hard-bottom areas that exhibit varying degrees of relief. Species range from small hinds weighing less than a kilogram to large jewfish (E. itajara) and warsaw grouper (E. nigritus) exceeding 200 kg. Groupers important to the fisheries occur over a wide range of water depths. Species generally occurring in deep water (50 to 300 m) include yellowedge (E. flavolimbatus), snowy (E. niveatus), warsaw, and speckled hind (E. drummondhayi) groupers. Typical shallow water (less than 80 m) species include red grouper (E. morio), black grouper, (M. bonaci), gag (M. microlepis), scamp (M. phenax), jewfish, and smaller hinds (Epinephelus spp.). The young of the shallow water group are found in inshore waters associated with seagrass beds, rocky areas, and patch reefs. Moe (1969) found that red

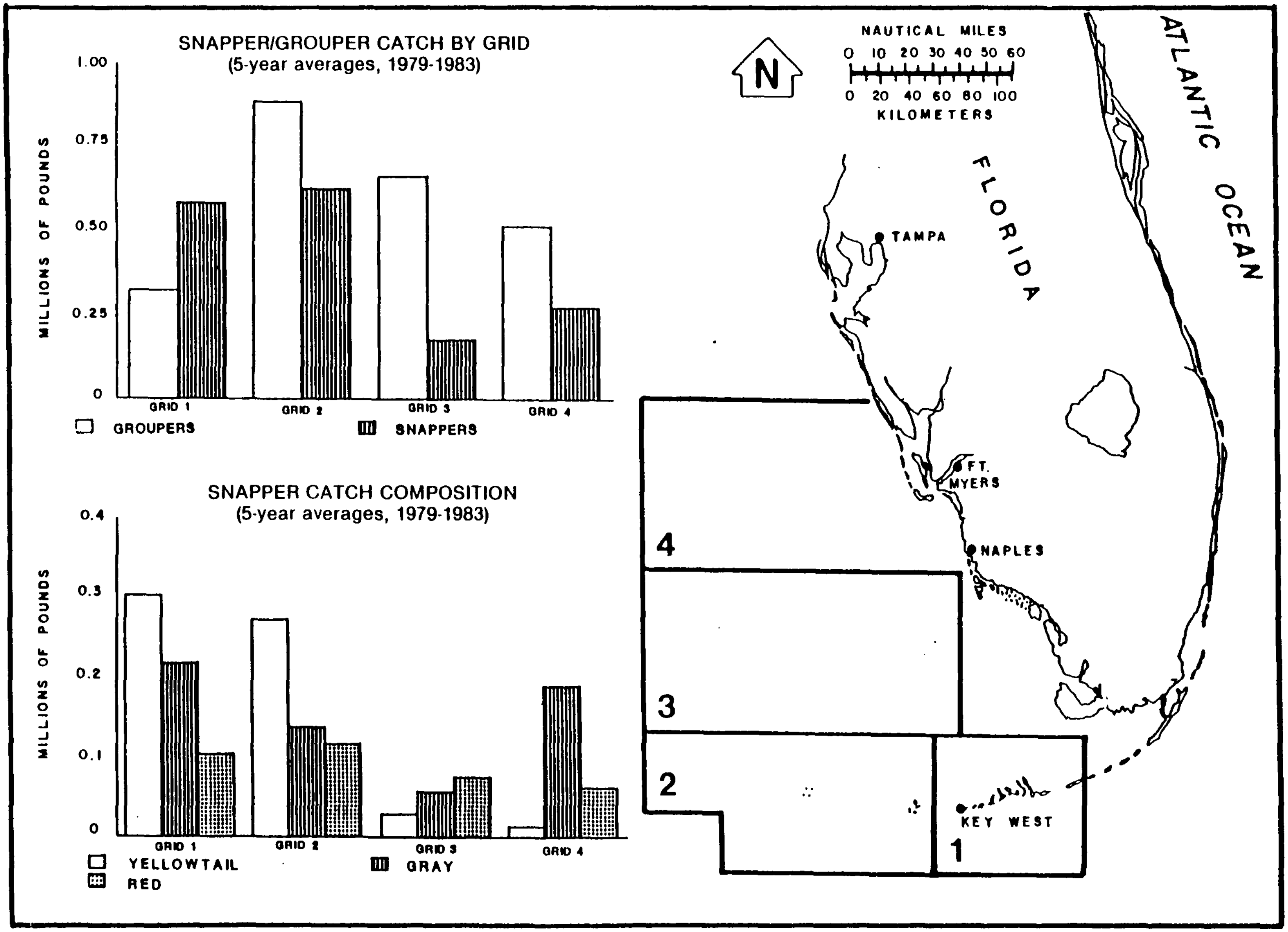


Figure 3.10-4 **Commercial snapper and grouper catch within NMFS statistical grids.**

grouper are hermaphroditic, changing sex from female to male at some particular age. Red grouper spawn in April and May on the west Florida shelf (Moe, 1969). The red grouper, the gag, the scamp, and, to a lesser extent, the black grouper are the most important commercial finfish species on Florida's west coast (Gulf of Mexico Fishery Management Council, 1981). Grouper were caught in all NMFS grids during 1979 to 1983, but most were reported from Grid 2 (see Figure 3.10-4). The most common grouper fishing methods include handlining, bottom longlining, spearfishing, and fish trapping.

Shellfish

In fisheries applications, the term shellfish refers to invertebrates, including shrimps, crabs, oysters, scallops, and lobsters. In the southwest Florida region, decapod crustaceans (shrimp, stone crab, and spiny lobster) dominate the commercial catches. These invertebrates bring high dockside prices and are responsible for the high dollar values of the Monroe and Lee County fisheries (Figure 3.10-2). Pink shrimp are the most important shellfish species occurring in the area, followed by spiny lobster and stone crab. Some recreational participation is involved, particularly with spiny lobster harvest by recreational divers (Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council, 1986). The pink shrimp, spiny lobster, and stone crab fisheries in the area are described in the following sections. Not included in the discussion is the blue crab (Callinectes sapidus), a less important shellfish species in the study area that is landed mostly in Grid 4 (see Figure 3.10-5).

Pink Shrimp (Penaeus duorarum)

The Tortugas grounds and the Sanibel grounds are Florida's most productive areas for pink shrimp and are within the study area (see Figure 3.10-6). Both areas combine suitable substrate characteristics with proximity to estuarine nursery grounds; Florida Bay lies north of the Tortugas grounds, and the Sanibel grounds are located west of Charlotte Harbor-Tampa Bay estuaries.

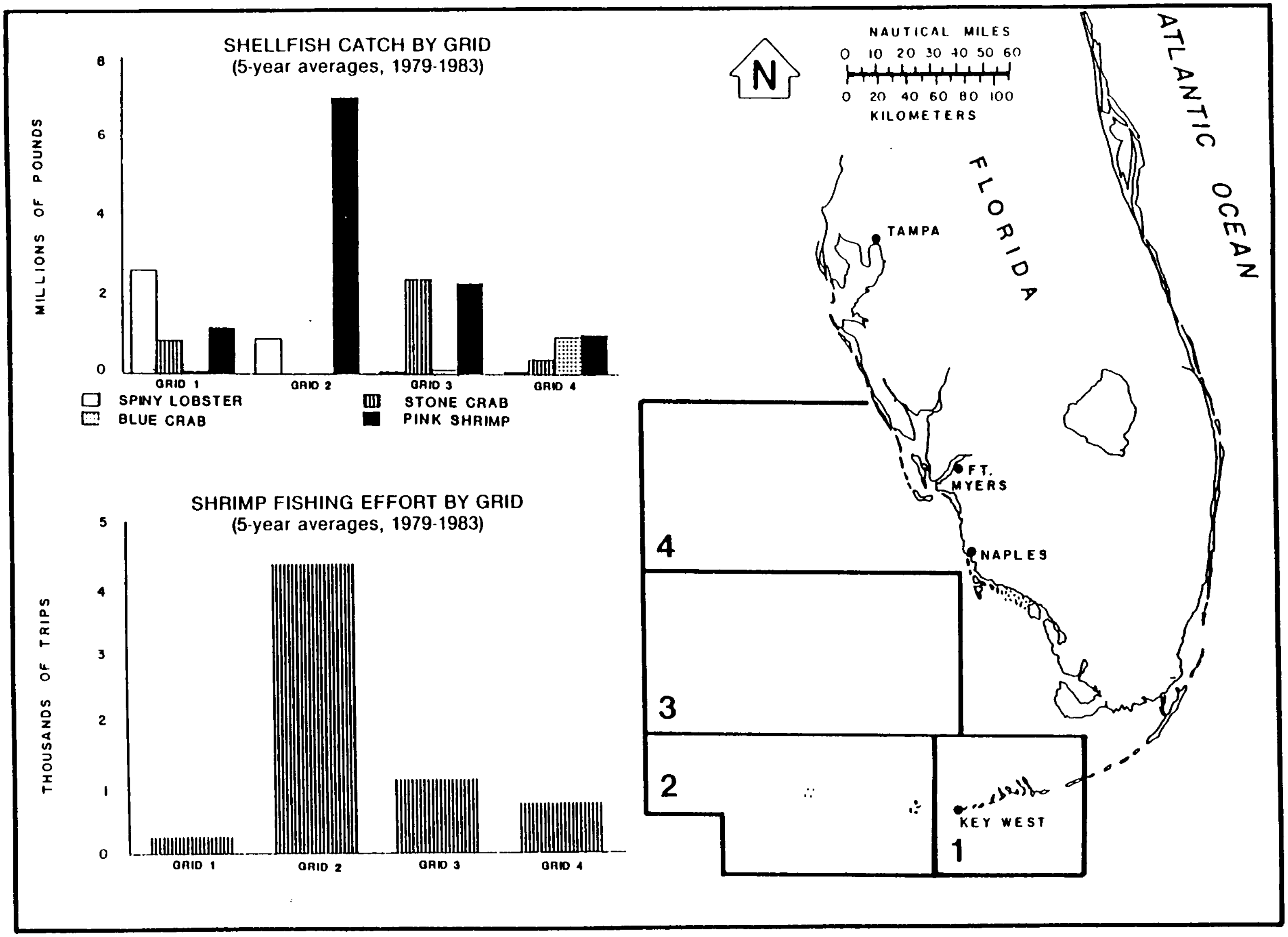


Figure 3.10-5 Commercial shellfish catch within NMFS statistical grids.

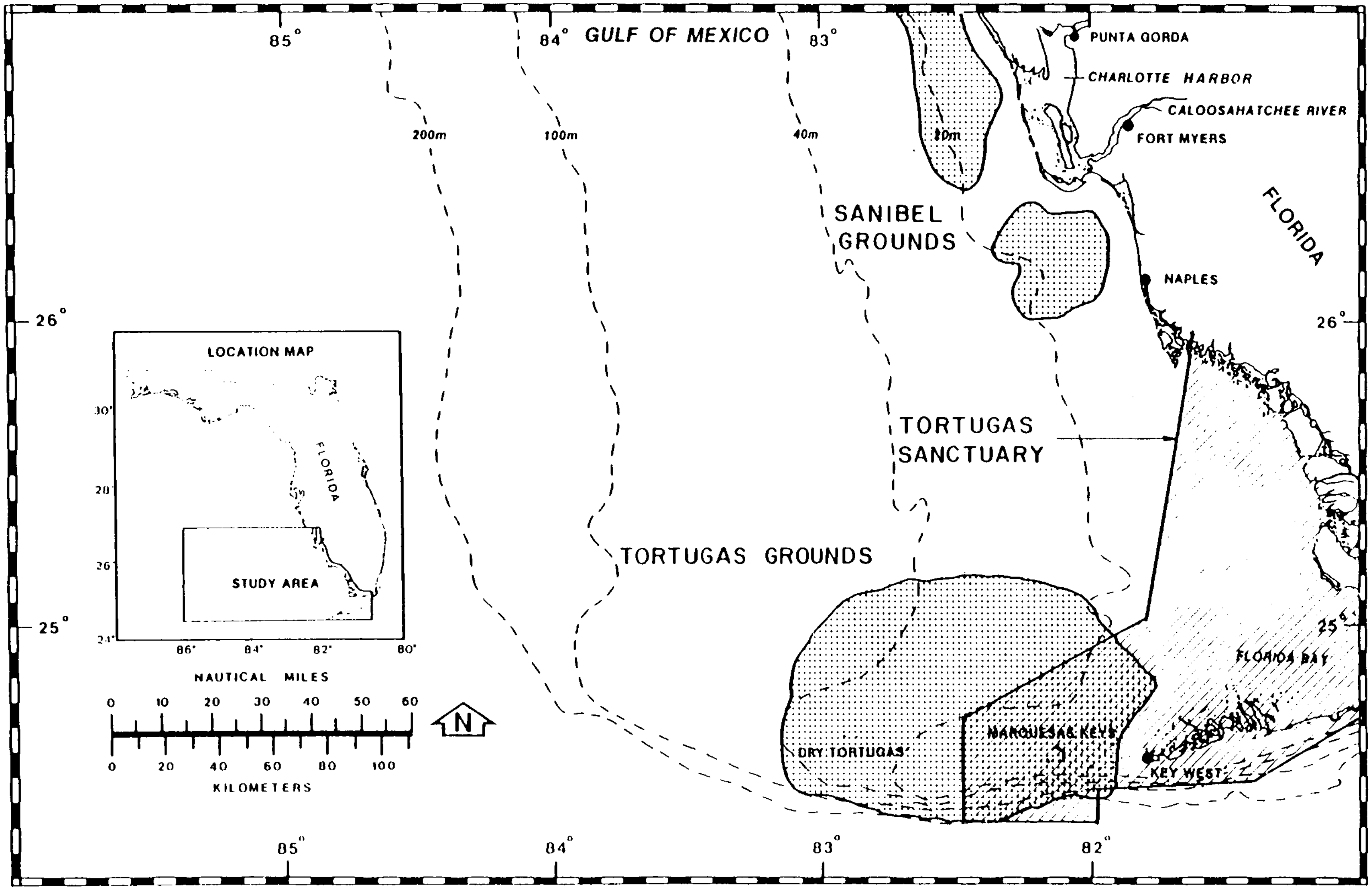


Figure 3.10-6 Location of Tortugas and Sanibel shrimp grounds and the Tortugas sanctuary.

Pink shrimp are dependent on inshore, estuarine nursery areas for the growth and survival of young stages, which undergo an ontogenetic migration from inshore nursery habitat to the offshore spawning grounds (Costello and Allen, 1966). Spawning occurs in oceanic waters 4 to 48 m deep throughout the year. In the Tortugas grounds, spawning occurs during the last phase of the lunar month (Munro et al., 1968). Larvae are transported by currents from spawning grounds to nursery areas in the Everglades National Park. Young spend 2 to 6 months in nursery areas before migrating offshore. Adults prefer calcareous sand bottoms. The Tortugas grounds produce 48% of the pink shrimp landed annually in Florida, and the Sanibel grounds comprise about 28% of the state's production (Bielsa et al., 1983).

Pink shrimp are the most important fishery species on the southwest Florida shelf in terms of volume and value. Other shrimp species, such as rock shrimp (Sicyonia brevirostris) and the deep-water royal red shrimp (Hymenopenaeus robustus), are included in the shrimp catches of the area but are only of minor commercial importance. From 1979 to 1983, the highest pink shrimp catches came from NMFS Grids 1, 2, and 3 (see Figure 3.10-5). Monroe County landed more than 20 million pounds of shrimp worth more than $32 million in 1985 (G. Davenport, personal communication). Commercial shrimping is conducted from vessels 15 to 26 m long, using 14-m otter trawls with 45-mm mesh. Fishing is conducted almost exclusively at night because pink shrimp are buried during the day. Trawls are usually fished from 2 to 3 hours at a time.

In 1981, the Tortugas sanctuary was established as a cooperative closure between the State of Florida and the U.S. Department of Commerce (see Figure 3.10-6). The sanctuary area of 1,124 nmi^2 was officially closed in 1984 after research by NMFS biologists.

Spiny Lobster (Panulirus argus)

Spiny lobster life history involves several phases, beginning with spawning, which occurs during late spring and early summer in Florida waters. Several larval stages remain in the plankton for approximately 6 to 12 months until settling in shallow waters as benthic juveniles. The duration of the planktonic stage has led some investigators to believe that most of Florida's spiny lobster are recruited from southern waters. Two hypotheses currently are invoked regarding the source of settlement-stage larvae reaching the Florida Keys. The first maintains that larvae from Caribbean spawning stocks are transported downcurrent to Florida; the second contends that larvae are derived from local spawning populations retained by local currents (Lyons, 1981; Marx and Herrnkind, 1986). Regardless of origin, the larvae that settle in the shallow waters of the Florida Keys demonstrate an affinity for attached macroalgae as habitat (Marx and Herrnkind, 1985). Adult spiny lobsters congregate under rock ledges, coral heads, and other structures during daylight hours and emerge at night to forage over adjacent sand or seagrass flats (Marx and Herrnkind, 1986).

Florida's spiny lobster fishery, which is concentrated in Monroe County, ranks second to the shrimp fishery in terms of value. In 1985, Monroe County reported more than 3 million pounds of spiny lobster valued at over $8 million (G. Davenport, personal communication). Spiny lobsters are taken by wooden slat-traps and diving, whereas recreational catches are made primarily during skin or scuba diving and, to a lesser extent, using bully nets and nightlights. Little fishing effort for spiny lobsters occurs north of Monroe County on the west coast of Florida (Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council, 1986). In recent years, fishing effort has increased; in 1984, a record 675,000 traps were fished in southern Florida, but catches have declined, resulting in a decreased catch per unit of effort (Gulf of Mexico Fishery Management Council and South Atlantic Fishery Management Council, 1986). Consequently, several management measures are under consideration.

Stone Crab (*Menippe mercenaria*)
Stone crabs are distributed throughout Florida's coastal waters and reach peak abundances off southwestern Florida. This species is reproductively active throughout the year but spawns most frequently during March and September, apparently within seagrass habitats. Each individual passes through six planktonic larval stages of relatively short duration (20 to 40 days) before settling as a juvenile crab. Estuarine dependency of the young has not been established; the greatest concentrations of adults have been found adjacent to nonbarrier, marsh, or mangrove coastlines. Seagrass beds are the preferred habitat, and, in the Florida Keys, sponges, rocks, soft corals, and algae are utilized by juveniles as shelter (Lindberg and Marshall, 1984).

Wooden slat-traps are the most common capture method for stone crabs in southwest Florida. The fishery is unique in that, after capture, the crabs are declawed and returned to the water. Over half of the total state catch is landed in Collier and Monroe Counties. During 1979 to 1983, the catch from NMFS Grid 3 averaged more than 2 million pounds of claws (Figure 3.10-5). Fishing effort is concentrated in shallow waters from northern Florida Bay and west of the Ten Thousand Islands from Cape Romano to Cape Sable (Sullivan, 1979).

3.10.3 SOCIOECONOMICS IN RELATION TO CONTINENTAL SHELF DEVELOPMENT

Southwest Florida's socioeconomics is greatly dependent on water resources. The importance of fishing to local economies was discussed in the previous section. Tourism, Florida's biggest industry, is also heavily dependent on coastal recreation, fishing, and other water sports. General socioeconomics of the southwest Florida region (including population and demographic characteristics, transportation, residential and industrial development, agriculture, mineral and oil resources, recreation and tourism, commercial and sport fisheries, multiple-use conflicts, and environmental issues and regulations) has been characterized by French and Parsons (1983).

Socioeconomic impacts of continental shelf oil and gas development activities will depend on location of the activity (e.g., onshore, offshore, or both), the nature of the local economy, the phase of operation, the size of the find, and the intensity and importance of water-dependent activities (i.e., coastal recreation, fishing, and water sports) in the area. Onshore support facilities for fixed or temporary offshore structures usually locate as close to drilling sites as possible. Onshore activities present various degrees of potential impacts to the surrounding social and natural environments.

Although the probability of major continental shelf onshore facilities being located in southwest Florida is low, certain basic facilities would be required in the event of a find, including a service base, pipeline or pipeline landfall, and a marine terminal (French and Parsons, 1983). The Southwest Florida Regional Planning Council (1983) and the State of Florida Department of Community Affairs (1984) evaluated potential sites for suitability as onshore facility bases. From more than 65 possible sites, 2 (both located in Lee County) have potential for onshore development: San Carlos Island and Port Boca Grande at the southern end of Gasparilla Island (see Figure 3.10-7). Review of these sites reveals that the sites are only marginally suitable for small operations. The San Carlos Island site currently supports limited industrial marine activity (marinas, commercial fishing, docking, and fueling) and would be able to absorb a few continental shelf support vessels, but problems would arise if a major find occurred. The Port Boca Grande site offers only short-term advantages as an onshore facility site, and naturally deep water is the only positive characteristic of this location. Exposure of this site to storms and anticipated opposition from Charlotte County officials and residents would detract from its utility as anything but a temporary shore base. If these sites were chosen as support bases, they would require modification if a major strike were involved. Required modifications could lead to environmental impacts that might negate some of the positive aspects of petroleum development.

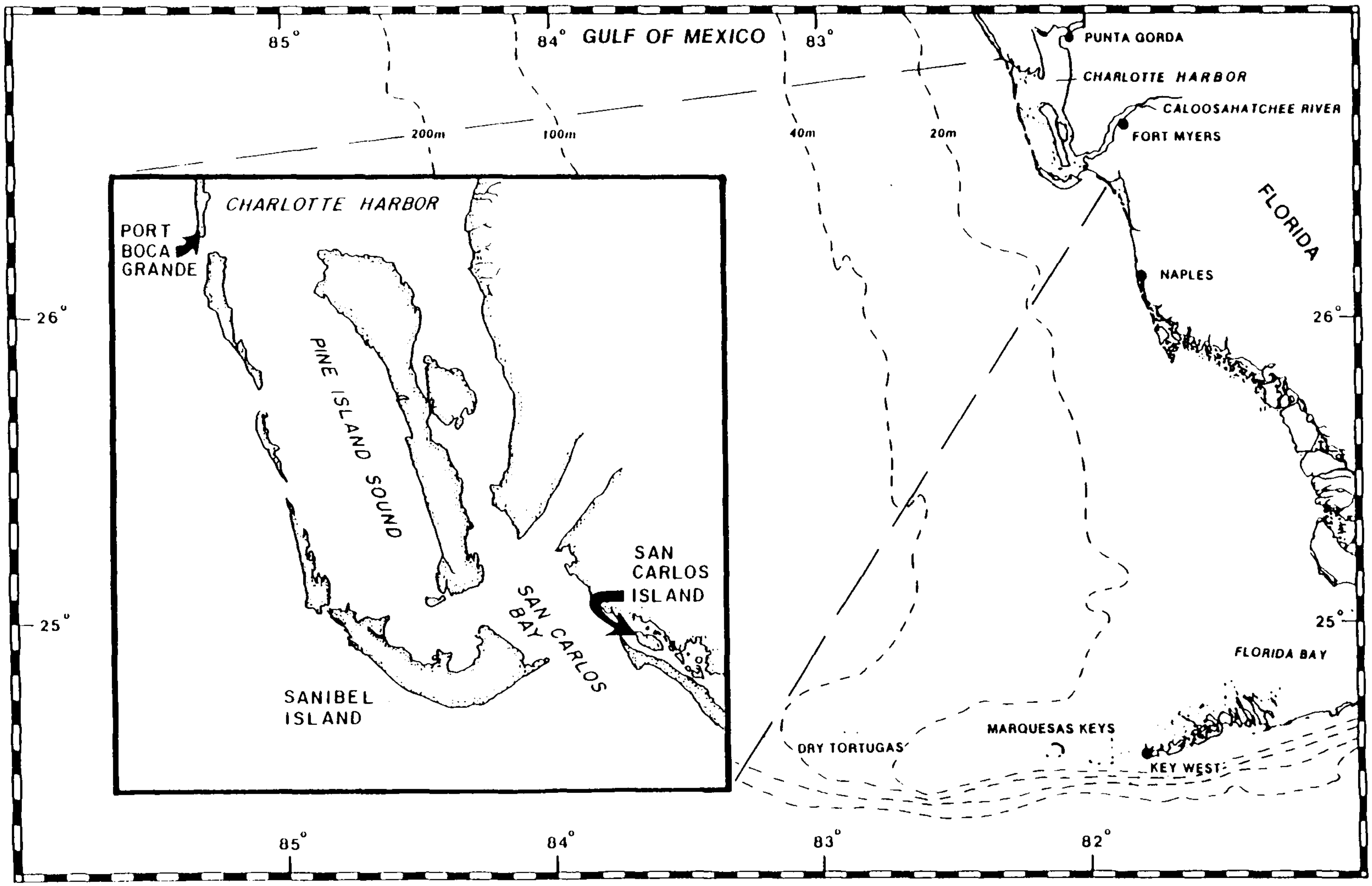


Figure 3.10-7 **Potential onshore facilities sites evaluated by the Southwest Florida Regional Planning Council.**

The State of Florida Department of Community Affairs (1984) reported that local governments in southwest Florida do not have existing policies that adequately address problems associated with continental shelf industry. Most communities in the region depend on tourism, residential construction, commercial fishing, and light industry; most local policies downplay or discourage heavy industry. Siting of continental shelf operations may also conflict with planned land use. The Charlotte County Commission was the only local government agency to specifically endorse continental shelf development; however, the commission also specified that careful monitoring of any and all activities must be conducted. In summary, only small onshore sites with relatively little activity will be able to locate in the southwest Florida region. The most likely alternative will be to use existing areas in the Tampa Bay region (such as Port Manatee) as a shore base for continental shelf oil- and gas-related activities. Port Manatee has been profiled in another regional planning council report (Gee and Jenson, 1982).

3.11 ENDANGERED SPECIES

Florida's geographic position, geologic history, and habitat diversity favor the existence of vertebrates and plants having specific habitat requirements (Pritchard, 1978; Barnett et al., 1980; McCoy, 1981; Woolfenden, 1983). As habitat degrades or disappears, such species become in danger of extinction. The wetlands of Collier and Monroe Counties harbor most of the 68 rare, threatened, or endangered vertebrate species found in southwest Florida (Woolfenden, 1983). Most of these are terrestrial species and are not relevant to the present study. For the marine environment, the most recent Federal listing of endangered species includes six mammals, four birds, and five reptiles that could occur over or in waters of the study area (USFWS, 1986).

The endangered mammals are five whales and one manatee. Endangered whale species known to occur in the Gulf of Mexico include the fin (*Balaenoptera physalus*), blue (*B. musculus*), humpback (*Megaptera novaeangliae*), right (*Balaena glacialis*), sei (*B. borealis*), and sperm (*Physeter catodon*). These large, open-ocean mammals could enter the study area during annual movements, but only rarely (Schmidly, 1981). Fritts et al (1983) reported a single sperm whale from approximately 200 km west of Naples, Florida. This was the only endangered whale reported by them for the study area. Another more frequently sighted mammal, the West Indian manatee (*Trichechus manatus*), is restricted to coastal and inshore waters of the study area. Irvine et al. (1982) estimated the Florida Gulf coast manatee population as 350 to 400 animals. During aerial surveys conducted from July to December 1979 over southwest Florida, the highest numbers of sightings were made in coastal waters of Collier, Lee, and Monroe Counties (Irvine et al., 1982). Most of the manatees (58.5%) were located in the brackish water of Everglades National Park (Monroe County) and Ten Thousand Islands (Collier County).

The Everglades National Park and Ten Thousand Islands are also known nesting and roosting havens for many water bird species, three of which, the brown pelican, the southern bald eagle, and the least tern, are considered endangered (USFWS, 1986). The brown pelican (Pelecanus occidentalis) inhabits coastal areas, particularly mangrove-lined shores. Pelicans nest in mangrove trees, usually on small coastal islands, from early spring through summer (Schreiber, 1978). Kunneke (1983) identified brown pelican nesting colonies in the following places within the study area: Bird Key, Hemp, Cork, and Mason Islands in Pine Island Sound, Lee County; San Carlos Bay and Estero Bay, Lee County; inshore of Marco Island and Chokoloskee Bay, Collier County; Cottrell Key, Big Mangrove Key, Marathon Key, and Crane Key, Monroe County; and Bush and Long Keys in the Dry Tortugas. The endangered southern bald eagle (Haliaeetus leucocephalus) was once common along Florida's entire coastline and, to some extent, in the interior. In coastal areas, eagles usually nest in mangrove trees and lay their eggs from October to February (Robertson, 1978). The least tern (Sterna antillarum) is distributed worldwide, although considered endangered in Florida. Nesting colonies within the study area were indicated by Kunneke (1983) and included Johnson Shoals, Sanibel Island, the southern end of North Captiva Island, and the southern end of Estero Island, all in Lee County; the coast of Collier County north of Naples; and Bahia Honda Key, Monroe County.

In addition to the three bird species discussed above, the peregrine falcon (Falco peregrinus) is worth mentioning as an endangered species that may occur over waters of the study area as a migrant and winter visitor. Though the species is found primarily in estuarine habitats (Woolfenden, 1983), which are beyond the scope of this overview, 12 individuals have recently been reported from the Dry Tortugas (R. Dawson, personal communication). The peregrine falcon roams widely and preys mainly on medium-sized birds from many habitats (Woolfenden, 1983).

Five sea turtles, green (Chelonia mydas), loggerhead (Caretta caretta), Kemp's ridley (Lepidochelys kempii), hawksbill (Eretmochelys imbricata), and leatherback (Dermochelys coriacea), potentially occur in the study area; all but the loggerhead are considered endangered (USFWS, 1986). Although all of these species may occur within the study area, only the loggerhead and green turtles are expected to occur there frequently and migrate through the area to their nesting sites along the beaches of southwestern Florida (MMS, 1984). Of all the turtle observations reported by Fritts et al. (1983) from the study area, 89% were loggerheads, 9% were unidentified, and 2% were kemp's ridleys, greens, and leatherbacks. Sanibel Island (Lee County) and other barrier islands of the area are used as nesting sites by loggerhead turtles (Barnett et al., 1980). The American crocodile (Crocodylus acutus) inhabits coastal swamps and rivers in extreme southern Florida, the Greater Antilles, Mexico, Central America, Columbia, and Ecuador. In Florida, crocodiles are restricted to Monroe and Dade Counties, where the population is estimated as 200 to 400 individuals with only about 25 breeding females. Specific areas of crocodile occurrence include southern Biscayne Bay, Card Sound, Barnes Sound, Lake Surprise, Blackwater Sound, and Buttonwood Sound, and within eastern and central Florida Bay. A disjunct population exists in the Key Deer National Wildlife Refuge on Big Pine Key, in the lower Florida Keys. Nesting is apparently restricted to eastern Florida Bay and southern Biscayne Bay and takes place in April (Ogden, 1978).

3.12 AREAS OF SPECIAL CONCERN

This section discusses habitats that are considered to be biologically valuable and/or particularly sensitive to impacts from continental shelf oil- and gas-related activities. The discussion focuses primarily on coastal habitats and excludes hard-bottom areas on the continental shelf, since these have been described in detail in previous sections of this report.

Two areas of special concern, the Tortugas and Sanibel shrimp grounds, have already been discussed in Section 3.10 (see Figure 3.10-6). Other biologically valuable habitats in the study area that should be considered in an evaluation of continental shelf impacts include mangrove forests, seagrass meadows, tidal marshes, and coral reefs. It has become dogmatic that seagrass beds, mangrove forests, and tidal marshes are valuable because of their primary productivity, sediment trapping, and stabilization abilities, detrital production, nutrient cycling, and habitat value for fishes and invertebrates. These plant communities also exchange energy, materials, and organisms with the continental shelf and, therefore, are relevant to this study.

Seagrass meadows consisting of mixed associations of turtle grass (*Thalassia testudinum*), Cuban shoalgrass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*) occur along the northwest and southwest coasts of peninsular Florida. Iverson and Bittaker (in press) delineated two major offshore seagrass beds on the west Florida shelf, with the southern seagrass bed occupying most of Florida Bay between the Florida Everglades and the outer edge of the Florida Keys reef tract, including the Dry Tortugas and offshore to approximately 10-m depths. They estimated areal seagrass cover within these boundaries to be approximately 5,500 km^2 (550,000 ha) (see Figure 3.12-1). North of Florida Bay from Cape Sable to Tampa Bay, seagrass distribution is discontinuous and mostly confined to inshore lagoons. McNulty *et al.* (1972) estimated there are 20,235 ha of seagrass meadows in Charlotte Harbor. The role of seagrasses as nursery habitat for fishes and

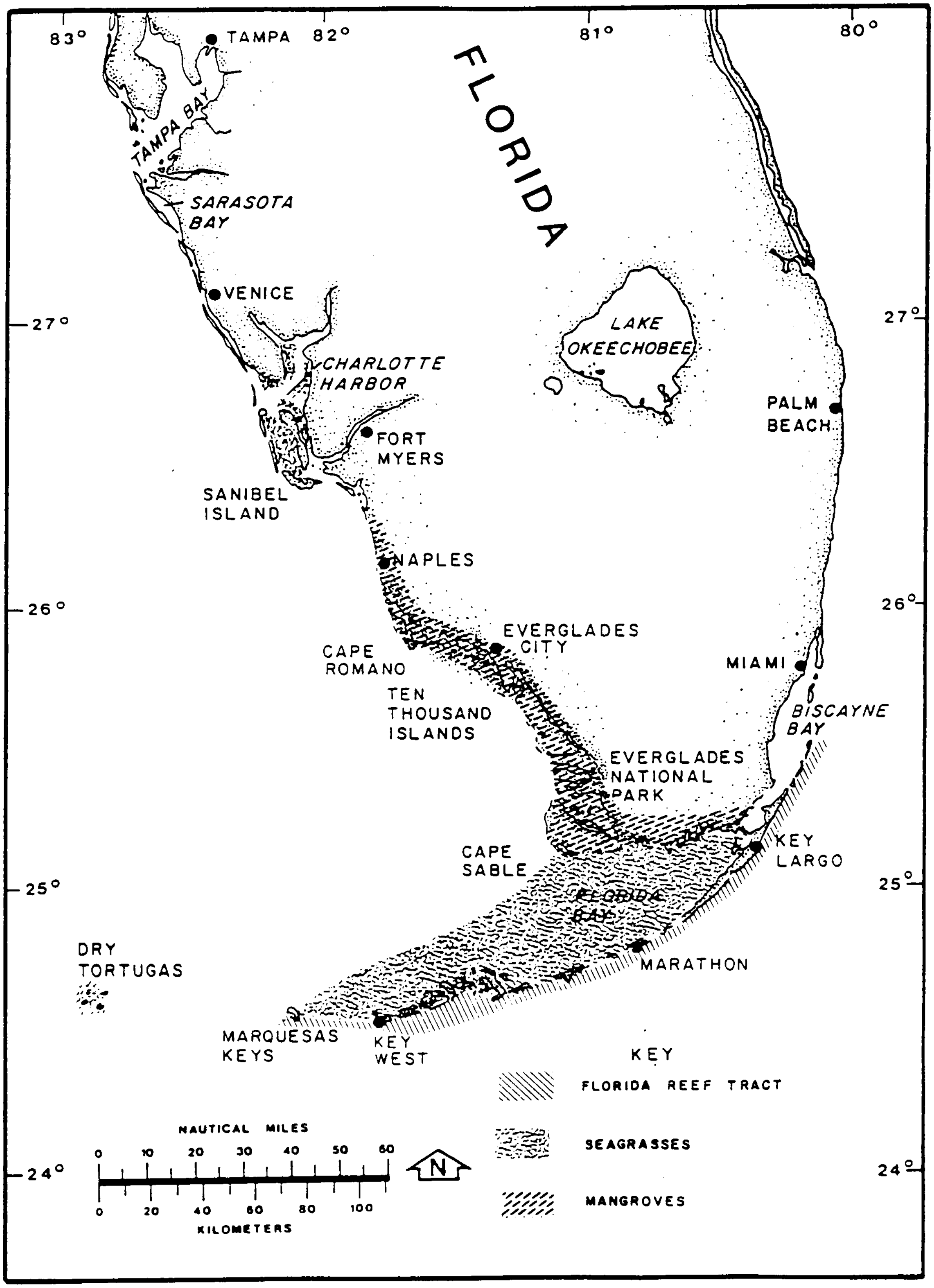


Figure 3.12-1 **Locations of environmentally sensitive coastal habitats in southwest Florida.**

invertebrates is well known, and trophic relationships (herbivory, detrital production, etc.), faunal associations, and human impacts on south Florida seagrasses have been summarized by Zieman (1982). Seagrass distribution within the study area has been mapped by Kunneke (1983) and MMS (1984).

Coastal swamps and lagoons located inshore and north of the Florida Bay seagrass bed, from Cape Sable to Charlotte Harbor, are typified by red (Rhizophora mangle), black (Avicennia germinans), and white (Laguncularia racemosa) mangroves interspersed with tidal marshes (Drew and Schomer, 1984). Mangrove stands, like seagrass meadows, are considered important as wildlife habitats, detrital carbon producers, nutrient cyclers, and sediment stabilizers. The densest mangrove stands exist along the coast from Cape Sable north to Cape Romano. Favorable environmental conditions in this area, particularly warm climate and substrate of suitable slope, are responsible for the proliferation of mangrove forests (Lewis et al., 1985). Estimates of mangrove areal coverage for the coastal counties of the study area (Charlotte, Lee, Collier, and Monroe) exceed 200,000 ha and represent over 75% of the total mangrove coverage for the State of Florida. Tidal marshes constitute about 13,229 ha of the shoreline vegetation in Charlotte, Lee, Collier, and Monroe Counties (less than 4% of the state total) (Lewis et al., 1985). Mangrove distribution in the study area has been mapped by Kunneke (1983), and a summary of mangrove ecology in southern Florida is provided by Odum et al. (1982).

In tropical waters worldwide, seagrasses, mangroves, and corals are known to co-occur in what has been termed a functional and facultative successional sequence (McCoy and Heck, 1976). A similar co-occurrence is found in subtropical Florida owing to a combination of environmental factors, most notably the warm, clear waters of the Florida Current. These factors have promoted the growth of the Florida reef tract, which exhibits many characteristics of a developed Caribbean coral reef (Hoffmeister, 1974). The Florida reef tract forms an arc parallel to the eastern coast of the Florida Keys from Fowey Rocks southward to the Dry

Tortugas (see Figure 3.12-1) (Marszalek et al., 1977). The reef tract has a length of more than 200 km and an average width of about 6 km. Jaap (1984) recognized four coral community types within the reef tract; beginning shoreward, these are as follows:

1. Live bottom--hard, exposed limestone with small stony corals, algae, sponges, and octocorals;
2. Patch reefs--massive dome corals and octocorals in discrete assemblages, usually near seagrass beds;
3. Transitional reefs; and
4. Bank reefs (seaward face spur-and-groove systems with branching and stinging corals).

Marszalek et al. (1977) examined the distribution of outer bank reefs and patch reefs through aerial surveys. Outer bank reefs occur in water depths of 5 to 10 m from Fowey Rocks to the Marquesas Keys, a distance of approximately 95 km. Patch reefs, discrete aggregations of massive corals, octocorals, and sponges sometimes occupying areas of up to 450 m^2 are found inshore of the bank reefs; there are more than 6,000 patch reefs distributed from Fowey Rocks to Marquesas Keys. Similar reef development occurs in a 22,000-ha area around the Dry Tortugas (Davis, 1982). Community ecology of the Florida reef tract has been summarized by Jaap (1984), and Marszalek (1982) has mapped the area.

4.0 POTENTIAL IMPACT PROJECTIONS

4.0 POTENTIAL IMPACT PROJECTIONS

The goal of this section is to present projections of potential impacts that might be expected if major oil and gas development of the southwest Florida shelf proceeded. Impacts were estimated primarily for localized areas or specific ecological compartments, again assuming oil and gas development proceeds. The assessments are generic in nature; therefore, they may differ somewhat from the specific Planning Area Impacts generated by Minerals Management Service (MMS Environmental Impact Statement for Sales 113/115/116). For specific information on impacts from the eastern Gulf of Mexico for the Sale 116 proposal, refer to that official document which is in preparation as of March 1987.

As a first step, regional-scale community descriptions are provided including: (1) evaluations of important physical/chemical oceanographic factors that likely control community development, (2) the types and structure of the different community types occurring across the shelf, and (3) generalized trophic relationships exhibited by marine communities comprising the regional ecosystem.

The nature of impacts related to oil and gas development were then evaluated using a factor train analysis approach (Darnell et al., 1976) to identify primary, secondary, and tertiary effects of development on the shelf habitats in sequential order. Habitat effects were then translated to ecosystem effects.

The next step in the analysis was to develop submodels for specific components of the ecosystem having value to man (VECs). Each submodel is presented as a flow diagram connecting the development activities through intermediate steps to the final presumed impact on the organism of concern. Some 15 submodels are presented, which, if arrayed together in an overall ecosystem diagram, would yield the system conceptual model. Taken together, the VEC submodels include representatives of producers and consumers at all trophic levels and of all communities from the beach to the shelf edge. The diagrams also include species of recreational and commercial interest, ecosystem dominance, environmental sensitivity, and representation on the endangered species list. The submodels are integrated as an impact summary matrix in Section 4.4. The matrix is annotated in terms of level of impact, probability of impact, and spatial extent of impact.

Several background comments need to be made. First, the impacts delineated were conceptualized in terms of a given structure or activity; therefore, the perceived impacts must be considered in a local versus regional context. Many structures or events would need to be in place or occur before widespread effects would likely be evident. Whereas loss of ecosystem value is often by means of chronic impacts as opposed to a single catastrophic event, the estimated level of petroleum reserves for the southwest Florida shelf does not suggest that development of the area poses a substantial threat to the area ecosystem.

Another consideration as the impact assessments are reviewed is that these assessments are presented in the absence of any mitigative measures and lease stipulations, which have heretofore been imposed by MMS on all leases in the eastern Gulf (for a complete discussion of these stipulations see Section II of MMS 1984). One of these, the Live-Bottom Stipulation, requires that live-bottom areas in the vicinity of proposed drilling operations be specifically identified. With this information, MMS may take various measures to prevent damage to live bottoms and/or to monitor the actual impacts to these areas. Many other technological features are required by MMS to reduce the probability of catastrophic events during drilling and production, and other federal regulatory agencies have operating regulations designed to protect the environment. Provided that existing environmental regulations are enforced and that MMS will continue to impose their historical stipulations, the envisioned impacts presented below, especially those concerning live bottoms, would be greatly reduced.

4.1 DELINEATION OF DISTINGUISHABLE COMMUNITIES

During this 5-year study, a wealth of detailed information about the environment and biota of the southwest Florida continental shelf has been accumulated. This section focuses upon the key environmental factors, community components, and ecological processes: (1) to present a simplified, coherent picture of the major community types; and (2) to lay the foundation for consideration of potential generic impacts of petroleum exploration and development in this environment.

4.1.1 ROLE OF PHYSICAL FACTORS IN DETERMINING DISTRIBUTION OF COMMUNITY TYPES

The distribution of benthic and demersal species and communities is strongly dependent upon water depth. Many physical parameters are correlated with depth; among these, light penetration is probably the most important to benthic plants. Light penetration decreases with increasing depth and suspended (and to some extent, dissolved) matter in the water column. Near-bottom waters increase in clarity with greater depth and distance from shore. On continental shelves, the amount of dissolved and suspended matter in the water column is normally highest nearshore due to such factors as terrestrial runoff, plankton blooms, and sediment resuspension by water motion.

Traditionally, a value of 1% of surface illumination has been used as the lower limit of the euphotic zone in phytoplankton studies (i.e., the compensation depth at which photosynthesis equals respiratory requirements). The 1% isolume may not be appropriate for corals (cf. Chalker, 1981; Sheppard, 1981), but it is used as a starting point. The maximum depth limits of some photosynthetic species are greater than the depth of the 1% isolume. Light penetration is clearly the controlling factor in the depth zonation of the photosynthetic species, and any significant interference with light penetration can be expected to reduce the maximum depth distribution of those species which are already at their compensation depths. Direct measurements of light penetration on the shelf reveal that, in water about 45 m deep, the theoretical lower limit of the euphotic zone (1% light penetration) should be at about 36 m. In water 62 m deep and beyond, the lower limit of the euphotic zone should be about 56 m. Of course, light penetration varies depending upon the amount of suspended matter in the water column. This general depth-related gradient in near-bottom transmissivity and light penetration was reflected in the pattern of maximum depth distributions of the various photosynthetic species and groups, as shown in the following table.

Maximum Depth Limits for Various Photosynthetic Species and Groups

Species or Group	Depth Limit (m)
Thalassia	9 to 10
Halodule	20
Photosynthetic gorgonians	
North	20
South	45
Foliose algae	45
Hermatypic corals	60
Anadyomene (Transects D and E)	100
Algal nodules	
North	85
South	110
Algal pavement (Transect E)	80

As noted previously, there is latitudinal variation in the depth limits of some photosynthetic species.

The second key factor determining the distribution of benthic organisms and communities of the southwest Florida continental shelf is the nature of the substrate. Hard-bottom types in the area include flat pavement limestone, low-relief rock outcrops, and isolated coral or rock pinnacles. Where exposed, hard substrate provides a foothold for attached species such as algae, sponges, alcyonarians, gorgonians, corals, and (in deeper waters) crinoids. The attached species form clusters or patch reefs that may eventually reach a vertical height of 1 m or more. A variety of cryptic and noncryptic species find food and shelter or otherwise associate with these vertical structures growing on hard bottoms.

Soft bottoms include a band of predominantly quartz sand nearshore (out to a depth of 10 m). Carbonate sediments blanket most of the remainder of the shelf, with a narrow zone of mixed quartz/carbonate separating the two areas. Soft bottoms may be further characterized on the basis of their particle size composition. Finer particulate bottoms are limited to shallow water a short distance north of the lower Keys and the Tortugas. Both species diversity and species richness of the infauna were found to be positively correlated with sediment carbonate content, but the details of this relationship are unclear. Particle size may be the more important factor.

The Southwest Florida Shelf Ecosystems Program (Years 1 through 6) has provided the most complete account of seasonal patterns of bottom temperatures and salinity of the study area and will serve as the basis for the following discussion. The greatest temperature extremes are observed in the shallow nearshore waters and the waters of Florida Bay. Water temperatures normally range from a winter low of 15°C to a summer high in excess of 30°C. Schomer and Drew (1982) and Walker (1981) have reported water temperatures as high as 38°C and as low as 9°C in Florida Bay. The temperatures of the shallow waters of the Florida Keys and Florida Bay can change 8 to 10°C within 24 h following the passage of a meteorological front.

The near-bottom water temperatures of the southwest Florida shelf from 20 to 200 m range between 14 and 22°C during the winter and from 13 to 30°C during the summer. Compared with the middle shelf, the near-bottom water temperatures inshore of the 30-m isobath are generally warmer (30°C) during the summer and cooler (15°C) during the winter. Near-bottom temperatures in excess of 20°C prevail on the middle shelf (30- to 70-m isobath) throughout the entire year, making the middle shelf habitable for many tropical species. The near-bottom temperatures between the 70- and 100-m isobaths remain constant throughout the year, decreasing from 20 to 18°C only with depth. Beyond the 100-m isobath, the near-bottom water temperatures change no more than 2°C during the year, remaining consistently below 18°C throughout the year. The temperature decreases with increasing depth and distance south, reaching a minimum value of 13°C at the 200-m isobath along the southern transect (Transect E) of the study area.

Bottom salinities are nearly uniform, showing only small seasonal, depth, or latitudinal variation. Thus, these variations are of little consequence in determining distribution patterns of species or communities. Bottom salinity values outside of Florida Bay are within $\pm$ 1°/oo of 36°/oo; within Florida Bay, Schomer and Drew (1982) report salinities as low as 13°/oo and as high as 66°/oo.

Throughout the shelf, near-bottom current speeds were generally less than 20 cm/s (the speed at which sediment transport is possible). Nevertheless, sediment transport did occur, particularly at stations located in water less than 50 m deep. This sediment transport (in the form of suspended load) was attributed to the action of storm waves which are episodic. The major effect of this sediment transport is to alternately expose and cover the limestone bedrock where the sediment is thin. Under extreme weather conditions, sediment scour could remove small or soft-bodied attached species. Under less extreme conditions, burial of low-profile individuals takes place. This exposing, scouring, and burial of hard substrate creates and destroys local sites for settlement and growth of sessile biota.

In summary, light penetration sets the maximum limits of depth distribution of the various photosynthetic species. Within a given depth zone, the distribution of hard bottom determines the distribution of attached species (photosynthetic and otherwise). The availability of exposed hard substrate is determined mainly by alternate exposure and coverage of bare areas by moving sediments under the control of bottom currents and wave energy. If the exposure period is sufficient, tall or projecting species such as gorgonians and sponges may survive subsequent coverage of the bottom by thin sand. Particle size and carbonate content of soft sediments determine, to some extent, the distribution and abundance of the infauna. Toward both the outer and inner shelf zones, seasonally low temperatures may play a role in limiting the distribution of tropical species, but salinity appears to be too uniform to be significant. Unanalyzed factors, such as organic content of the sediments, plankton concentrations in the water column, and species interactions, undoubtedly also play important roles in determining species distribution.

4.1.2 GENERAL NATURE OF COMMUNITY TYPES

A biological community consists of a group of species that live together in a common habitat and exhibit various types and degrees of inter-relationships. A minor community may consist of a large sponge together with all of its symbionts. A major community may include all the species affiliated with a given depth zone of the sea.

A logical framework for defining the communities of the southwest Florida shelf is the depth zonation of the larger sedentary biota. Emphasis in this report is placed on growth forms and higher categories, rather than upon individual species. Within a given depth zone, sub-community types are distinguished as necessary and useful. Attention is given to those larger and more motile species that tend to associate with a given community of sedentary species.

Community types are defined in terms of the longer lived benthic sessile organisms and their ecological associates (e.g., benthic and demersal fishes). The plankton and more mobile nektonic species are considered less useful for this purpose. The benthic and near-benthic environment is more likely to be impacted by petroleum-related operations than are other environments on the shelf. For example, plankton is widespread, and local damage would likely be masked by mixing. Nektonic species are generally capable of avoiding unfavorable conditions.

4.1.3 DISTRIBUTION OF COMMUNITY COMPONENTS AND COMMUNITY CHARACTERIZATION AND DYNAMICS

The biological communities of the southwest Florida shelf are best defined in terms of the attached species. Mobile demersal species associated with each community type must also be considered. Plankton that is swept through on the water currents is best considered simply as advective input to and output from the benthic systems. Nektonic species also may be viewed in the same fashion, unless they show major interactions with the benthic communities.

Benthic communities are strongly influenced by light penetration to the bottom. It has been shown that the 1% light level intersects the bottom at a depth of about 45 m. The bottom shoreward of this depth is considered arbitrarily to lie within the euphotic zone, and all the bottom seaward should be in the aphotic zone. However, biological and sediment data indicate that both areas should be subdivided into two zones. The four basic zones or benthic communities in the study area are defined as follows:

1. Nearshore community (0 to 10 m)--Euphotic, nearshore zone
2. Inner shelf community (10 to 45 m)--Euphotic, shelf zone
3. Middle shelf community (45 to 100 m)--Twilight zone
4. Outer shelf community (100 to 200 m)--True aphotic zone

Each of these community types is discussed in the following sections in terms of physical parameters, biological composition, and ecological dynamics. Schematic diagrams depicting the depth-related distribution of the conspicuous attached biota and major motile species are presented in

Figures 4.1-1 and 4.1-2. Figure 4.1-1 represents a transect from shore to the 200-m isobath in the northern portion of the study area (just south of Charlotte Harbor), and Figure 4.1-2 is a transect in the southern portion of the study area (off the Everglades).

Nearshore Community

The nearshore community, from shore to a depth of 10 m, was not studied in detail in this project, but enough information is available to provide a reasonable picture of the ecology of this system. Lying well within the euphotic zone, the nearshore community receives sufficient sunlight to support photosynthesis of rooted macrophytes, even though the waters may sometimes become quite turbid due to the suspension of fine particulate material of both organic and inorganic origin. Except south of the Everglades, the bottom is composed largely of quartz sand mixed with muds and organic matter. The coastline receives relatively little energy from water motion. However, wave action and alongshore currents are sufficient to remove much of the finer particulate matter north of the Everglades, except where it is trapped by submarine seagrass meadows. Scattered (but sometimes extensive) seagrass beds extend seaward to a depth of 10 m. These are dominated by Thalassia, but also contain other macrophytes, including Halodule, Syringodium, and Halophila. Sponges, corals, photosynthetic gorgonians, and other attached species are encountered in this community. Filamentous and foliose algae are also present. Stone crabs are taken throughout the year, and pink shrimp are seasonally abundant as they migrate from the nursery areas to the spawning grounds. Darnell and Kleypas (1986) recorded 86 species of fishes from this area, of which 14 were abundant or very abundant and the rest were rare. Twelve species were not recorded elsewhere in the eastern Gulf, and a distinct tropical element is present in the fish fauna. Twenty-one fish species were estuary related, and the same number were reef related. Shrimp and fish densities varied considerably with season.

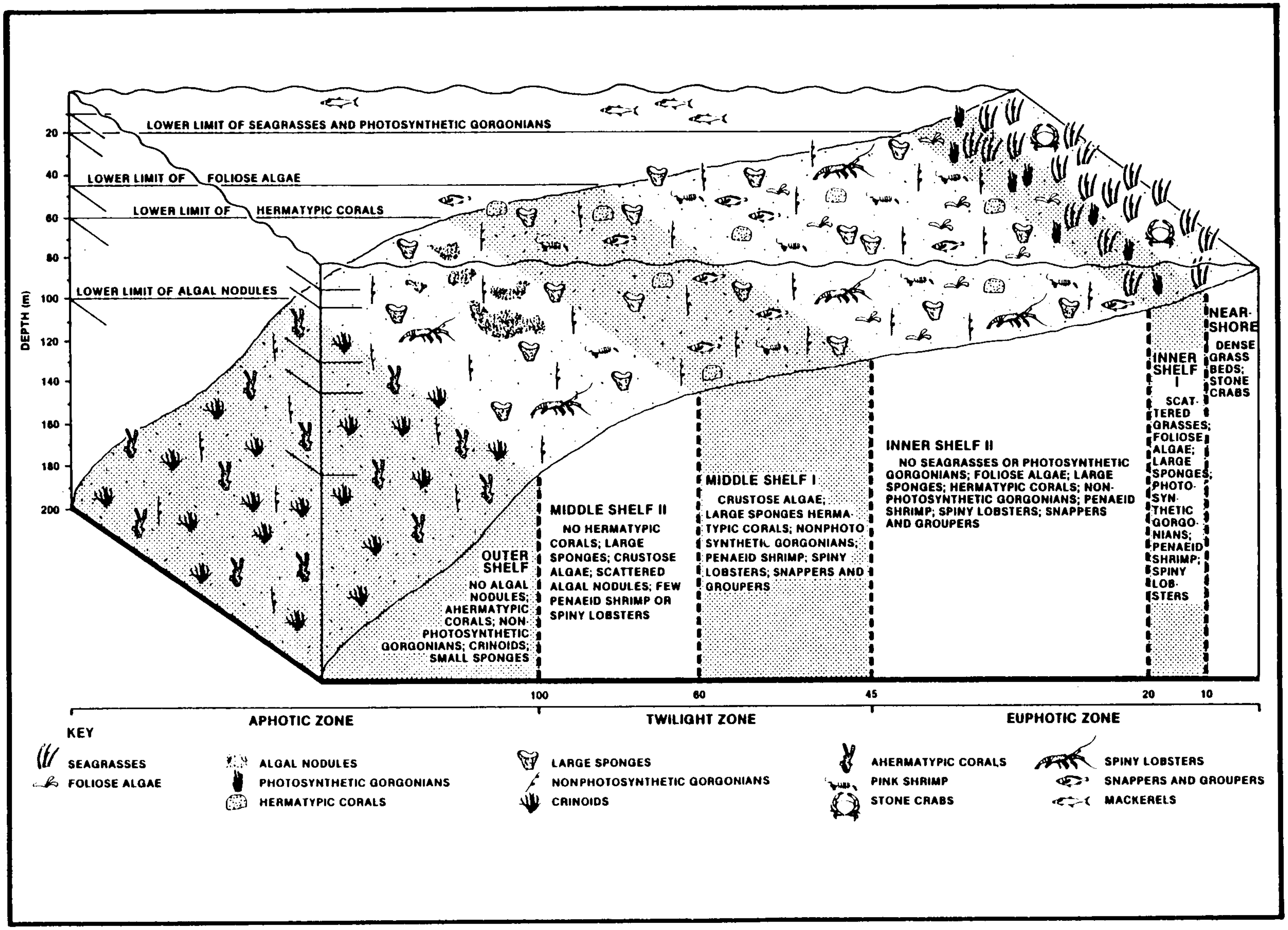


Figure 4.1-1 Biotic zonation of the southwest Florida continental shelf (northern transect, e.g., Transect A) showing general distribution patterns of major components of the flora and fauna.

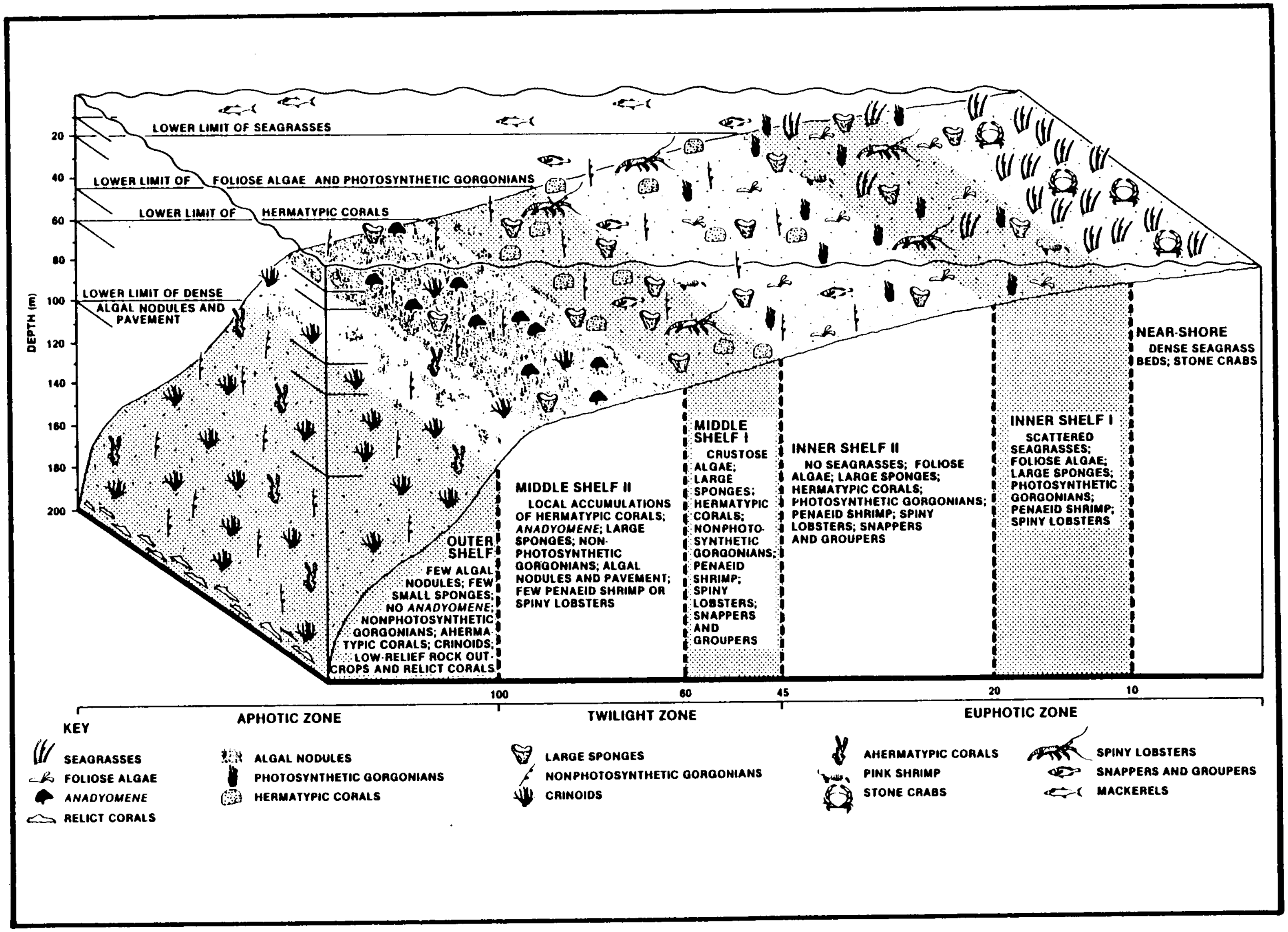


Figure 4.1-2 Biotic zonation of the southwest Florida continental shelf (southern transect, e.g., Transect E) showing general distribution patterns of major components of the flora and fauna.

Community dynamics of the nearshore community are treated in terms of trophic interactions within the ecosystem and relationships with other communities. The nearshore community is a complex system of dense grass beds, scattered grass clumps, scattered patch reefs, and intervening sand patches. Seagrasses are particularly effective in producing organic detritus and fine sediments and sequestering and retaining plankton and other suspended fine particles. Producers include the seagrasses, foliose and nonfoliose thallic algae, photosynthetic gorgonians, and hermatypic corals. Filamentous algae coat various surfaces (particularly the distal portions of Thalassia blades), and phytoplankton is brought in by water currents. Much organic detritus originates within the community, and some is brought in from external sources.

Lower consumers include filter feeders, detritus feeders, herbivores, and omnivores. Mobile and sessile invertebrates, including various worms, molluscs, crustaceans, and echinoderms, belong to lower consumer groups as do some fishes. Higher consumers include some adult crabs (blue and stone crabs), adults of many fish species, and possibly some sea turtles and marine mammals. As noted by Jaap (1984), Zieman (1982), and others, some fishes and larger invertebrates associate with reefs during the daylight hours and forage in the nearby grass flats at night, providing trophic connections between subunits of the community.

The nearshore community is not a closed ecosystem, but is tied to neighboring systems by many interactions. As noted by Odum (1970) and Heald (1970), organic detritus is exported from the mangrove swamps of south Florida to the neighboring shelf. Advected plankton is trapped by both the seagrasses and patch reefs. Plankton is released from the system in the form of zooxanthellae, gametes, and the larvae of the various species. Storms are known to break and uproot seagrasses and transport them elsewhere. As noted by Darnell and Kleypas (1986) and others, the seagrass beds serve as a major nursery area for larvae and young of many species whose adults live elsewhere. Darnell and Kleypas (1986) also pointed out that the nearshore area off the Everglades provides a major migratory route for the pink shrimp and other species that seasonally inhabit the Everglades. Finally, the shallow grass flats of the southwest Florida shelf provide a major forage area for adults and subadults of certain large fish species which are seasonal transients. Among the more conspicuous of these are several sharks, tarpon, ladyfish, bonefish, snook, and jacks. For these reasons, the nearshore community (particularly the seagrass beds) is of broad regional significance in the biological economy of the southwest Florida continental shelf.

Inner Shelf Community

The inner shelf community occupies the 10- to 45-m depth range. It lies outside the zone of extensive seagrass beds and extends to the outer limit of the benthic euphotic zone (as defined by 1% of surface radiation). A thin layer of bottom sediments (of variable thickness) is primarily carbonate, except in a narrow band of mixed quartz and carbonate in the 10- to 20-m depth range. The loose sediments blanket a hard carbonate platform and shift around sporadically, exposing some low-lying portions of the limestone pavement. There is some vertical relief due to rock outcrops.

Major photosynthetic species include seagrasses (Halophila) (to a depth of about 20 m), photosynthetic gorgonians (to 20 m in the northern portion and about 45 m in the southern portion of the area), hermatypic corals, and foliose algae (both throughout the area). Nonphotosynthetic sessile biota include sponges of various sizes (many of massive proportions) and nonphotosynthetic gorgonians. Sessile species tend to be clustered in areas of exposed hard bottom and, thus, are discontinuously distributed. The largest, most persistent groups of sessile biota and their associates are found where vertical relief is greatest and where sand cover is thinnest for long periods of time.

Among the mobile demersal invertebrates are pink and rock shrimp, spiny lobsters, echinoderms, and a great diversity of molluscs. A few stone crabs extend out into the inner shelf zone. The penaeid shrimp and demersal fish fauna have been discussed by Darnell and Kleypas (1986), although these authors combined the ichthyofauna of the inner and middle shelf zones in their discussion. Ten species of penaeid shrimp and 125 species of fishes were reported from this area. Both pink and brown shrimp were listed, as well as five species of rock shrimp. Twenty-one species of fishes were abundant or very abundant, and the rest were rare in the collections. Only 5.2% of the fishes were estuary related, but 28.5% were reef related. About 8% of the fishes of this area were not recorded elsewhere on the eastern Gulf shelf. Numerically dominant fish groups included the lizardfishes, brotulid eels, sea basses, snappers and groupers, searobins, and flatfishes.

The inner shelf community depends upon three sources of organic matter: (1) local producers (scattered seagrasses, foliose and filamentous algae, photosynthetic gorgonians, and hermatypic corals), (2) imported phytoplankton and zooplankton, and (3) imported organic detritus (primarily from the nearshore zone). As in the nearshore community, lower consumers include various worms, molluscs, crustaceans, echinoderms, and some fishes. Major demersal carnivores include the spiny lobster and various fish species (including sharks, sea basses, snappers, and groupers). Pelagic carnivores also forage on the demersal fauna of the area. These carnivores include such fishes as sharks, tarpons, jacks and their relatives, dolphins, mackerels, and billfishes. The same basic trophic categories are encountered in both the nearshore and inner shelf communities, but the actual species composition shifts with depth. Not much is known about the trophic relations between the biota of the isolated patch reefs and gorgonian beds and the biota of the intervening flat bottoms. Most of the benthic photosynthesis is probably associated with the gorgonians and reefs, and the flat bottoms must be largely dependent upon imported plankton and detritus. Larger motile reef-related species tend to forage in the flats at night. There also appears to be a dramatic difference between the species that live on the flats and those that associate with the reefs.

Middle Shelf Community

The middle shelf community extends from 45 to 100 m deep. It lies below the level of 1% light penetration to the bottom, yet it supports some photosynthetic species. The middle shelf is the twilight or transition zone between the true euphotic and completely aphotic communities. Light is clearly the primary limiting factor for inner shelf species. Bottom types are generally similar to most of the inner shelf zone (i.e., a limestone platform overlain by shifting coarse carbonate sediments of thin, but variable, thickness). Scattered rock outcrops are present. In the northern sector, a line of rocky outcrops occurs around a depth of 50 m. In the southern sector, rock outcrops and relief corals appear in the 70- to 90-m range.

The only major photosynthetic species are the alga Anadyomene at a depth of 66 to 75 m (southern area only), coralline algal nodules (in the depth range of 61 to 85 m of the northern area and 67 to 110 m of the southern area), algal pavement at 64 to 70 m (southern area only), and a few platelike hermatypic corals of the genus Agaricia that extend to a depth of 80 m (in the southern area only). Seagrasses, most foliose and thallic algae, most photosynthetic gorgonians, and most hermatypic corals are absent.

Nonphotosynthetic attached species include large and small sponges, gorgonians, and scattered crinoid beds beginning at a depth of about 64 m (in the south only). Larger motile invertebrates include rock shrimp and some pink shrimp and spiny lobsters. Molluscs are abundant. The demersal fish fauna includes many of the species already indicated for the inner shelf community.

Trophically, the middle shelf community must be largely a detritus-based system, since the few benthic photosynthesizers are largely inedible and must enter the food chains soon after death. In addition to the locally derived detritus, advected plankton and detritus must be considerably important in supporting the consumer species. Most of the attached and many of the benthic species are filter feeders; bottom scavengers also are important. Carnivores include lizardfishes, various eels, and snappers and groupers. Thus, to a very large extent, the middle shelf community is trophically dependent on imported organic material derived both from the water column above and from the adjacent inner shelf area.

Outer Shelf Community

The outer shelf community extends through the depth range of 100 to 200 m. This is the aphotic zone proper. A few algal nodules are found in the upper reaches, but these may or may not be living. Sediments are entirely carbonate with both coarse and fine sands present. Low-relief limestone outcrops occur in the 180- to 200-m depth zone in the southern portion of the area. This cold, dark environment is swept by currents resulting from frequent Loop Current intrusions.

Attached biota include small sponges (primarily hexactinellids), scattered antipatharians and ahermatypic corals, nonphotosynthetic gorgonians, and clusters of crinoids. The latter are most dense above 150 m, but probably extend to depths greater than 200 m. Motile invertebrates include a variety of polychaetes, molluscs, crustaceans, and echinoderms.

The fish fauna of the aphotic zone may be inferred from the studies of Darnell and Kleypas (1986) and Pequegnat et al. (1983) and from sampling at Station 36 (125 m deep) using the underwater television and trawl during this study. Darnell and Kleypas (1986) included southwest Florida stations to a depth of 120 m, and depth distributions of fishes known to inhabit the continental shelf of south Florida are found in the data of Pequegnat et al. (1983). Furthermore, most of the outer shelf/upper slope species range fairly widely. Even though Pequegnat et al. (1983) did not include south Florida stations, most of the outer shelf species collected in that study also must occur in this area. The dominant groups of fishes are the lizardfishes, codfishes (primarily of the genus

Urophycis), brotulid and other eels, small serranids, batfishes, tilefishes, scorpionfishes, armored and unarmored searobins, and flatfishes.

The community of the aphotic zone is trophically dependent upon organic matter imported primarily from the plankton of the euphotic zone above it, augmented (to some extent) by organic matter transported from the middle shelf. For all practical purposes, benthic photosynthesis does not occur on a large scale in this area despite the presence of a few algal nodules. The aphotic community is, in part, detritus based. Filter feeders and bottom scavengers support populations of demersal carnivores. However, the pelagic food chain must be linked thoroughly to the demersal food chain. In the water column, large populations of myctophids and other small schooling fishes make nocturnal migrations into the upper layers to feed upon plankton. During the daylight hours, these fishes migrate back down to the 100- to 200-m depth zone, where they are subject to predation by demersal carnivores. Copepods and other planktonic crustaceans also exhibit daily vertical migrations and may be consumed by demersal species when they are concentrated below the euphotic zone during the daylight hours. The operation of this vertical "food ladder" may be the most important factor in the trophic economy of the outer shelf community, but this process was not examined during this study.

Trophic Models

One method of displaying the organization and integration of marine communities is through the presentation of trophic models that show the inputs, storage compartments, and pathways of nutrient and energy flow through the systems. Although conceptually useful, trophic models suffer from three main drawbacks. First, to be visually clear, these models must be gross oversimplifications of structural and functional aspects of the systems. Second, since most ecological systems are organized along the same general lines, trophic models tend to be quite unspecific to the systems under study. Third, since such models are designed to depict trophic relations only, they generally fail to take into account physical and chemical factors that may exert controlling influences on the composition and dynamics of the systems. Therefore, trophic models are of only limited use for management purposes.

The southwest Florida shelf communities have been depicted in two conceptual trophic models. The first represents all the community types in which photosynthesis plays a major and direct role (see Figure 4.1-3). This model shows the directions of passage of energy and chemical elements through the systems. Producers are toward the left, and, passing to the right, the various consumer groups are arranged in vertical columns representing succeeding trophic levels. Contributions from and losses to the water column are depicted along the top, and the benthic/demersal system is shown below. Pathways leading to organic detritus and microbial decomposers are indicated by dashed lines to facilitate visual discrimination. Figure 4.1-3 represents the trophic structure of the inner shelf zone. The figure may apply equally to the nearshore community by the addition of seagrasses in the producer column. The figure could apply to the middle shelf twilight community by the removal of all producers except the coralline algae.

The second model represents the aphotic zone community of the outer continental shelf (see Figure 4.1-4). This system contains no producers. Both systems show internal benthic/demersal pathways involving living organisms and organic detritus, and both show interactions with the water column above. Systems of the euphotic zone are obviously more complex. Together these models emphasize the importance of light, the detritus pathways, and import/export phenomena in the trophic economy of the Florida shelf communities.

Relations With Other Nearby Communities

The various living communities of the continental shelf of southwest Florida are clearly related with one another and with adjacent systems to form a regional complex that is ecologically balanced and evolutionarily

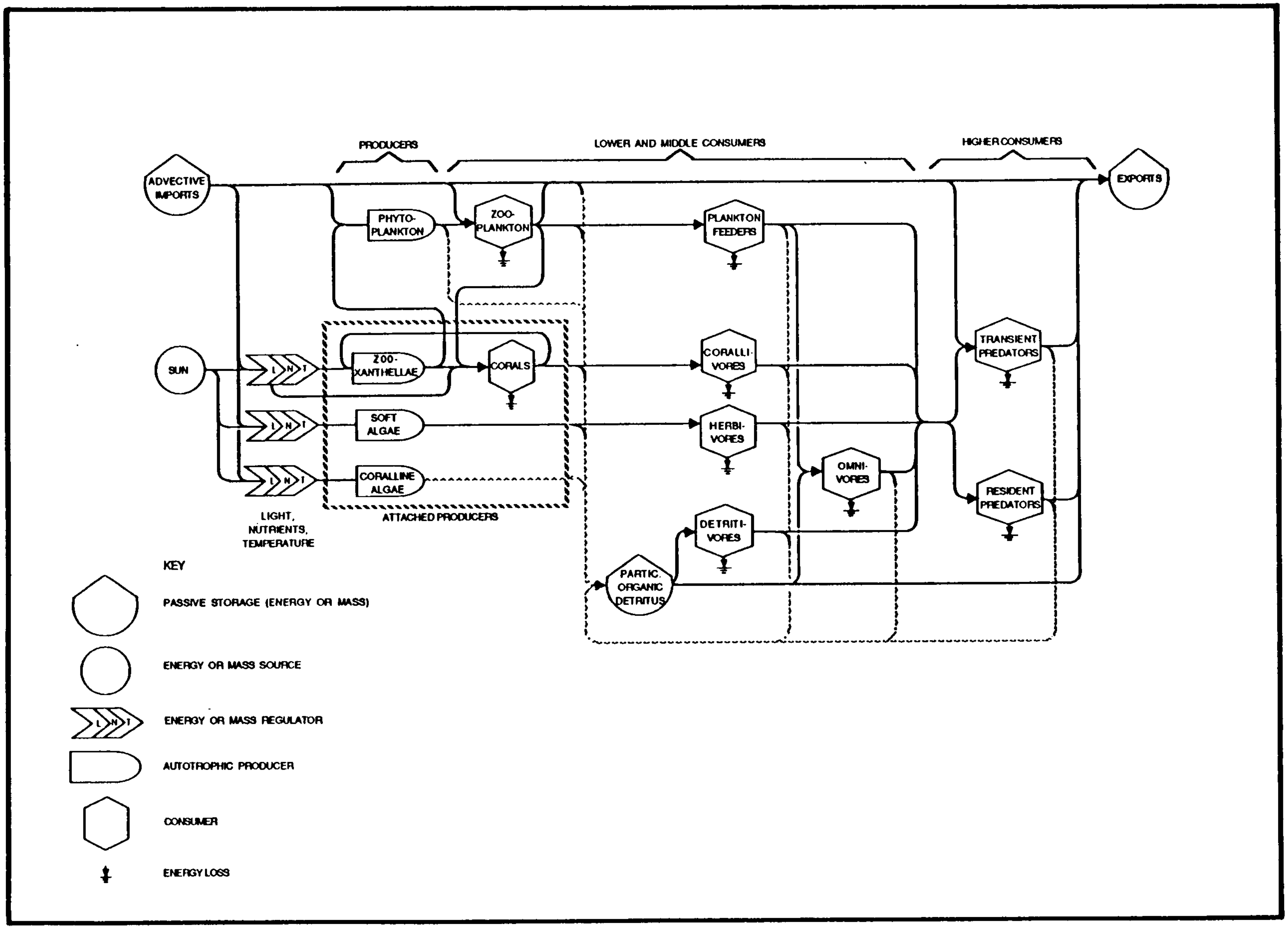


Figure 4.1-3 **Nutrient and energy flow in the euphotic zone.**

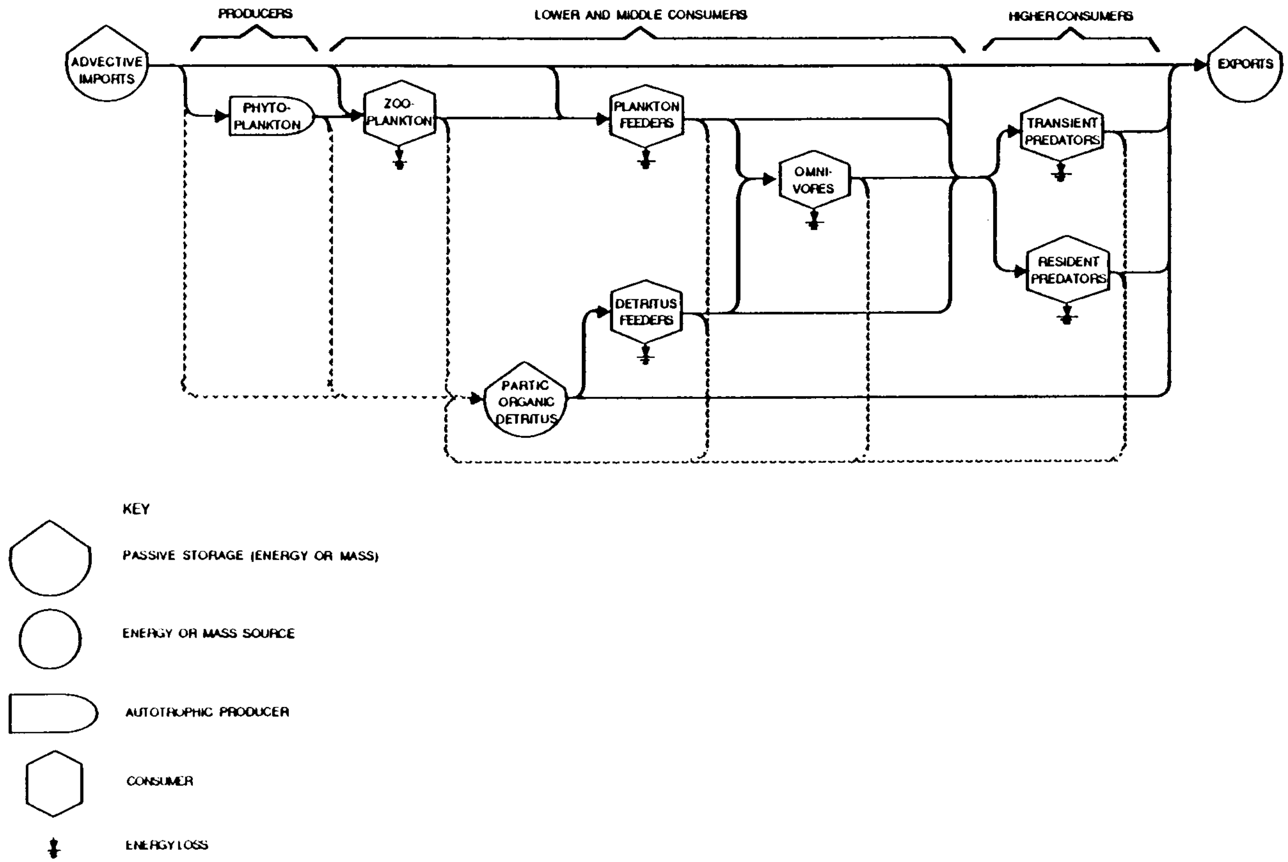


Figure 4.1-4 Nutrient and energy flow in the aphotic zone.

stable. Within this framework, life history patterns of the various species must have been genetically adjusted through long periods of time to achieve the functional relationships that are observed today. Only a fraction of these relationships can be discerned from the present database.

The seasonal water circulation on the shelf exhibits only weak patterns that are not reliably predictable. The currents are dominated by tidal currents, with only small residual currents that result in large dispersion potential but only small net transport. This knowledge of dispersion and net transport must be available to understand mechanisms of larval transport, a major means of regional integration. Most of the plants and invertebrates and many of the fishes produce seeds, eggs, or larvae that depend upon the water currents for dissemination to appropriate environments for early growth; therefore, the survival of the shelf ecosystem depends, in part, on dispersal. The success of each year's class and the colonization of newly exposed or damaged areas is controlled by physical factors (e.g., sand movement), as well as the arrival of propagules (e.g., from existing populations in the area and elsewhere).

Regional integration also must take place through the transport of organic detritus from the Everglades and other inshore areas to the shelf and from one area of the shelf to another. Such transport depends upon the water currents (which are quite variable) and on prevailing winds that drive the near-surface transport. A high percentage of the consumer species of this area are filter feeders that depend upon plankton and detritus swept in on the water currents. To the extent that one community contributes to the plankton upon which another community feeds, there is intersystem nutritional flow.

Many of the more motile species utilize more than one habitat during their lives. Some are estuary related, such as the pink shrimp, even though the adults are associated with the inner and middle shelf communities. Others use the seagrass beds as nursery areas and are reef related as adults. The larger carnivores appear seasonally and forage in various communities, cropping some individuals from each community, but leaving the various overall integrity of each community intact.

It is unclear how all these integrative mechanisms relate to the neighboring environments of the Everglades, Florida Bay, the lower Keys, and the Marquesas and Tortugas islands. There is an interchange of larval and other reproductive forms permitted by the prevailing currents. Organic detritus is known to be exported to the shelf from the Everglades, and it is probably exported from other shallow water areas as well. Shallow water habitats provide nurseries for numerous invertebrate and fish species whose adults are found in deeper waters. The presence of many productive sites in the area may provide the mobile carnivores with enough choices so that they do not overexploit any one system. Other integrative mechanisms undoubtedly exist. Although the current knowledge base is limited, enough is known to believe that there is a considerable level of organization and exchange among the ecological components of the larger regional ecosystem. The tightness of specific linkage mechanisms has not been determined.

4.2 NATURE OF IMPACTS FROM OFFSHORE PETROLEUM ACTIVITIES

The assessment of potential environmental impacts from human activities involves a series of logical steps that must be clearly recognized and kept in mind. These steps involve separate assessments of (1) probability of impact, (2) nature of impact, and (3) importance of impact in human values.

In considering probability of impact (e.g., a blowout), the first concern is the probability of the impact occurring at all. For example, if only one well is drilled, the probability of the blowout may be quite low; but, if an oil field is developed, the probability of the blowout occurring rises. The probability of occurrence is a direct function of the amount of human activity, which often cannot be predicted in advance.

The second consideration is the probability of an environmental effect if the event does occur. A blowout may impact the ecosystem or some part of it, based on the magnitude of the event and the prevailing conditions (wind, currents, etc.). Best- and worst-case scenarios might be developed to set limits on the scope of probable impact.

The nature of the impact is determined by whether the impact will likely be localized or widespread, of short- or long-term duration, and mild or severe. To conduct the analysis, the impact assessor must have considerable knowledge of the nature of the impacting agents, the ecological system affected, the biology of individual species, and the potential mechanisms of interaction.

The importance of impacts in human values includes consideration of both economic and non-economic values of the impacted systems. The effect of the blowout on the pink shrimp fishery could provide a dollar-value assessment. However, intrinsic values also must be considered (e.g., warm-blooded animals such as porpoises and dolphins, rare or endangered species such as the Florida manatee or sea turtles, and aesthetically pleasing areas such as coral reefs). There are environmental and ecological values that would be missed by society if the ecological systems were severely damaged (e.g., marine food chains and protection of shoreline from erosion).

Considering these factors, impact prediction involves a series of logical steps and depends on a large body of knowledge, only a portion of which is likely to be available. Therefore, only potential impacts on targets of greatest concern can be considered, and these impacts can be expressed only in relative terms of severity or importance.

Assessment of the potential impacts of oil and gas exploration and development on the southwest Florida continental shelf involves knowledge of the species and ecosytems of the area as developed in this project and described previously. Assessment also involves knowledge of the world literature concerning oil and gas development and impact in other areas. Unfortunately, much of this literature concerns very different types of marine environments, and translation to the subtropical, clear water, carbonate platform of the southwest Florida shelf must be undertaken with caution. In this exercise, the following references have been particularly useful: Boesch and Rabalais, 1985; Clark and Terrell, 1978; Continental Shelf Associates, Inc., 1982; Darnell _et al_., 1976; Fritts _et al_., 1983; Gettleson and Putt, 1979; Jaap, 1984; Smith, 1974; Stursa, 1974; Tetra Tech, Inc., 1985; Vandermeulen and Gilfillan, 1984; Woolfenden, 1983; and Zieman, 1982. Also, MMS has produced comprehensive environmental impact statements for the region (e.g., MMS, 1983, 1987) that treat the same topics covered herein but on a more specific basis. Analyses results presented herein basically support the MMS conclusions, considering the differences in approach and geographic scale of the assessments.

4.2.1 NATURE OF OIL- AND GAS-RELATED ACTIVITIES

Certain activities are involved in the development of an offshore oil and gas field. These are described briefly in the following paragraphs to provide a background for impact assessment of each phase of the operation. The initial step is the geophysical evaluation, which usually entails seismic surveying and sediment sampling. The second step is the exploration phase, which involves exploratory drilling from movable drilling rigs, and, if successful, platform (drilling and production) emplacement, drilling, routine production operations, and platform servicing. If economic reserves are located, the production-and-development phase will take place. This phase includes platform fabrication and installation; drilling and completion of wells; platform operations including servicing by helicopter and boats; and development and implementation of storage and transport facilities for the oil and gas including offshore storage tanks, and pipelines and/or tanker-loading facilities. The postproduction phase involves disposition of the offshore structures (removal, retention for use as artificial reefs, etc.) which is addressed in Section 4.5. Potential impacts of the activities occurring during the other phases will be considered in the following sections.

4.2.2 POTENTIAL IMPACTS OF OIL- AND GAS-RELATED ACTIVITIES ON SOUTHWEST FLORIDA SHELF HABITATS

The first step in the analysis of potential impacts resulting from oil- and gas-related operations involves identification of specific activities resulting from each phase of these operations. Exploration, development, and production have been combined since they involve essentially the same types of activities. Once the activities have been identified, the primary, secondary, and tertiary effects on the habitat may be derived in sequential order. This analysis is presented in Table 4.2-1. A general category of habitat impact may result from several different activities; for example, chemical pollution may result from the release of drilling fluids, produced water, treated sewage, accidental hydrocarbon spillage, blowouts, and from tanker and other vessel operations associated with lightering, supply, and transportation.

To clarify potential habitat effects, Table 4.2-2 lists the habitats and shows the impacts and their causes. These generalized habitat effects could be defined more specifically if the oil- and gas-related activities were more specific. However, for current purposes, it is satisfactory to keep the categories general.

4.2.3 POTENTIAL IMPACTS OF OIL- AND GAS-RELATED ACTIVITIES ON SOUTHWEST FLORIDA SHELF ECOSYSTEMS

Potential impacts on ecosystems of the southwest Florida shelf are outlined in Table 4.2-3. Since ecosystem effects are derived largely through habitat effects, the first column of this table is derived from the habitat effects listed in Table 4.2-2. Although much information is included, the potential ecosystem effects could be expanded several times to include all known potential effects of all known agents (particularly the chemical species) on the various biological inhabitants of the area. Much of this information is available in a report by Boesch and Rabalais (1985) and is not repeated here. Some summary comments about the

Table 4.2-1. Factor train analysis of potential impacts on oil- and gas- related activities on habitats of the continental shelf of southwest Florida.

Operational Phase	Activity	Primary	Secondary	Result
Geophysical Evaluation	Seismic Surveying	Increased Noise		Habitat Disturbance
	Bottom Sampling			Bottom Damage
Exploration and Production	Platform Emplacement (Mobile Rigs and semi-permanent structures)	Bottom Scraping and Abrasion		Bottom Damage
		Provision of Habitat Relief		Attraction of Marine Animals
	Drilling	Increased Noise		Habitat Disturbance
		Drilling Fluids	Suspended Sediments	Increased Turbidity Bottom Sedimentation Increased Resuspension and Transport
			Chemical Pollutants	Chemical Pollution
		Drilling Cuttings	Temporary Suspended Sediments	Bottom Sedimentation Resuspension and Transport
			Chemical Pollutants	Chemical Pollution
		Bottom Cutting, Abrasion, and Scraping		Bottom Damage
	Routine Production Operations	Produced Water Effluents	Chemical Pollutants	Chemical Pollution
		Deck Drainage	Chemical Pollutants	Chemical Pollution
		Sewage Effluents	Chemical Pollutants	Chemical Pollution
			Nutrients	Fertilization
		Debris		Bottom Fouling Bottom Damage
	Blowout	Fire		Heat
		Rig Collapse		Bottom Fouling Bottom Damage
		Hydrocarbon Spill	Spreading, Sinking	Chemical Pollution
			Clean-up Activity	Chemical Pollution Habitat Damage
		Capping Activity	Ship Activity	Habitat Disturbance
			Bottom Operations	Bottom Damage
Transport and Storage	Pipeline Development	Above-surface Pipeline	Pipeline Laying and Anchoring	Bottom Damage Bottom Scouring and Increased Deposition from Current Alteration Attraction of Marine Animals Potential Rupture and Leak
		Buried Pipelines	Blasting and Cutting (Hard Bottoms)	Bottom Damage Increased Turbidity Increased Sedimentation, Resuspension, and Transport
			Dredge and Filling (Soft Bottoms)	Bottom Damage Increased Turbidity
	Offshore Storage and Lightering	Offshore Storage Tanks	Accidental Spills	Chemical Pollution
		Tanker and Lightering	Noise	Habitat Disturbance
			Bilge Washing	Chemical Pollution
			Accidental Spills	Chemical Pollution
			Chronic Spills	Chemical Pollution

Table 4.2-2. Potential habitat impacts resulting from oil- and gas-related activities on the southwest Florida continental shelf.

Habitat	Potential Impacts	Intermediate Factors	Causes
General	Habitat disturbance	Noise and disturbance from increased offshore activities	Seismic surveying, drilling, construction of platforms and offshore storage facilities, lightering, spill clean-up.
Water Column	Chemical pollution 1. Hydrocarbons	Spillage, leakage, blowouts, bilge washings	Spillage and leakage (chronic and episodic), blowouts, pipelines, tankers and barges, bilge washings.
	2. Sewage and garbage	Discharge and discard	From rigs, platforms, vessels.
	3. Other chemical pollutants	Drilling fluid additives, produced water and additives, heavy metals, other chemicals	Discharge of drilling fluids and cuttings, produced water leakage and deck drainage, accidents, accumulation of metal debris.
	Nutrient inputs	Sewage and food remains	Sewage and garbage disposal.
	Increased turbidity	Suspended and resuspended sediments	Release of drilling fluids and cuttings, bottom cutting, dredging and filling activities.
	Interference with bottom currents	Bottom barriers	Above-surface pipelines, platforms, templates, well heads.
	Increased heat	Fire	Blowouts.

Table 4.2-2 (Cont.).

Habitat	Potential Impacts	Intermediate Factors	Causes
Bottom	Mechanical bottom damage and disturbed sediments	Cutting, scrapping, abrasion, dredging and filling	Rig and platform emplacement, drilling, capping of blowouts, pipeline dregdge and fill, anchoring.
	Bottom scouring	Movement of above-surface pipelines	Storm surges, waves.
	Bottom channelization	Subsurface trenches	Subsurface pipeline trench cutting.
	Mechanical cluttering and debris accumulation	Bottom accumulation of tools, cables, and other debris	From construction, operation, and servicing of rigs, platforms, pumping, and offshore storage facilities; rig collapse during blowouts.
	Sedimentation	From initial dumping as well as settling of resuspended materials	Drilling fluids and cuttings, pipeline dredge and fill, pipeline trench cutting; materials acted on by bottom currents and storm surges.
Other	Potential pipeline rupture and hydrocarbon leakage	Anchor fouling, ship and boat damage	Above-surface pipelines.

Table 4.2-2 (Cont.).

Habitat	Potential Impacts	Intermediate Factors	Causes
Other (Cont.)	Navigation hazards	Unmarked subsurface structures	Above-surface pipelines, debris piles, other structures.
	Attraction of marine animals	Structure attraction	Presence of rigs, platforms, exposed pipelines and construction debris.
	Barrier to migrations	Linear structures and depressions	Above-surface pipelines, trenches for buried pipelines.

Table 4.2-3. Potential impacts of oil- and gas-related activities on ecosystems of the southwest Florida continental shelf.

Factor	Potential Ecosystem Effects and Considerations
Noise and disturbance from increased offshore activities	Impacts not known, but disturbance could interfere with behavior of some higher animals (i.e., feeding, migration, reproduction, etc.) of marine mammals.
Chemical pollution	
1. Hydrocarbons	Hydrocarbon impacts are poorly known for tropical waters.
	The most severe hydrocarbon impacts are likely to occur in shallow marine waters, along the shoreline, and in bays and estuaries.
	Floating fractions can coat seabirds and mammals and also impact digestive systems. Becoming mixed with sediment particles, these fractions gain density and ultimately sink to contaminate the bottom.
	Dissolved hydrocarbons contain toxic components that specifically damage gonadal tissue and reduce recruitment but tend to be quickly diluted.
	Bottom animals, such as corals, exhibit greater mucous production, ciliary activity, and pulsation, as well as an increased demand for oxygen when exposed to hydrocarbons.
	Highly mobile animals, such as pelagic fishes, tend to avoid major oil spill areas.
	Invertebrates at all levels may suffer reduced reproduction, larval mortality, settlement difficulties, and reduced juvenile growth.
2. Sewage and garbage from rigs, platforms, boats, and ships	These factors might result in the presence of local food supplies in the water column and on the bottom.
	This organic material may attract mobile animals and concentrate them around the rigs and platforms.

Table 4.2-3 (Cont.).

Factor	Potential Ecosystem Effects and Considerations
Chemical Pollution (Cont.)	
3. Other chemical pollutants	Impacts are poorly known for tropical waters.
	Some drilling fluid and produced water system additives (e.g., biocides) are highly toxic to most marine animals and represent the most dangerous group of likely chemical pollutants.
	Heavy metals can leach from structures and the metallic debris that accumulates on the bottom.
	Bilge washings may contain all of the above plus other unknown chemical pollutants.
	Such chemicals may be expected to cause highly localized mortality, to reduce food supplies slightly, and to perhaps concentrate up food chains to the higher predators (e.g., stone crabs, groupers, and mackerels) that may represent human food sources (see Middleditch, 1981).
Increased suspended sediment	Impacts tend to be very local, especially considering that they are subject to resuspension and transport.
	Increased suspended matter would reduce light penetration and inhibit photosynthesis in algae, hermatypic corals, photosynthetic gorgonians, etc., many of which are already living near their lower limit of light utilization. Thus, there could be increased mortality of those photosynthetic species in the deeper portions of their present ranges, if episodic discharges are prolonged.
	Increased suspended matter could clog the delicate feeding mechanisms of larvae and other zooplankters, thereby influencing valuable species directly as well as indirectly through reduction of food supplies.

Table 4.2-3 (Cont.).

Factor	Potential Ecosystem Effects and Considerations
Increased suspended sediments (Cont.)	Suspended sediments tend to adsorb toxic chemicals and, if ingested, could be toxic to various mucous, filter, and other feeding types.
Increased heat from oil and gas fires	Most tropical species live near their upper limits of thermal tolerance, and even small increases in temperature could prove fatal. Such effect should be of local occurrence.
Mechanical damage to the bottom	Cutting, scraping, and breaking of attached benthic species (e.g., corals, gorgonians, and sponges) result in direct damage, infection, and dislodgement. This destroys the larger species and reduces the habitat of a host of smaller cryptic species which are important in the food chains. In addition, there may be loss of habitat for young and/or adult stone crabs, spiny lobsters, groupers, and other large species.
Bottom channelization	Construction involving cutting, dredging, and spoil placement would destroy much habitat and many benthic communities in a linear pattern.
	The resulting trenches might influence migrations of such species as the pink shrimp.
	Channels could provide additional habitat for adult stone crabs and other species.
Mechanical cluttering of the bottom	Bottom clutter could cause increased mortality in local native benthic communities, but would provide hard substrate for attachment of fouling organisms and might add to local niches and food supplies.
	Metallic debris could be a source of heavy metals leachate.
Bottom sedimentation	Impacts would likely be local, even considering that the sediments would be subject to resuspension and transport.

Table 4.2-3 (Cont.).

Factor	Potential Ecosystem Effects and Considerations
Bottom sedimentation (Cont).	Most of the bottom is calcareous and coarse grained with well oxygenated crevices between the grains. Heavy sedimentation by fine-grained material might blanket this substrate with noncalcareous sediment. This would have many deleterious effects.
	Reduced light penetration could cause stress or mortality in many photosynthetic species.
	Interstitial microfauna could be smothered, thus reducing the food supplies of benthic species.
	Attachment sites for larvae would be greatly reduced.
	Smaller attached species and the young of larger species would be subject to burial and reduced oxygen supplies, at least in local areas.
	Larger mobile species such as the pink shrimp, whose adults prefer coarse calcareous bottoms, may encounter conditions unfavorable for spawning or adult habitat.
Above-surface pipelines	Emplacement and anchoring of above-surface pipelines, as well as their periodic servicing, would cause local linear damage to bottom communities.
	Movement during storms would scour neighboring bottoms.
	Leakage or rupture (from anchors and boat accidents) would provide near-bottom sources of hydrocarbon pollution.
	Pipelines could interfere with migrations of benthic invertebrates, including the spiny lobster, pink shrimp, and stone crab.

information in Table 4.2-3 are presented in this section. The offshore structures for hydrocarbon development and their associated bottom debris will almost certainly concentrate settling species, fishes, turtles, and other organisms. Offshore structures will provide outstanding fishing and recreational diving. Some species (e.g., VECs and species already protected by law) may require legal and/or educational measures to prevent their being caught or injured, since they will be more accessible to fishermen and divers at platforms.

Rapid settlement of organisms on arrays and settling plates by many species in shallow water, at least, confirms that typical sessile communities will develop on offshore structures. The arrays were also focal points for fish and turtles, some of which became residents. Offshore structures on the Florida shelf will become artificial reefs and will continually attract more animals as their communities build in complexity and biomass. Turtles, jewfish, and other large groupers will probably become residential. Fishes such as grunts, jacks, and snappers were also attracted to arrays and will certainly become abundant around offshore structures.

The impacts of noise and disturbance resulting from increased offshore activities are unknown but are not expected to be of major consequence for most of the marine animals in question. Marine mammals (cetaceans) would represent a possible exception. The manatee population is largely restricted to coastal habitat in Everglades National Park and in the Ten Thousand Islands Region and would probably not be affected by offshore activity.

Boat traffic (service vessels and sports fishing craft) around platforms could have impacts on turtles, which may be vulnerable to boat injury on the surface. Turtles were sometimes present and, if so, typically remained at some of the in situ instrument arrays deployed in this program. Assuming that this observation might represent a possible attraction to structures and given sea turtles need to breathe at the surface, they may be subject to an increased risk of being hit by boats.

As elaborated in Table 4.2-3, varying degrees of chemical pollution can result from hydrocarbon spills, drilling muds and cuttings, sewage, produced waters, deck drainage, leaching of metal debris, etc. Of these, the occurrence of a major accidental hydrocarbon spill (such as IXTOC) has the highest potential for having wide-scale detrimental impacts.

Major accidental petroleum spills (e.g., from a blowout) could affect a wide area. Floating fractions would be expected to damage bird life, marine mammals, and young marine turtles. However, the major impact of this fraction would be expected in the intertidal area (involving seagrass beds, coral reefs, and mangrove swamps) and in the estuaries (including the Everglades). Dissolved fractions, which contain many toxic organic compounds, would be diluted and transported out of the area. However, experimental evidence supports the conclusion that if these toxic compounds persist for any significant period of time, local marine life of all types could be damaged. In both cases, a midshelf or nearshore spill would be more damaging than one on the outer shelf; the shallower the water, the greater the potential effect.

Chemical pollution resulting from minor spills and deck drainage and discharge of treated sewage, garbage, and debris from platforms and/or ships directly involved in offshore hydrocarbon development activities would be expected to be of minor ecosystem consequence. However, the beaches of the northwestern Gulf are typically littered with weathered oil and debris of which some can be traced to offshore production activities. Given the extensive recreational use of the west Florida coast, economic consequences could be expected. However, prevailing winds and currents in the area suggest that the amount of material reaching the western shore of Florida would be small, and that most material would be transported to the west and into the Loop Current.

Chemical pollutants often contained in the discharges of drill fluids and cuttings and produced waters can be highly toxic to marine life. However, the effects of these contaminants are likely to be local in nature due to rapid dilution, based upon the results of field studies in other regions of the Gulf and elsewhere (e.g., Fischel, 1983; National Research Council, 1983). Scleractinian corals and other organisms typical of the southwest Florida shelf, however, have been demonstrated to be adversely affected by fluids and cuttings contaminants even in low concentration. Nevertheless, the disposal of drilling fluids and produced waters probably will not have major effects over large areas of the shelf unless the discharges are unusually widespread, toxic, or chronic.

Residential species on offshore structures (all sessile forms and some motile forms) could be exposed to high levels of pollutants in accidental discharges. For example, some turtles and groupers were reluctant to leave established sites on the _in situ_ instrument arrays deployed in this program. It is possible, then, that they may remain near platforms, which would increase their exposure in the event of an accidental spill or release of toxic materials. Their behavioral responses to most contaminants are unknown, as are their abilities to detect those contaminants. These animals may not readily leave the structures; this should be a source of concern, especially with regard to benthic discharges or high-density fluids that may sink rapidly to the bottom. However, the fact that the turtles are frequently observed around platforms and are in apparent good health suggests the impacts may be small.

Increased suspended sediment levels and bottom deposition and resuspension resulting from offshore development activities, particularly drilling fluids disposal, will have impacts on light penetration and could even cover benthic organisms if the discharges were large and the activity widespread. Light penetration is the primary limiting factor that determines ecosystem zonation on the southwest Florida shelf. Any significant long-term reduction in light penetration might exert a deleterious effect on the photosynthetic species, particularly in waters in the depth range of about 40 to 100 m.

While drilling effluents suspended in the water can reduce light levels on the bottom and may be deposited on benthic organisms, these effects are not considered likely to be of sufficient magnitude to be detrimental at shallow sites, except possibly on a short-term, localized basis. Throughout most of the shelf, bottom water velocities are usually high enough to keep fine particulates in suspension for long periods. In shallow water, wave-induced velocities are frequently high enough to resuspend even calcareous sand. During winter, daily resuspension rates due to wave action and currents at a shelf station 13 m deep have been measured up to 1,000 metric tons/km^2/day, over 100 times the daily fluid and cuttings discharge rate of a typical drilling rig. As a result, little or no buildup of drilling fluid components should take place--at least in shallow water. However, some local accumulation of cuttings may occur.

Benthic organisms on the shallower portions of the shelf are routinely exposed to low-light intensities and intense sedimentation during storms. Time-lapse cameras have revealed periods of several days or more during which benthic visibility is reduced to near zero by sediment resuspended by storms. Also, tidal and wind-driven currents at most shallow stations are sufficiently strong to prevent the long-term deposition of fine particulates.

Some fishes showed a high tolerance for suspended sediment. Fish seen in time-lapse camera frames prior to turbidity storms were sometimes observed at the same locations immediately afterward, without apparent ill effects. It is also probable that species of fish adversely affected by localized suspended particulates from drilling operations will simply move to another location until the situation improves.

Whether sediment from drilling fluids would accumulate in deeper water is another matter. Water velocities are relatively low there; it is possible that particulate matter could build up on the bottom, immediately adjacent to discharge points. However, the depth of the water and the slow settling velocity of drilling fluids suggest the fluids will be dispersed over a large area before reaching the bottom. Cuttings will probably accumulate in the proximity of the drill rig.

Ecosystem damage from mechanical activities (drilling, dredging, emplacing or deploying pipelines, and anchoring) would tend to be localized around the activity. Mechanical damage associated with pipeline deployment would be extensive along the linear corridors. The severity of mechanical damage to the ecosystem would be expected to be different between low- and high-relief habitats.

Mechanical damage from offshore construction is likely to be ecologically unimportant in many low-relief areas, such as patches of sand and hard bottom populated by sponges and gorgonians. Most live-bottom stations shallower than 50 m fit this description. Shelf organisms routinely repopulate bared areas exposed by shifting sand; there is an extensive amount of similar bottom covered with organisms whose offspring can aid the repopulation process. In addition, disturbance of the sand community (e.g., echinoids and tube-dwelling polychaetes) routinely occurs due to bioturbation, as evidenced by time-lapse camera results. Furthermore, several examples of very rapid sponge growth were recorded with high-resolution benthic photography, and some sponges may be capable of repair and regrowth in a short period of time.

Mechanical damage may be long-lasting in high-relief areas in either shallow or deep water or where scleractinian corals, algal nodules, or other unusual benthic features are abundant. Stations in the outer portion of the middle shelf typically fit this description. Mechanical damage can cause short- and long-term losses in corals. Corals tend to be very slow-growing and may be permanently damaged by abrasion or impact. In shallow water, corals were most abundant on high-relief spots where they may not be subject to periodic inundation by sand. In deeper water, agariciid corals and algal nodules form extensive beds with unknown ecological importance. Furthermore, coral and algal nodule beds provide attraction and shelter for many fish and invertebrates. Areas of high relief are of concern since the corals and other organisms in these areas differ from those on flat, sandy bottom.

In conclusion, it would seem that the greatest potential impacts from oil and gas development would be felt by two ecosystems, the nearshore and the midshelf (twilight) zones. The nearshore systems would be in greatest danger from surface floating oil resulting from accidental spills, even though the probability of a spill is low. The twilight systems may be in jeopardy if suspended solids significantly reduced light penetration for long periods of time.

Attracted motile species and settling species at platforms may be exposed to locally high contaminant levels and increased mortality due to recreational and commercial harvest and, for turtles, boat traffic. High-relief communities in both the nearshore and midshelf regions contain species especially sensitive to contaminants (if exposed) and local mechanical damage. Recovery of such communities would not be expected to be rapid. Such areas should be identified and avoided.

4.3 SUBMODEL (VEC) ANALYSES

The deficiencies of ecosystem impact analyses as presented stem from their general nature. It is virtually impossible to list the individual components of an ecosystem and the potential impacts that oil- and gas-related activities might have on each component. As an alternative, the impacts on a selected and manageable number of important ecosystem components were evaluated. The approach and results of these analyses are presented in the following section.

4.3.1 SELECTION OF VALUED ECOSYSTEM COMPONENTS (VECs)

VECs are those species, groups of species, or other ecosystem features that have been identified as being of special importance for a given ecological analysis. The importance may stem from economic value, rare or endangered status, dominance or prominence of ecological role, or sensitivity to environmental disturbance. For a given ecological analysis, VECs were determined by a group of knowledgeable and interested persons. The VECs for this study were selected by representatives from the U.S. Department of Commerce (NMFS); U.S. Department of the Interior (USFWS and MMS); the State of Florida (Office of the Governor); Continental Shelf Associates; Environmental Science and Engineering, Inc.; LGL Ecological Research Associates, Inc.; and Texas A&M University. The list of VECs selected for the southwest Florida shelf includes the following:

VEC	Reason Chosen
1. Seagrasses (Halodule, etc.),	Primary producer, provide habitat.
2. Anadyomene menziesii,	Primary producer, deep and restricted distribution.
3. Coralline algal nodules,	Primary producer, provide habitat.
4. Sponges (Ircinia and others),	Abundant, support dependent communities.
5. Hermatypic corals (Agaricia, etc.),	Abundant, support dependent communities.
6. Gorgonians,	Abundant, support dependent communities.
7. Crinoids (Comactinia, etc.),	Common form on outer shelf.
8. Pink shrimp (Penaeus duorarum),	Commercial and ecosystem importance.
9. Rock shrimp (Sicyonia spp.),	Commercial and ecosystem importance.
10. Spiny lobster (Panulirus argus),	Commercial and ecosystem importance.
11. Stone crab (Menippe mercenaria),	Commercial and ecosystem importance.
12. White grunt (Haemulon plumieri),	Most abundant, ubiquitous reef fish, recreational importance.
13. Snappers and groupers,	Commercial and recreational importance.

14. Spanish and king mackerels, and	Commercial and recreational importance.
15. Sea turtles (loggerhead, green, etc.)	Endangered species.

Collectively, this group of VECs represents producers and consumers at all trophic levels, all ecosystems from nearshore through the continental shelf, and benthic and nektonic elements, as well as species of commercial and recreational interest, ecosystem dominance, environmental sensitivity, and representation on the endangered species list.

4.3.2 POTENTIAL IMPACTS OF OIL AND GAS DEVELOPMENT ON VECs

This section presents an analysis of the potential impacts of oil- and gas-related activities on each of the VECs. Each analysis is presented as a flow diagram of potential pathways connecting the initial activities, through intermediate steps, to the final presumed impacts. All pathways should be carefully considered. The actual likelihood, degree, and spatial extent of the potential impacts provided in the following sections are discussed further in Section 4.4, Submodel Integration.

VEC No. 1. Seagrasses

Seagrass communities of south Florida have been discussed in detail by Zieman (1982). These communities are limited to the depth range of 0 to 20 m, and the densest beds do not extend deeper than 9 to 10 m. The seagrasses, which are most abundant south of the Everglades, provide forage and shelter for numerous species of regional importance. Life histories of many species are associated with these meadows. Located in very shallow water along a low-energy coastline without rapid water exchange, these seagrass beds are considered highly vulnerable to major oil spills; the resulting damage would be of regional consequence (see Figure 4.3-1). If major developments were to occur along the coast, extensive destruction of the beds from construction and ship traffic would be likely. Major drilling and dredging in or near the beds would likely result in physical disruption, heavy sedimentation, and

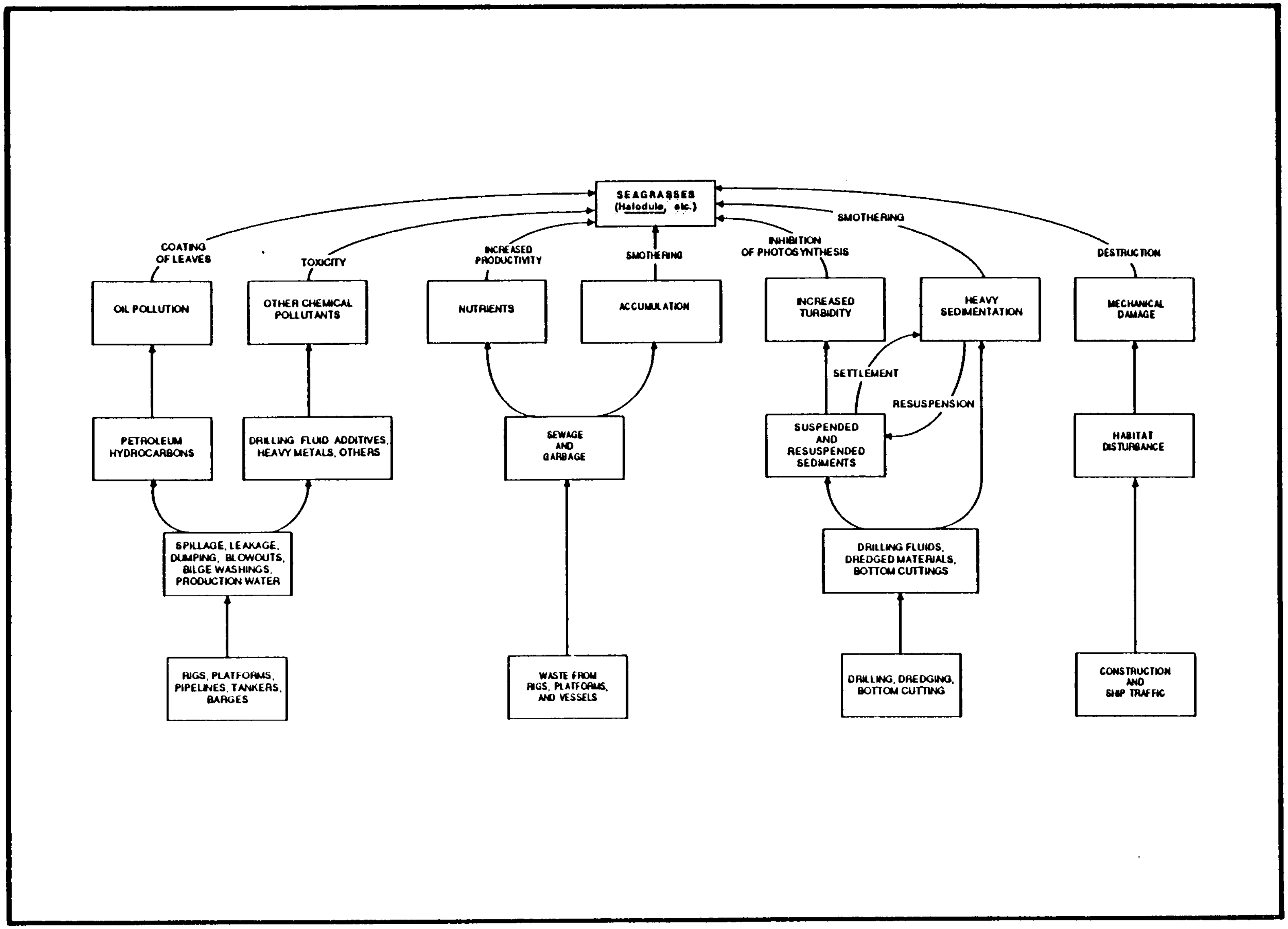


Figure 4.3-1 **Potential impacts of oil- and gas-related activities on seagrasses (*Halodule*, etc.).**

suffocation of the seagrasses. Increased turbidity could inhibit photosynthesis. Waste from rigs, platforms, and vessels could cause local suffocation (if waste quantities were large enough); however, to the extent that sewage and garbage were involved, some nutrient release might stimulate seagrass growth. It is unlikely, given the quantity and buoyance of sewage and garbage, that suffocation would result. Toxic effects of drilling fluid additives and heavy metals are not well known, but these would likely be of only local consequence. Of all the potential impacts, damage from major oil pollution is of the greatest concern since the damage could be widespread.

VEC No. 2. *Anadyomene menziesii*

This green alga was found only in the depth range of 66 to 75 m and was limited to the southern portion of the study area. It is probably the only major benthic producer in the twilight zone, and, because of its local distribution on the southwest Florida shelf, it should be listed as a rare species (although it is locally abundant). It is clearly light dependent in an area of extremely low-light penetration, and any long-term reduction in light level may be considered threatening to the local population. Increased turbidity would inhibit photosynthesis (see Figure 4.3-2), and heavy sedimentation would be likely to smother the individuals. Mechanical disturbance of the habitat from various construction activities could certainly destroy local populations.

Oil pollution and release of other chemical pollutants should be of less concern, considering the depth of the water, bottom currents in the area, and the potential for mixing and dilution. Nutrients from sewage and garbage might even stimulate growth in some spots if these nutrients reach the bottom. Hard-surfaced structures at the appropriate depths could provide attachment sites and locally increase the population. The two greatest concerns are inhibition of photosynthesis and smothering, which could result if increased turbidity and heavy sedimentation occurred. Considering the rarity of the species and its likely trophic importance, the consequences of damaging this species could be

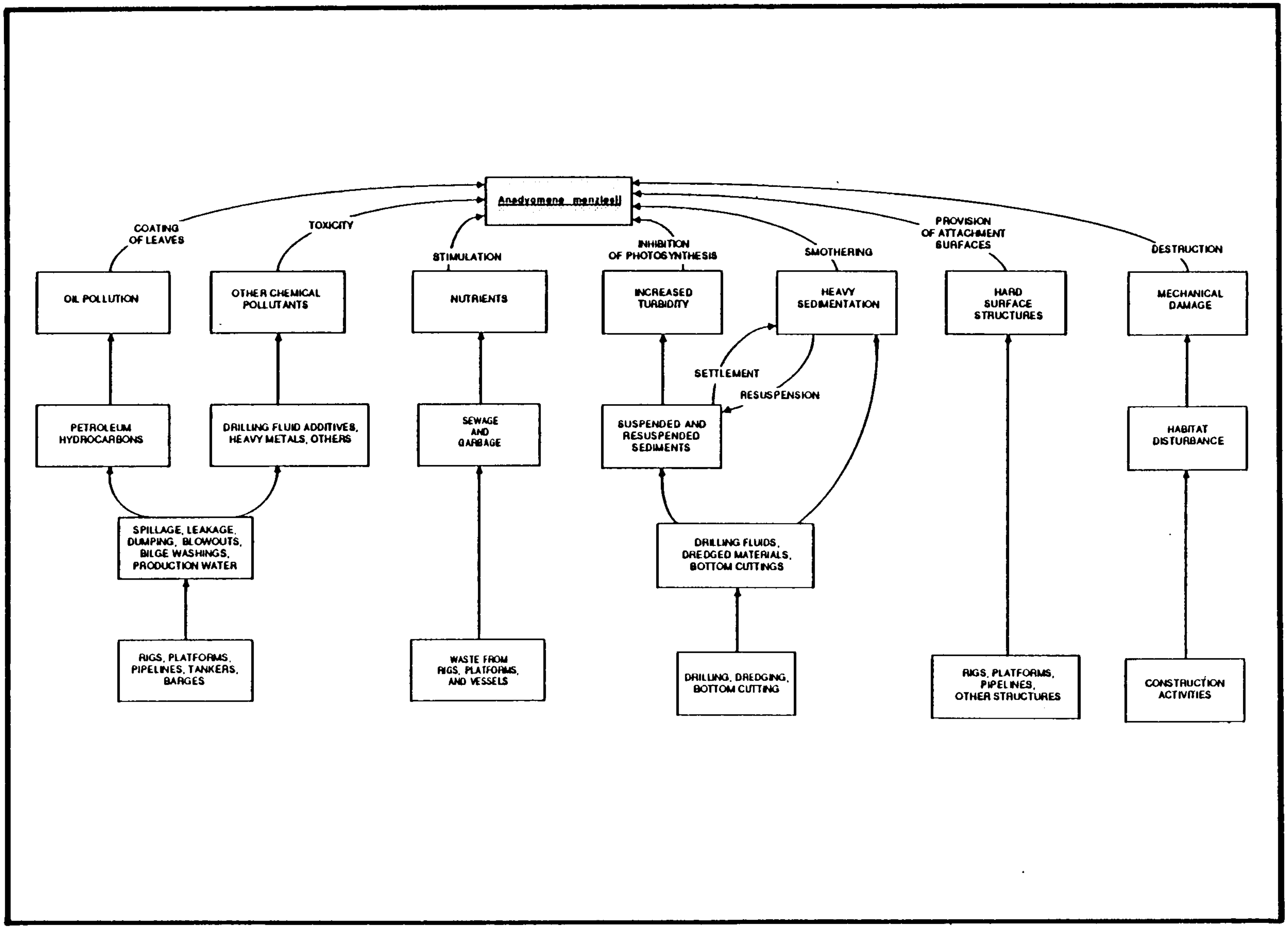


Figure 4.3-2 **Potential impacts of oil- and gas-related activities on perennial attached macroalgae (*Anadyomene menziesii*).**

twilight zone community, at least in the southern sector of the study area.

VEC No. 3. Coralline Algal Nodules

Algal nodules were found to be abundant in the southern portion of the study area in the depth range of 67 to 110 m. In the northern portion, these nodules were much less dense and were scattered through the depth range of 61 to 85 m. As in the case of Anadyomene, these nodules are probably living near their compensation depth. Thus, the nodules should be sensitive to light reduction by suspended matter. Also, since the nodules are only a few centimeters in height, they could easily be smothered by heavy sedimentation (see Figure 4.3-3). Bottom damage from construction activities would be expected to destroy local populations. Due to the depth and water-mixing processes, oil and other chemical pollutants should not have major impacts on the populations. Some smothering might occur from local accumulation of debris from rigs, platforms, and vessels. Algal nodules are of questionable trophic importance in the ecosystem and are known to be widely distributed in the Gulf of Mexico at appropriate depth levels. For these reasons, damage to the southwest Florida populations would not be a matter of great ecological concern on a regional basis. However, nodule beds shelter many small fish (e.g., serranids), and their destruction would be locally disruptive to these fishes.

VEC No. 4. Sponges (*Ircinia* and Others)

Sponges occur at all depths on the southwest Florida shelf. Massive sponges (e.g., Ircinia and Spheciospongia) occurred in the depth range of 10 to 137 m, but they were most dense between 20 to 100 m. Major damage could occur through osculum (pore) clogging by suspended sediments and smothering by heavy sedimentation. Local populations would be destroyed by construction activities that caused mechanical damage to the bottoms (see Figure 4.3-4). Growing well below the low tide level, most sponges would not be damaged by floating oil. In shallow waters, however, floating oil accumulates sediment particles and sinks to the bottom. If

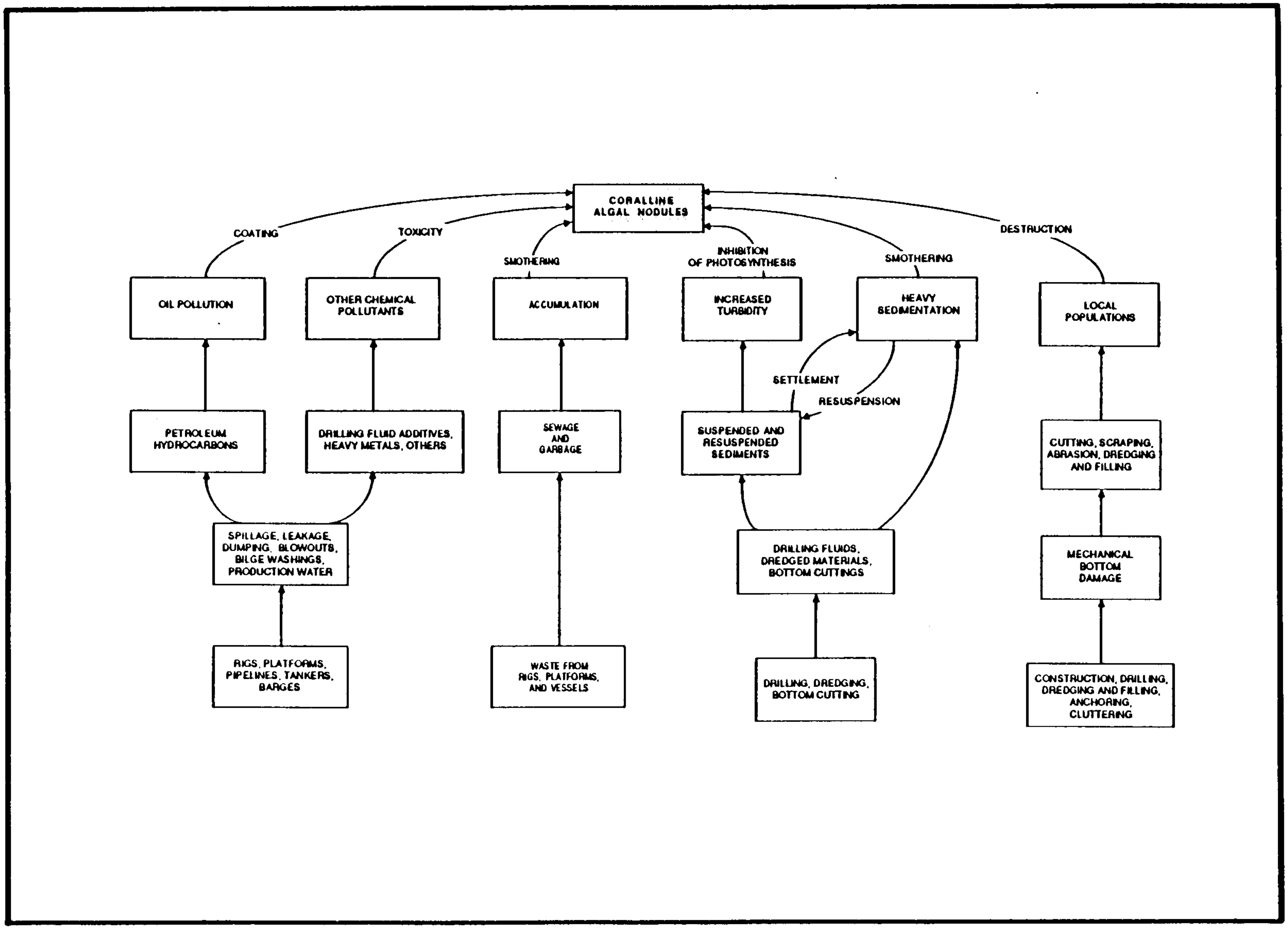


Figure 4.3-3 **Potential impacts of oil- and gas-related activities on coralline algal nodules.**

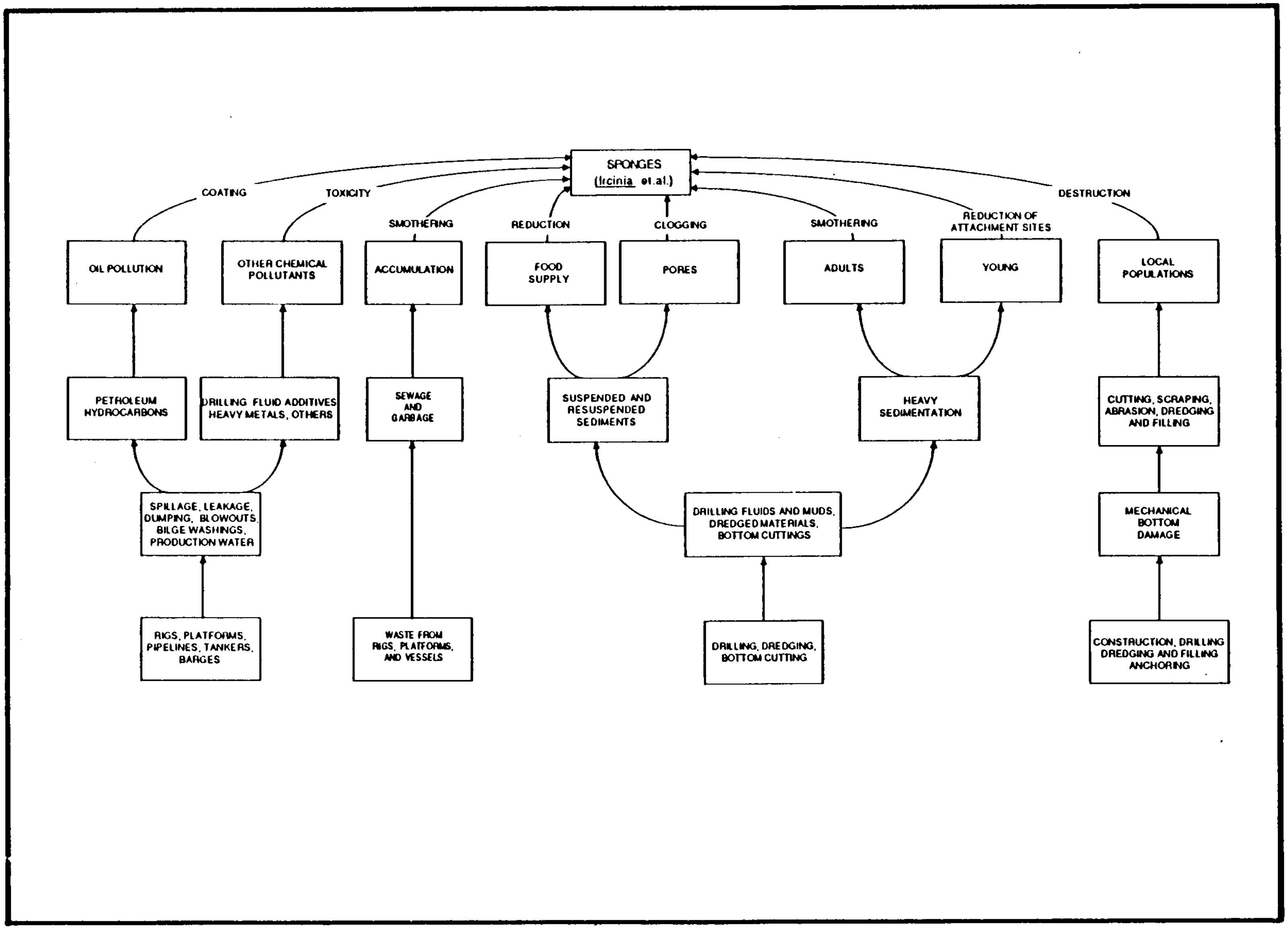


Figure 4.3-4 **Potential impacts of oil- and gas-related activities on sponges (*Ircinia et al.*).**

this fraction contacted the sponges, it could be of concern. Other chemical pollutants are of less concern. Local smothering might occur from debris piles, and food supplies might be reduced by suspended sediments in the water column. Heavy bottom sedimentation would reduce attachment sites for young sponges, but hard surfaces of offshore structures would provide additional attachment sites. Although some potential damage to the sponge populations seems highly likely, the species are widespread and able to recolonize readily.

VEC No. 5. Hermatypic Corals (*Agaricia*, etc.)

On the southwest Florida continental shelf, most hermatypic corals are limited to waters of 60 m or less, but specimens of Agaricia were observed out to 80 m in the southern portion of the study area. Shallow water corals would be subject to coating by petroleum from large oil spills (see Figure 4.3-5). At all depths, corals would be subject to coating and clogging of the polyps by suspended sediments and to smothering by heavy sedimentation, although these effects would be more important in shallow waters. Mechanical disruption from various construction activities could destroy local populations.

Other potential effects such as toxicity from various chemical pollutants, smothering resulting from debris, localized eutrophication, and attraction resulting from garbage and sewage disposal, and reduction of food supply by suspended sediments would probably be of less severe consequence. Photo-inhibition by increased turbidity should be relatively unimportant in shallower waters but would likely become a limiting factor in deeper waters where the corals are already living near their minimum light tolerances. On the positive side, offshore structures would provide attachment surfaces for additional coral growth.

VEC No. 6. Gorgonians

Photosynthetic gorgonians occur to a depth of 20 to 25 m in the northern portion of the study area and to about 45 m in the southern portion of

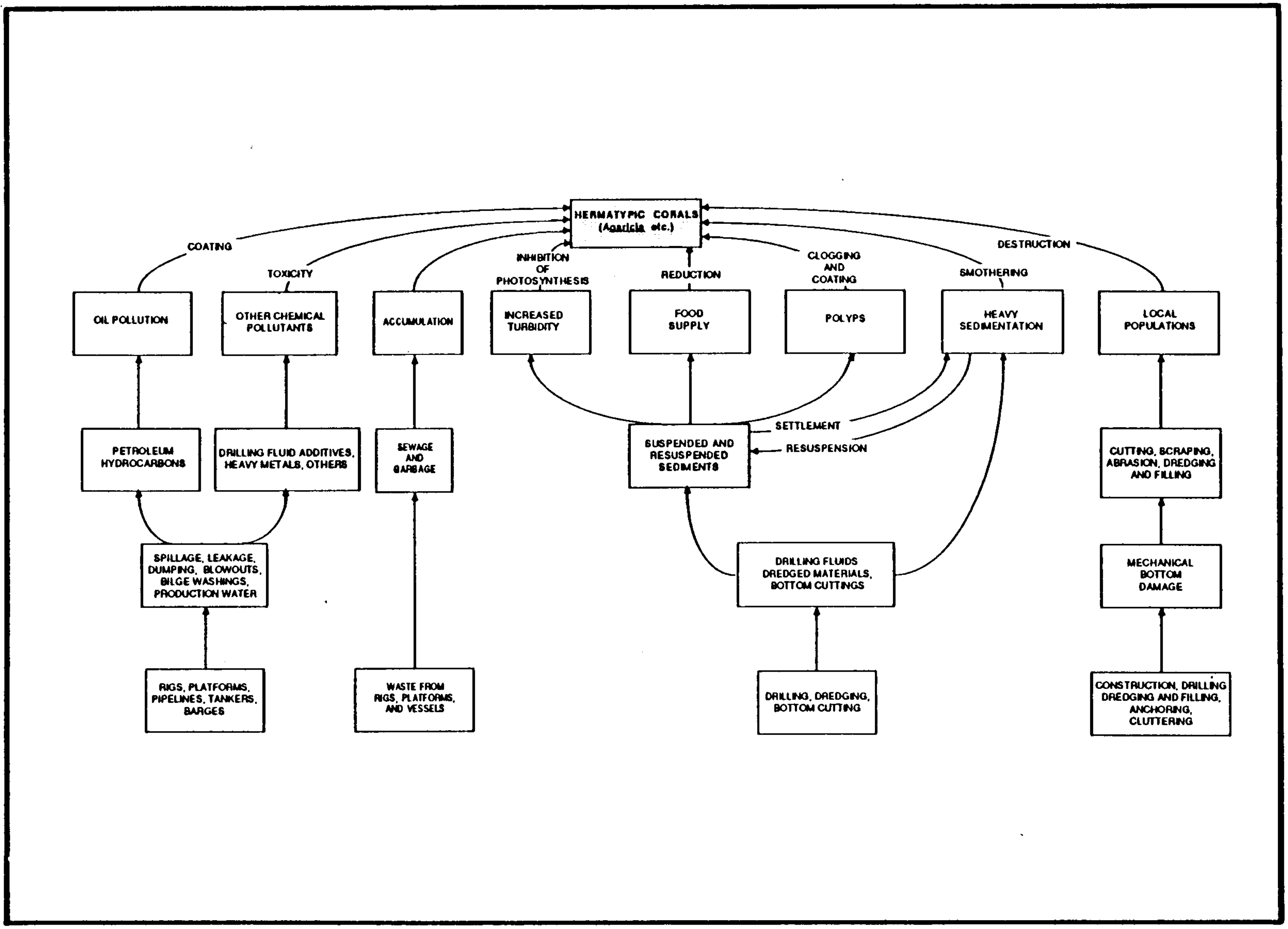


Figure 4.3-5 **Potential impacts of oil- and gas-related activities on hermatypic corals (*Agaricia*, etc.).**

the study area. Nonphotosynthetic species were observed from a depth of 20 to 159 m, and probably occur at least to 200 m. Wherever construction occurs on the continental shelf, local populations will undoubtedly be destroyed by mechanical activities (see Figure 4.3-6). Oil coating and chemical toxicity might affect the nearshore populations; however, all other potential impacts may be of less consequence. Photosynthetic species are of thin vertical structure and should not suffer from sediment retention interference. Some local smothering from platform debris might be expected. Suspended particulate matter could reduce food supplies or interfere with feeding behavior. Heavy sedimentation would reduce bottom attachment sites for young, but hard-surfaced structures would provide attachment sites. Available information suggests that, although local damage would be inevitable, the populations themselves would survive and rapidly recolonize damaged areas.

VEC No. 7. Crinoids (*Comactinia*, etc.)

Crinoids were observed as shallow as 64 m, but greatest population densities were observed in the depth range of 95 to 149 m and probably occur as deep as 200 m. Local populations would be damaged by mechanical activities. Some smothering might occur from heavy sedimentation and debris disposal (see Figure 4.3-7). Oil coating and chemical toxicity are unlikely due to the depth of the crinoids, and temporary reduction of food supplies and interference with feeding behavior should not cause major damage. Heavy sedimentation would likely reduce attachment sites for young, but hard surfaces of offshore structures should provide additional attachment sites. Although subject to some local damage, the widespread population would probably survive.

VEC No. 8. Pink Shrimp (*Penaeus duorarum*)

The life history of the pink shrimp includes planktonic larvae, as well as juvenile, subadult, and adult stages. Since the transport mechanisms and pathways of the larvae are poorly understood, they cannot be addressed in this study. The larvae generally begin life on the inner and middle shelf and make their way to inshore estuarine nursery areas,

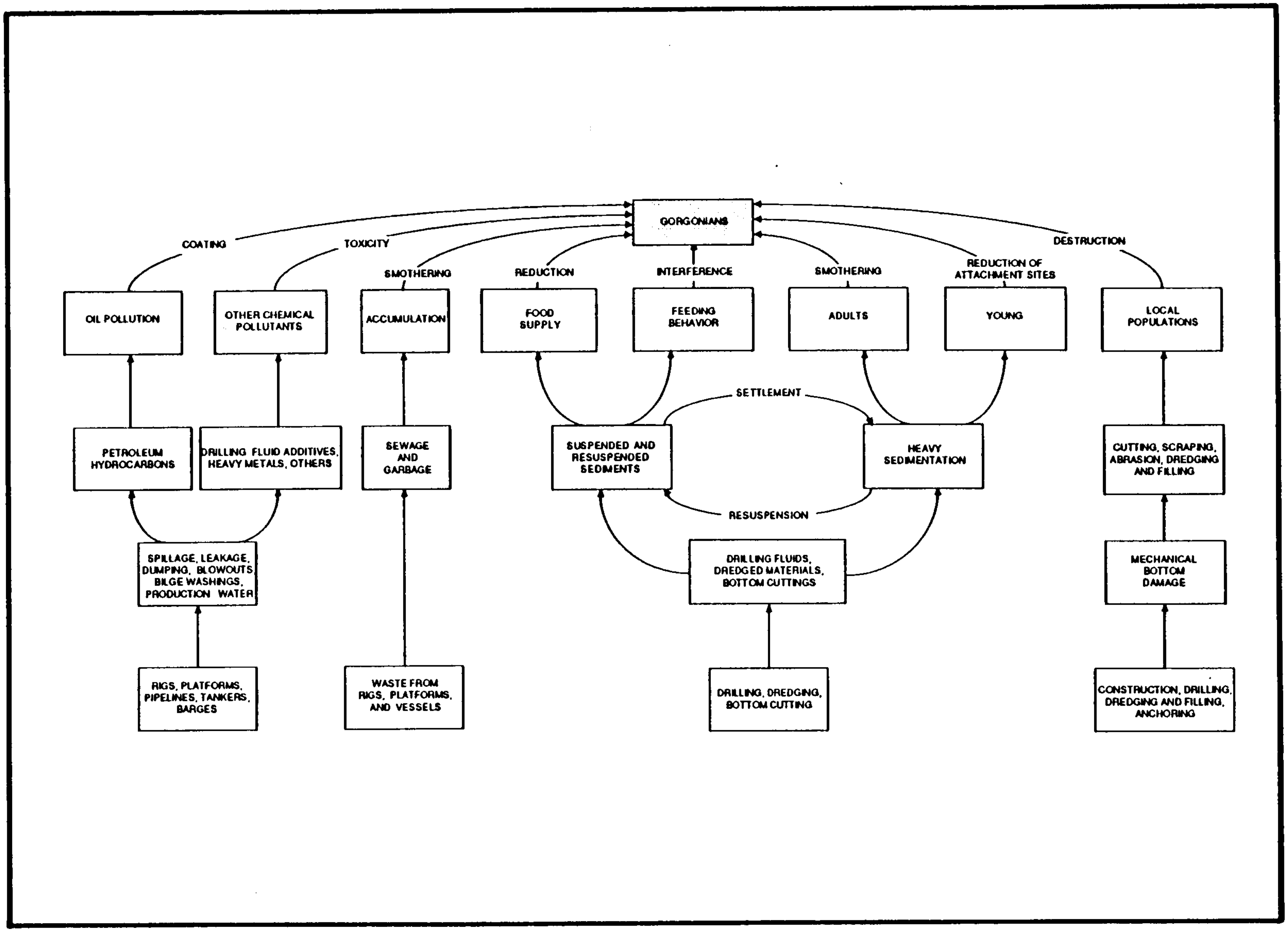


Figure 4.3-6 Potential impacts of oil- and gas-related activities on gorgonians.

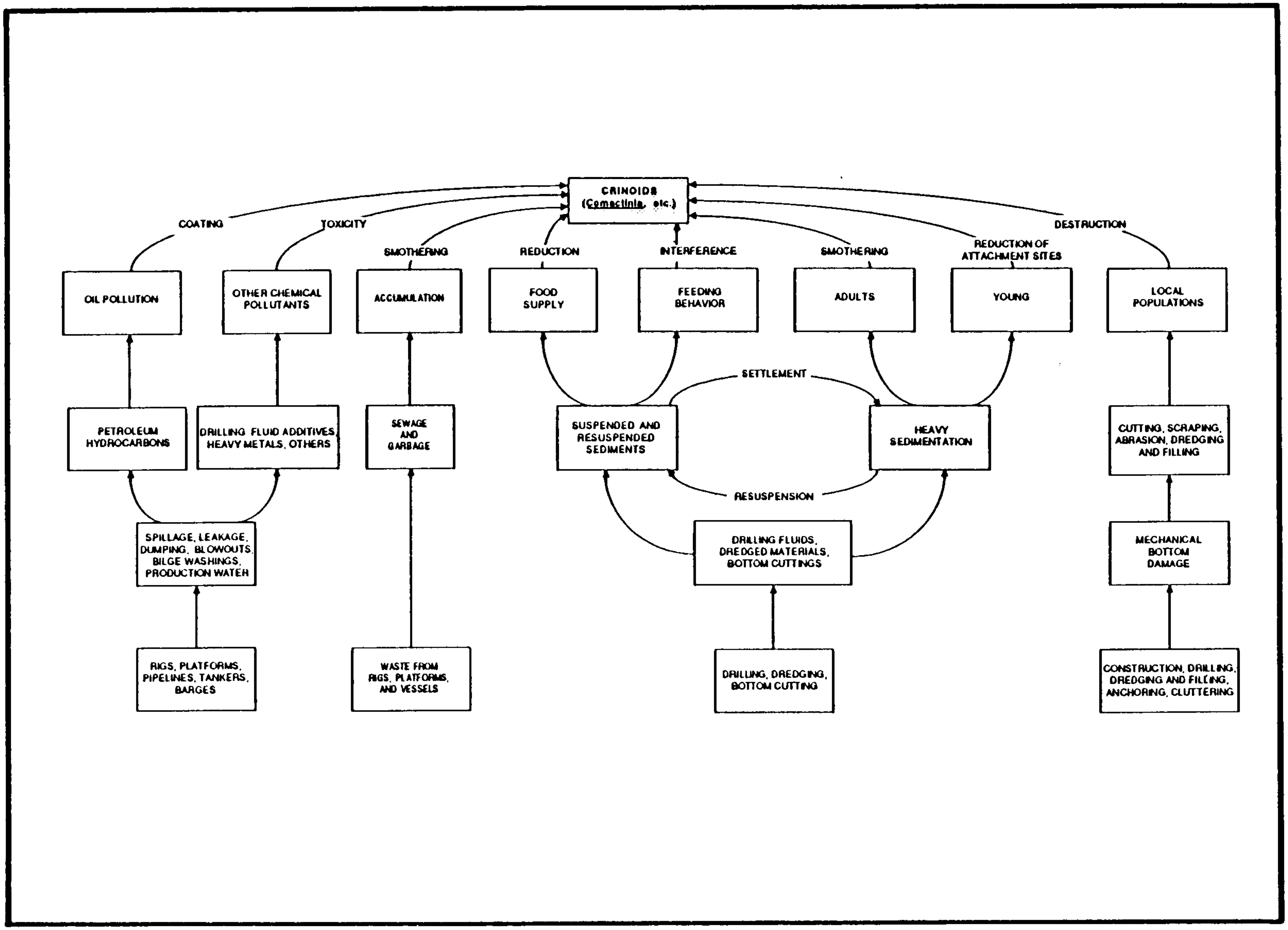


Figure 4.3-7 **Potential impacts of oil- and gas-related activities on crinoids (*Comactinia*, etc.).**

which in this study include the Everglades and seagrass beds. Subadults move out, and adults are found in the spawning grounds of the inner and middle shelf.

In relation to the total life history, one potential impact is of particular concern (see Figure 4.3-8). A major oil spill could impact the seagrass beds and the Everglades, destroying habitat and food supplies and coating and killing the young individuals. Of somewhat less concern, but still important, are impacts resulting from chemical toxicity, reduction of larval food supply, direct mortality of the larvae from suspended sediments, and interference with spawning migrations by linear barriers such as above-surface pipelines. Thus, oil pollution of the inshore areas is the prime concern.

VEC No. 9. Rock Shrimp (*Sicyonia* spp.)

Several species of rock shrimp occur in the project area; S. brevirostris is the most abundant and widespead as well as the largest and of most commercial importance. Highest densities are generally reached in the 20- to 60-m depth zone, but rock shrimp also occur at shallower depths around the outer Keys and Marquesas Islands. There are no potential impacts of major concern; however, a number of potential impacts are of moderate importance (see Figure 4.3-9). Local populations could be severely damaged by heavy bottom sedimentation and destruction of bottom habitat by mechanical activities. Oil and other chemical pollutants are not expected to be important at the depths involved, and larval mortality due to suspended particulates should not be a cause for concern. Population levels of most rock shrimp species are considered to be high enough to withstand the above impacts.

VEC No. 10. Spiny Lobster (*Panulirus argus*)

Spiny lobsters produce larvae which may persist more than a year as plankton. Local populations may be replenished by larvae originating in the West Indies or elsewhere. Thus, even if a local population were totally destroyed, spiny lobsters would be quickly replenished by larvae

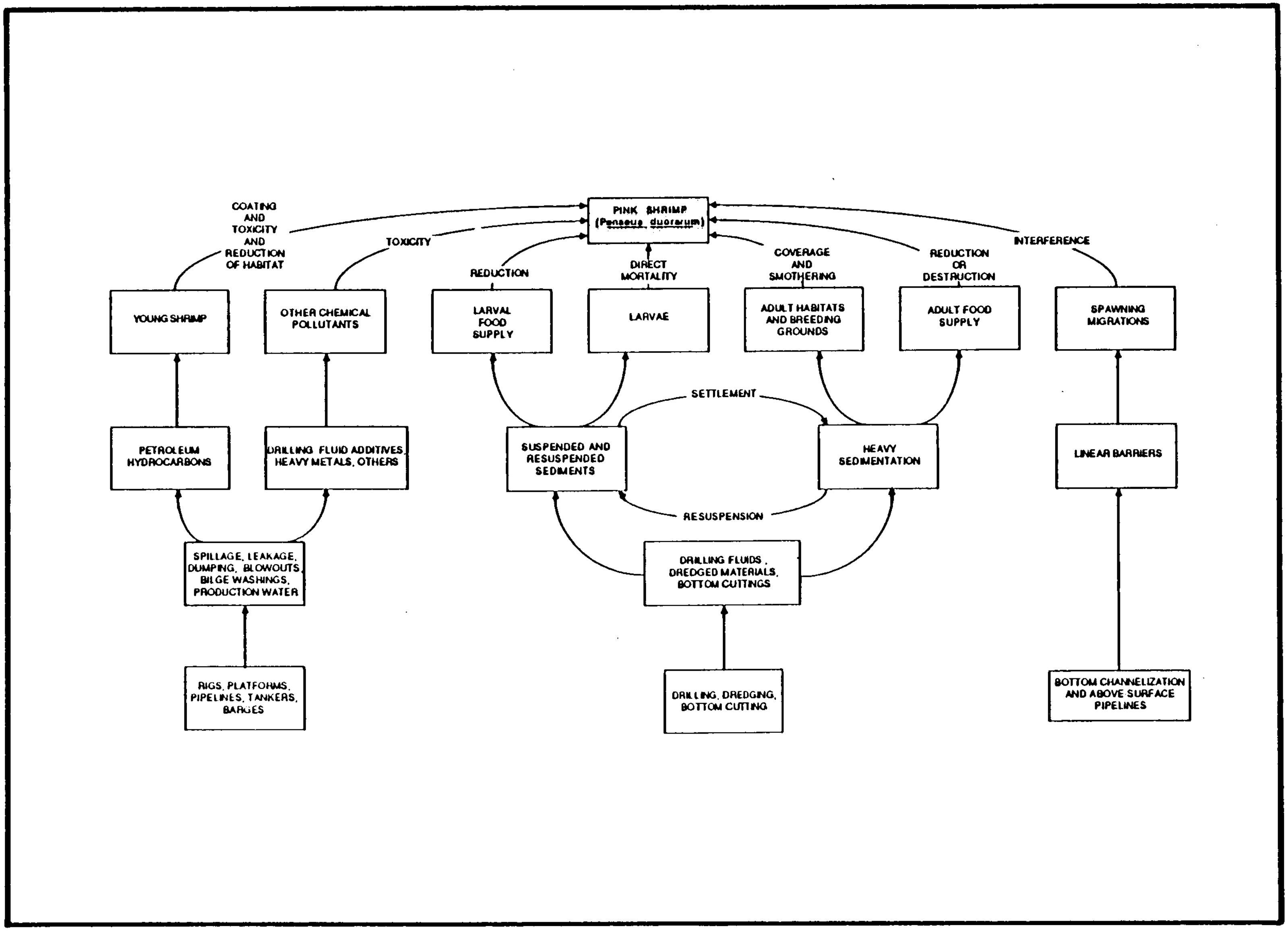


Figure 4.3-8 **Potential impacts of oil- and gas-related activities on pink shrimp (*Penaeus duorarum*).**

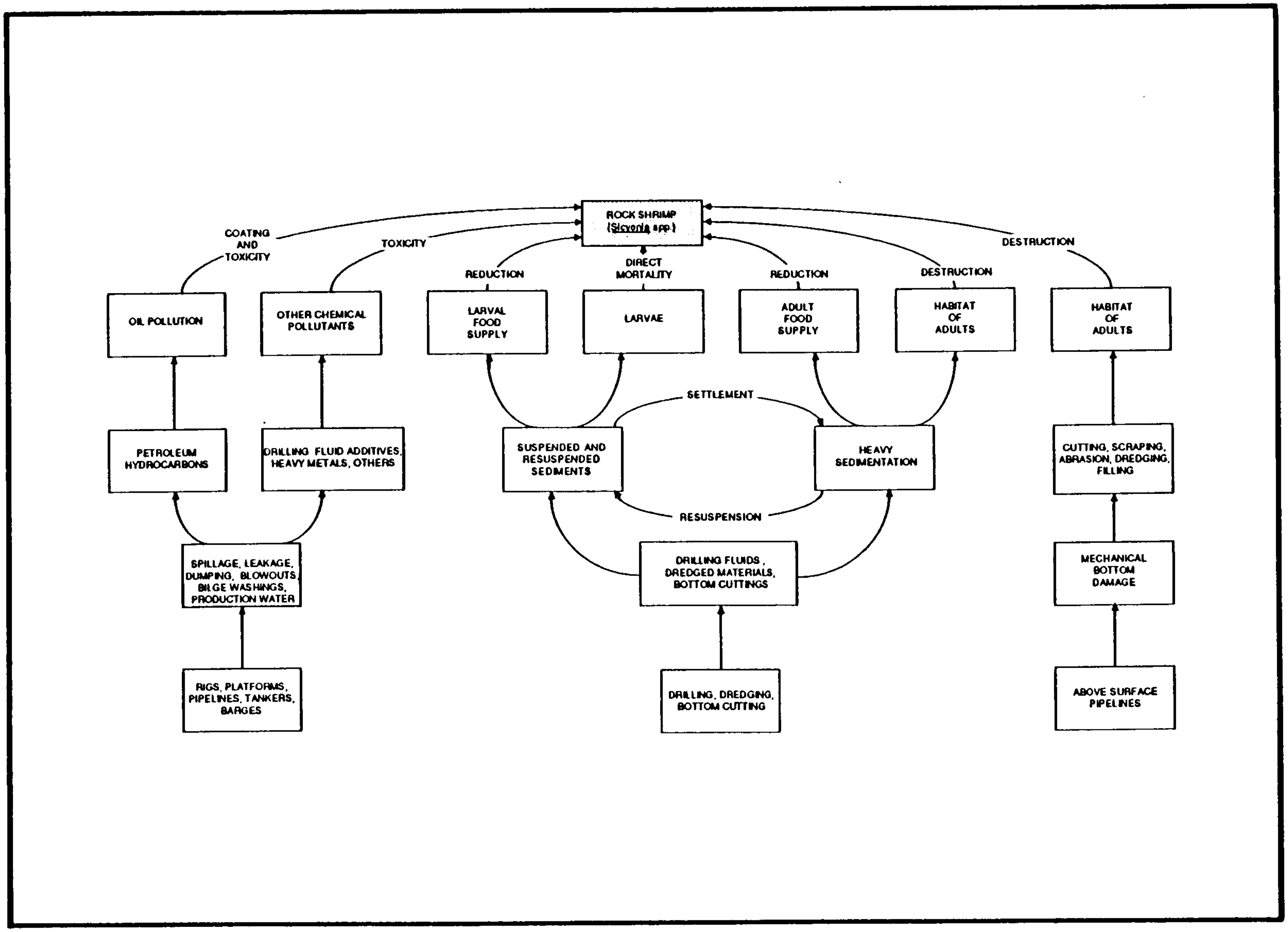


Figure 4.3-9 **Potential impacts of oil- and gas-related activities on rock shrimp (*Sicoynia* spp.).**

brought in by the Loop Current or migration. However, the resident subadult and adult populations of the southwest Florida shelf are considerably lower in number than those of the pink shrimp and rock shrimp discussed previously. The impact analysis must focus upon these resident populations. Spiny lobsters hide during the day in crevices of reefs and other structures (including offshore petroleum platforms), usually in the depth range of 20 to 60 m, although they do occur in both shallower and deeper water. At night, spiny lobsters often forage away from protective cover. Major concerns include heavy sedimentation (which can reduce habitat and food supplies) and mechanical damage to the bottom (which can destroy local habitats) (see Figure 4.3-10). Pollution from oil or other chemicals is not considered important except in the shallowest part of the habitat. The effects of suspended sediments on larval survival do not appear to be critical. Of unknown importance is the potential behavioral interference from noise and other habitat disturbance from heavy construction and ship traffic. Most of the potential impacts are likely to be mild or of local occurrence; they are not considered to be of major importance to the resident populations.

VEC No. 11. Stone Crab (*Menippe mercenaria*)

Stone crab larvae are transported widely by currents, but adults are never found in deep water and are seldom abundant beyond a depth of about 20 m. Within the shallow water zone, adults are generally found in burrows along the sides of channels or in crevices of vertical structures. Production platforms provide good habitat, and, in the northwestern Gulf, offshore platforms are heavily colonized by stone crabs. Adults do move around and there is some evidence of seasonal migration.

Of great concern is the possibility of major oil pollution in the shallow water habitats (see Figure 4.3-11). Oil could coat individuals, exert toxic effects, and destroy food supplies. Habitat destruction through heavy sedimentation of shallow waters could also be important, and local damage to adults and habitat would be evident from mechanical

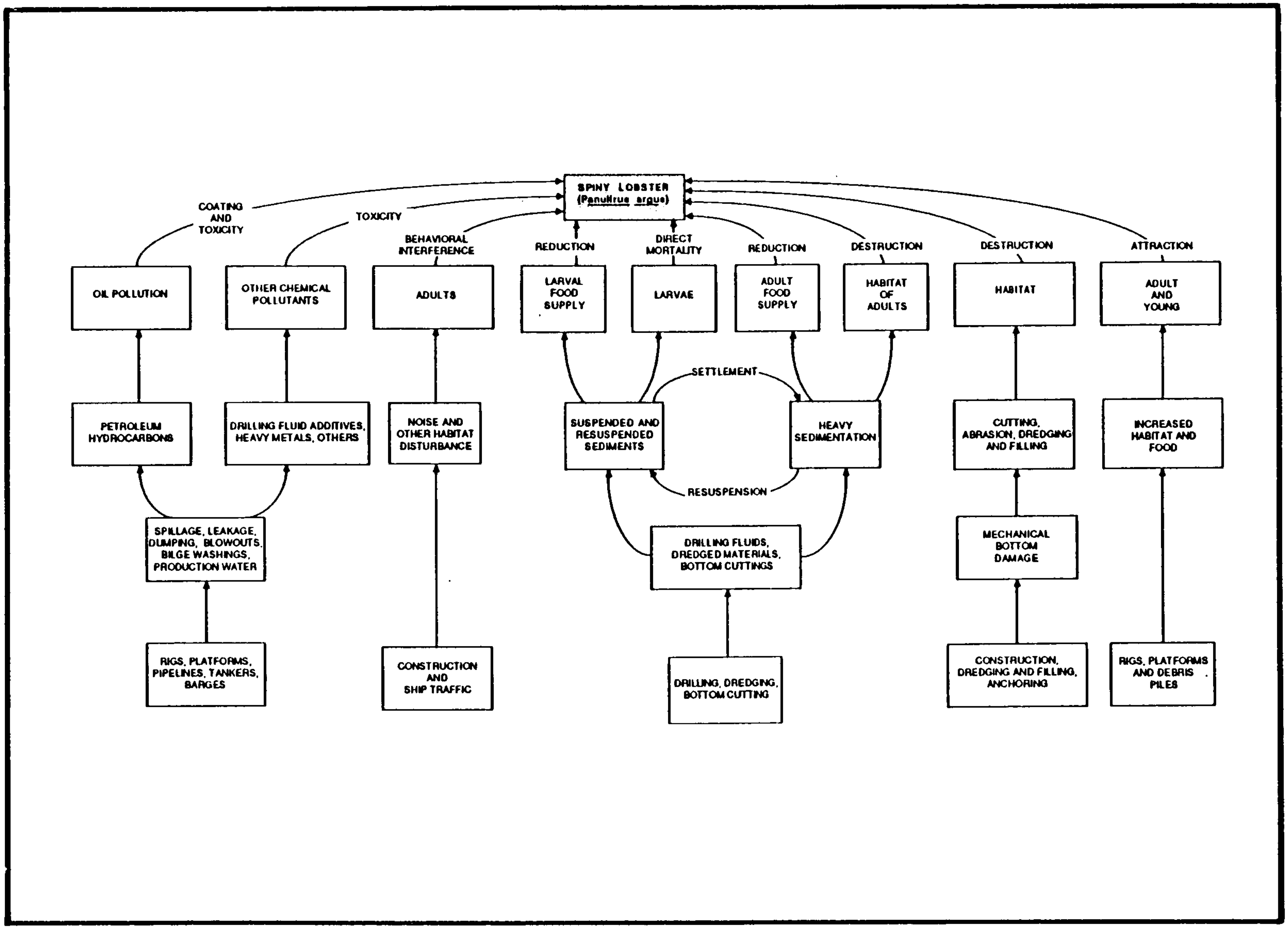


Figure 4.3-10 **Potential impacts of oil- and gas-related activities on spiny lobsters (*Panulirus argus*).**

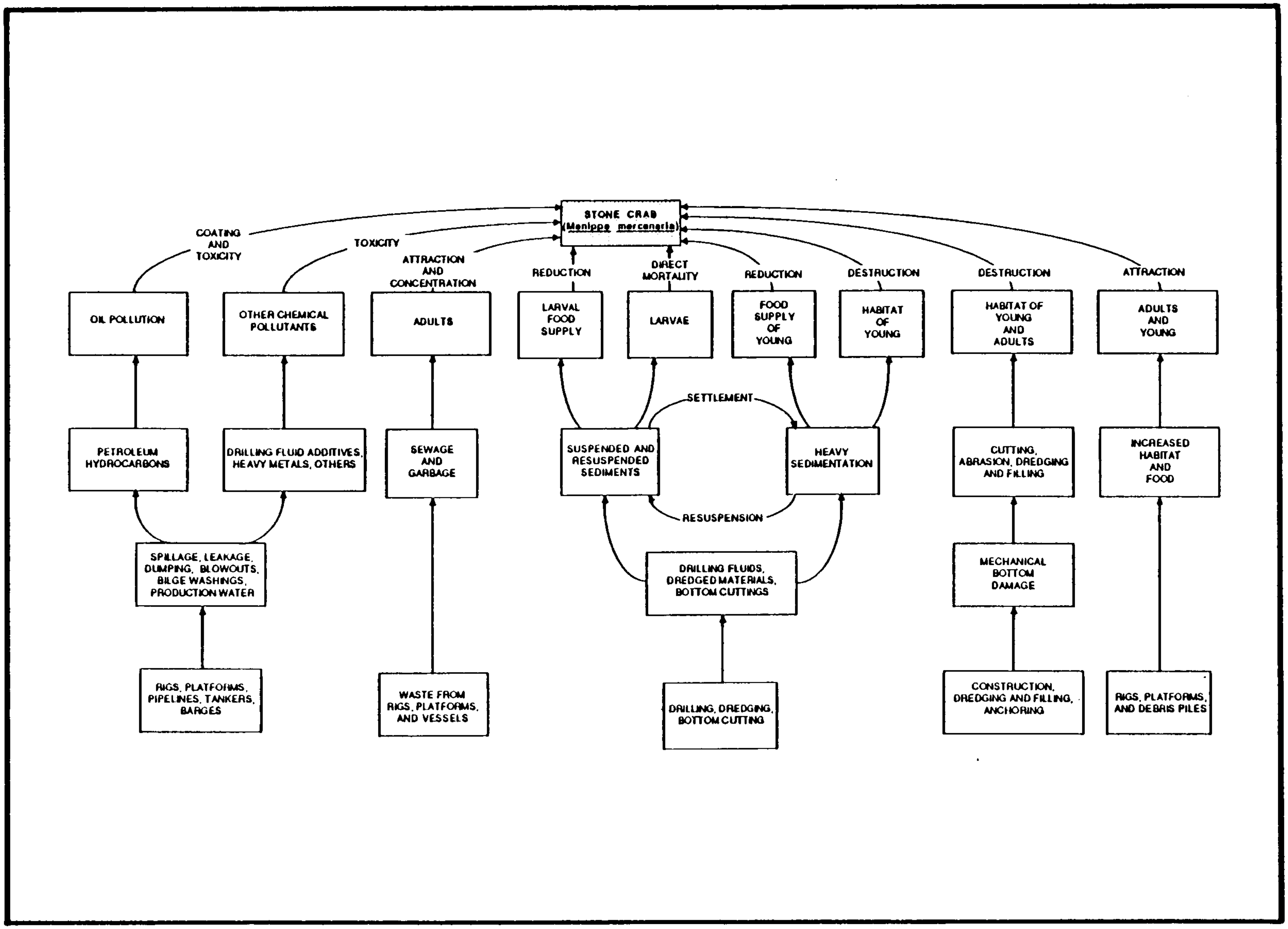


Figure 4.3-11 Potential impacts of oil- and gas-related activities on stone crabs (*Menippe mercenaria*).

construction activities. Of less concern would be toxicity from other chemicals and larval impacts from increased suspended matter. Platforms and other structures, debris piles, garbage, and sewage would tend to attract crabs. Of these concerns, the greatest is the possibility of major impact from a large nearshore oil spill.

VEC No. 12. White Grunt (*Haemulon plumieri*)

On the southwest Florida shelf, the white grunt occurs in small schools out to a depth of about 35 m. The grunt is a small fish with a relatively large mouth. It is a generalized carnivore and readily takes bait. Adults tend to concentrate around bottom relief. The primary expected impact is that large offshore structures would tend to concentrate adult populations where they could be subject to overfishing (Figure 4.3-12). Of less concern would be potential effects of pollution from oil or other chemicals. Sewage and garbage as well as epifaunal growth might increase the food supply and attract white grunts to offshore structures. The major potential impact would be expected from concentration and overfishing.

VEC No. 13. Snappers and Groupers

Snappers and groupers of the southwest Florida shelf extend through all the depth zones, but the largest concentrations tend to be found in the 20- to 60-m depth zone. Adults are generally associated with reefs, rock outcrops, and other vertical structures. As was the case for white grunt, the primary expected impact of most concern is that offshore structures would tend to attract and aggregate snappers and groupers where they could be subject to overfishing (Figure 4.3-13). Red snapper populations of southwest Florida are already depressed due to overfishing.

Large groupers might be impacted by toxicity from chemical pollution and by increased sedimentation. Such specimens exhibited a sedentary mode at experimental structures used in this study, from which they were reluctant to move, even when provoked by divers. Such a tendency would

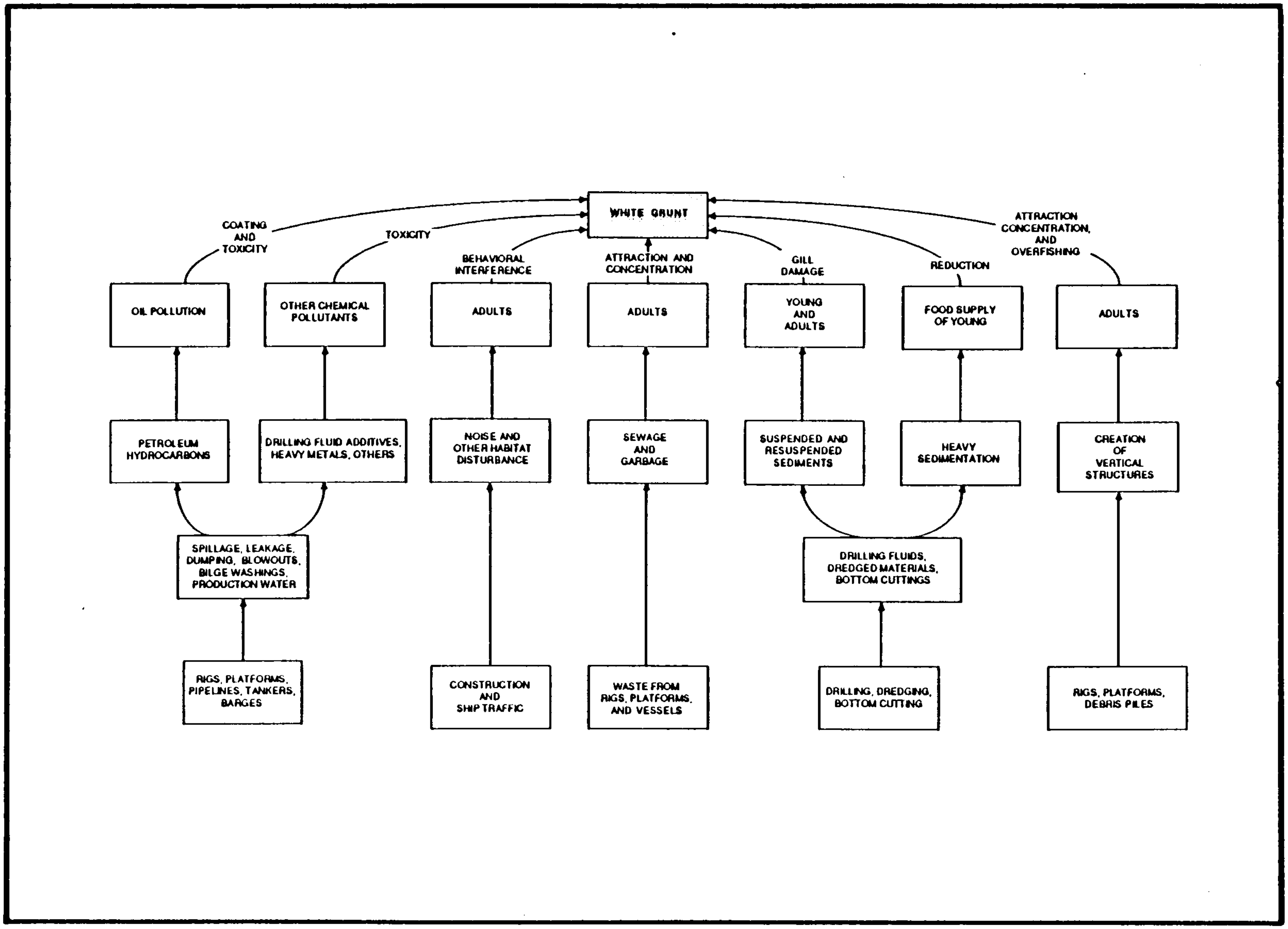


Figure 4.3-12 Potential impacts of oil- and gas-related activities on white grunt.

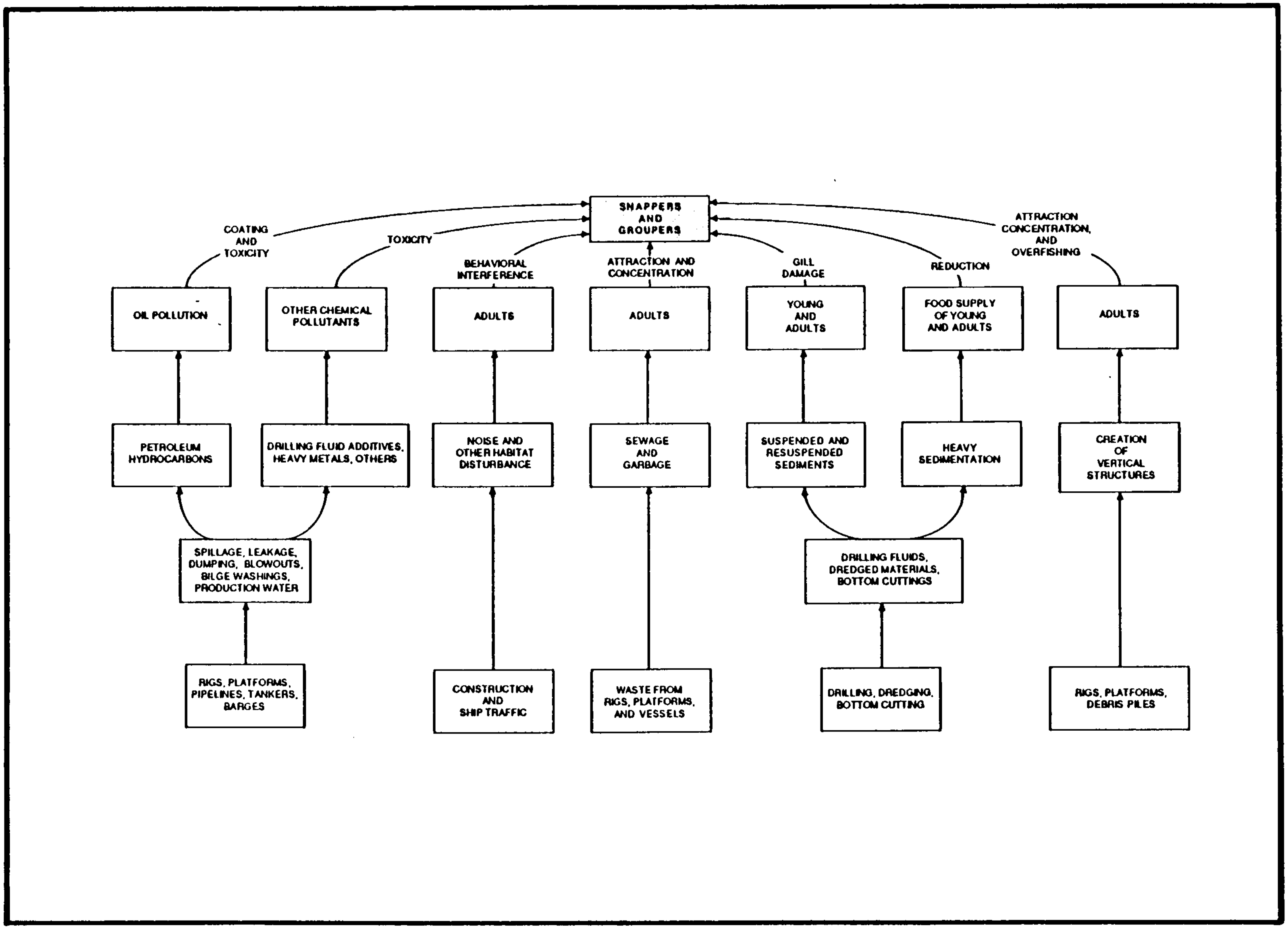


Figure 4.3-13 Potential impacts of oil- and gas-related activities on snappers and groupers.

result in increased time of exposure in areas where contaminant levels might be elevated.

VEC No. 14. Spanish and King Mackerels (*Scomberomorus maculatus* and *S. cavalla*)

Mackerels are large, fast-swimming pelagic fishes which feed largely in the water column but may forage on the bottom or in the near-bottom environment. They are seasonally present throughout the study area. Mackerels are not expected to be impacted by oil- and gas-related activities in any major way (see Figure 4.3-14). Available evidence suggests that large pelagic species detect and avoid oil pollution and would likely avoid other toxic chemicals well before encountering dangerous concentrations. Local avoidance of noise and other habitat disturbances also appears likely. Some reduction of the local food supply or interference with feeding might result from increased sediment loads in the water column, and heavy sedimentation of the bottom could reduce food supplies of the adults. The presence of offshore structures would undoubtedly attract the adults, however, keeping them in the area longer than they might stay otherwise. Increased harvest rates might result.

VEC No. 15. Sea Turtles (Loggerhead, etc.)

The loggerhead turtle (Caretta caretta) and green turtle (Chelonia mydas) are probably present throughout the area at all seasons. The hawksbill sea turtle (Eretmochelys imbricata) and Kemp's Ridley sea turtle (Lepidochelys kempii) are rare. In an extensive aerial survey study (Fritts et al., 1983), more than 97% of all turtle observations recorded for the Gulf were made in Florida waters with only 3% of the observations occurring in Louisiana and Texas waters. Potential impacts are depicted in Figure 4.3-15. Major oil spills in the area could interfere with food supplies and feeding behavior, and, if ingested, could cause direct mortality. The presence of tar balls in the mouths and esophagi of moribund young suggests direct ingestion (Witham, 1978). Heavy sedimentation could reduce bottom food supplies of adults. Plastic bags

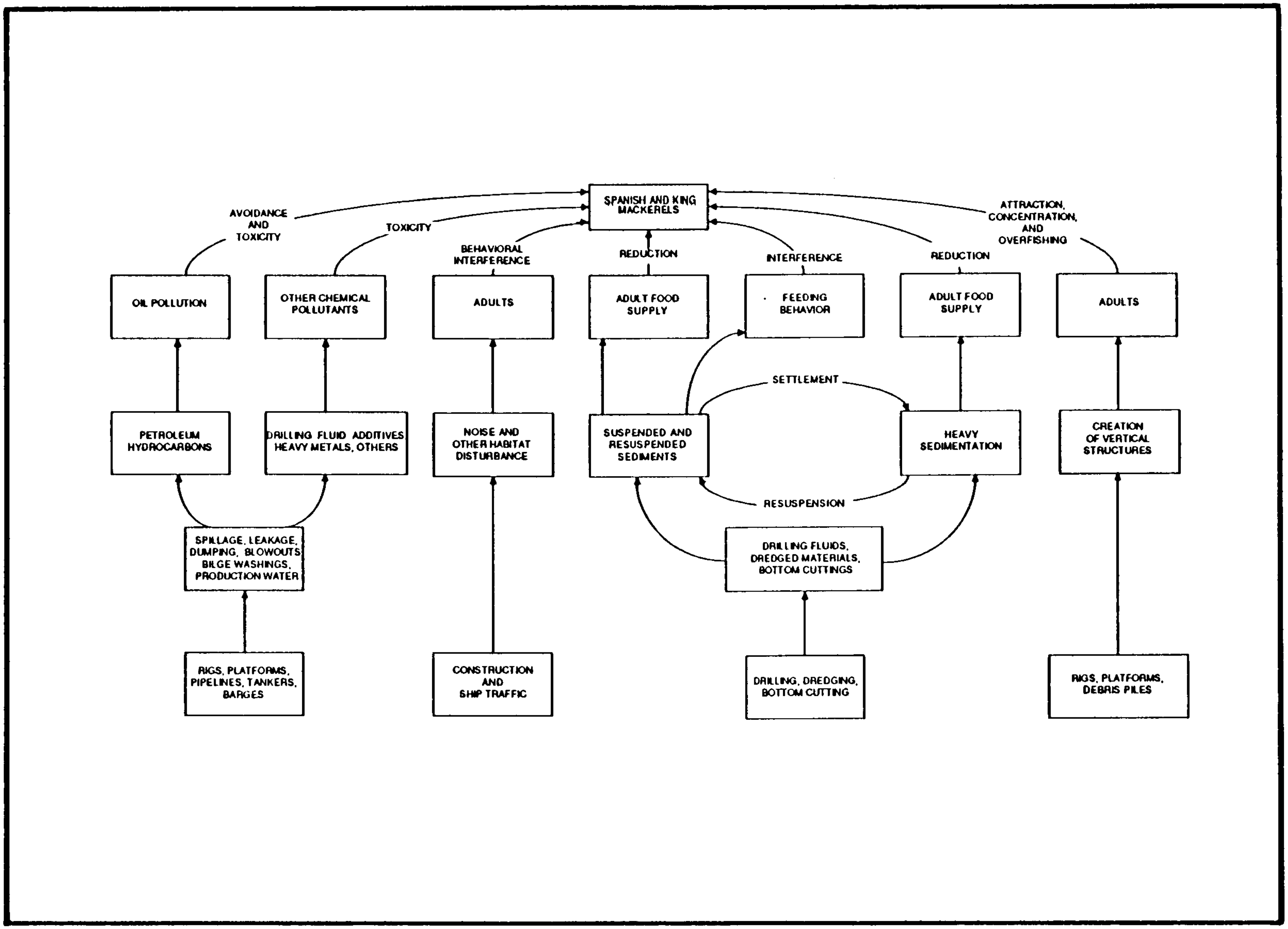


Figure 4.3-14 Potential impacts of oil- and gas-related activities on Spanish and king mackerels.

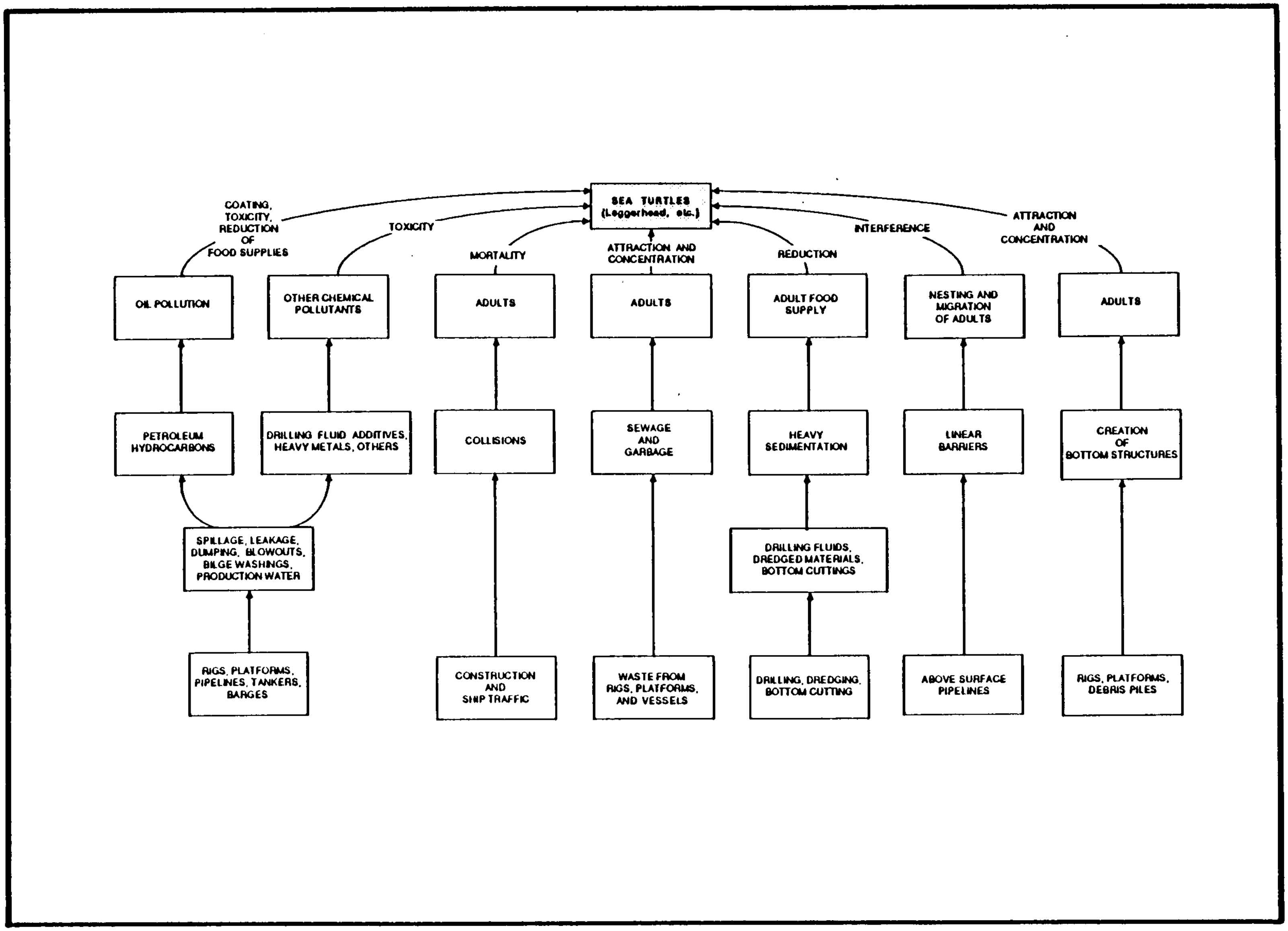


Figure 4.3-15 **Potential impacts of oil- and gas-related activities on sea turtles (loggerhead, *Caretta caretta*, etc.).**

and other debris discarded into the water are sometimes ingested and may lead to death. Other chemical pollutants might cause some deleterious effects, assuming the persistence of turtles to the immediate vicinity of structures (increased exposure) where contaminant levels would be highest. Of all these potential impacts, the most serious is the possibility of a major oil spill affecting the shallow water habitats.

Again, assuming the attraction of turtles to structures and given their need to breathe at the surface, they could be subject to increased mortality from collisions with service and recreational vessels.

4.4 SUBMODEL INTEGRATION

The purpose of this section is to bring together all information on potential impacts of oil- and gas-related activities into a useful summary so that a clear overview for management decisions may be obtained. Potential impacts have been examined at three levels: habitat impact, ecosystem impact, and VEC impact. These three levels will be examined in relation to each other in the following paragraphs.

As shown in Table 4.2-2, habitat impact can be deduced from knowledge of specific gas- and oil-related activities. A given type of habitat impact may result from several different types of activities. For example, increased suspended sediments may be the consequence of bottom cutting and drilling activities or release of drilling fluids and cuttings. The magnitude of a given habitat impact would depend on the magnitude of the activity; however, at this level of analysis, no value judgments were placed on the potential impacts.

Potential ecosystem impacts are presented in Table 4.2-3. The potential impacts were analyzed in terms of human concern. Two potential impact areas were considered to be of special concern. The greatest potential danger stems from the possibility of a major oil spill that could create great damage to the nearshore ecosystem. The second major concern is mechanical damage to high-relief bottom areas, particularly from pipeline installation but also from other activities. It is unknown how quickly damaged areas would recover.

Another area of concern deals with the possibility of increasing the level of suspended sediments in the middle shelf ecosystem (twilight zone). In this area, the species are near their minimum light limits, and even a small reduction in light penetration levels could eliminate photosynthetic species. Considering the volume of drilling fluids and cuttings likely to be discharged and the depths of the receiving waters, significant impact from this source seems unlikely.

Finally, the potential impacts of oil- and gas-related activities were analyzed in relation to each VEC (see Figures 4.3-1 through 4.3-15). Figure 4.4-1 is a matrix summarizing the potential impacts on all VECs. This matrix may be thought of as the integrated conceptual model (consisting of all 15 submodels). The summary impact matrix indicates the severity of an impact, the relative probability of occurrence, and the probable impact radius. The matrix is formed by listing the environmental factors associated with oil and gas structures and activities and their associated potential impacts down one side and the VECs across the top. Each cell is divided into two sectors by a diagonal (Figure 4.4-1). The upper left portion of the cell denotes the probability of occurrence of the impact, coded as high, medium, or low. A high impact is virtually certain (e.g., mechanical bottom damage associated with installing a platform). A low impact means that there is at least a probalistic chance that the impact could occur, but it is not very likely. A medium impact encompasses everything between these two extremes.

The probability of occurrence of the identified impacts associated with the factors of oil pollution, sewage and garbage disposal, noise, hard surfaces, and linear barriers is all considered low. MMS (1984) estimates that the total number of expected oil spills occurring within the Eastern Planning Area for MMS volume Scenario M (Most Likely Find

VALUED ECOSYSTEM COMPONENT

POTENTIAL IMPACT OF OIL- AND GAS-RELATED ACTIVITIES

FACTORS	POTENTIAL IMPACTS	SEAGRASSES	ANADYOMENE	ALGAL NODULES	SPONGES	HERMATYPIC CORALS	GORGONIANS	CRINOIDS	PINK SHRIMP	ROCK SHRIMP	SPINY LOBSTERS	STONE CRABS	WHITE GRUNTS	SNAPPERS AND GROUPERS	SPANISH AND KING MACKERELS	SEA TURTLES
OIL POLLUTION	COATING	3	3	3	3	3	3	3	3	3	3	3	3	3		3
	TOXICITY	3							3	3	3	3	3		3	3
	AVOIDANCE														3	
OTHER CHEMICAL POLLUTANTS	TOXICITY	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SEWAGE AND GARBAGE	NUTRIENTS	1	1													
	SMOTHERING	1		1	1	1	1	1								
	ATTRACTION								1	1	1	1	1	1		1
NOISE AND OTHER DISTURBANCE	BEHAVIORAL INTERFERENCE										1		1	1	1	1
SUSPENDED SEDIMENTS	INHIBITION OF PHOTOSYNTHESIS	1	1	1		1										
	EFFECTS ON FOOD AND FEEDING				1	1	1	1	1	1	1	1			1	
	DAMAGE AND MORTALITY				1	1	1	1	1	1	1	1	1	1		
HEAVY SEDIMENTATION	EFFECTS ON FOOD AND FEEDING								1	1	1	1	1	1	1	1
	HABITAT REDUCTION				1	1	1	1			1	1				
	SUFFOCATION	1	1	1	1	1	1	1	1							
HARD SURFACES	PROVISION OF ATTACHMENT SURFACES		1		1	1										
MECHANICAL BOTTOM DAMAGE	LOCAL POPULATION DESTRUCTION	1	1	1	1	1	1	1								
VERTICAL STRUCTURES	ATTRACTION										2	2	2	2	2	2
LINEAR BARRIERS	INTERFERENCE WITH MIGRATION								1		1	1				1

PROBABILITY OF IMPACT OCCURRENCE

HIGH

MEDIUM

LOW

IMPACT LEVEL

HIGH

MEDIUM

LOW

IMPACT RADIUS

(1) < 2,000 m

(2) 2,000 to 10,000 m

(3) > 10,000 m

Figure 4.4-1 **Matrix summary of potential impacts of oil- and gas-related activities on VECs.**

Scenario--0.06 billion bbl over an assumed production life of 18 years) and for volume Scenario T (Total Find Scenario--0.88 billion bbl over an assumed production life of 36 years) is as follows:

Spill Size (bbls)	Scenario M	Scenario T
1-49	23	334
50-999	.1	12
>1000	0.21	3.19
>10,000	0.10	1.46

These estimates are contingent on the assumption that oil is present. In addition, even if oil is present and a major oil spill occurs in the Eastern Planning Area, the probability (MMS, 1984) of the oil contacting the southwest Florida shelf, Dry Tortugas, Florida Keys, Straits of Florida, and the Everglades National Park within 10 days is less than 10%. The oil could possibly come ashore, however, along the east coast of southern Florida or the south side of the Keys.

The amount of treated sewage and garbage expected to be disposed, increased noise in the marine environment, additional hard substrate, and linear barriers resulting from bottom pipelines is expected to be too low to have appreciable impact on either the environment or biota, especially considering the likely volume of petroleum reserves under the southwest Florida shelf. The probability of occurrence of impacts from these sources is considered low (Figure 4.4-1).

There is reasonable probability that the volumes of chemical pollutants and suspended sediment levels associated with drilling and production may be of significant magnitude to result in measurable environmental impacts. Further, it is certain that the installation of structures and drilling activities will cause mechanical damage to the bottom. For a proper perspective, however, both these impacts (as well as the low-probability impacts) must be considered in terms of their severity and areal extent.

Severity of impacts has also been ranked as high, medium, and low. High severity means that mortality of biota is likely, or that sublethal effects might significantly impair growth, reproduction, or other key biological processes. Low means that the level of stress induced by the factor would be expected to be minimal. Medium covers the entire range between these extremes. The areal extents (impact radius) of the impacts, if they occurred, are defined as highly localized (<2,000 m), intermediate (2,000 to 10,000 m), or widespread (>10,000 m).

The potential impacts in the unlikely event of a massive oil spill would be widespread, and the severity of impacts would generally be high to medium in nature. This would be especially true if the spill occurred or reached shallow water regions. It is also possible that some pelagic forms such as Spanish and king mackerels might avoid offshore areas with large patches of floating oil.

Both drilling and production activities are sometimes associated with the release of toxic chemicals into the environment (e.g., biocides in produced waters). While such discharges are closely regulated to reduce environmental impacts, accidental releases sometimes occur. The impacts from these contaminants, because of rapid dilution by the receiving waters, can be expected to be of medium to low severity. However, such impacts are generally restricted to the immediate vicinity of the discharge point. Drilling fluid impacts have generally been measurable within only a few hundred meters of the rig or platform (National Research Council, 1983). Produced-water effects have generally been even more restricted in areal extent--on the order of a few meters from the point of discharge (Gallaway, 1981).

The effects from treated sewage and garbage discharges are likewise highly localized. In shallow waters, these discharges might be sufficient to stimulate increased plant production, but the volumes are so low that such impacts would be highly localized, on the order of meters. The disposal of all but organic garbage is presently prohibited, so smothering is unlikely. The attraction to organic garbage does occur, but on a localized basis.

Drilling and production rigs and platforms are noisy places. The project team has hundreds of hours of in situ observations beneath platforms and has seen little that could be interpreted as a behavioral response to noise. For the most part, petroleum structures attract large and diverse populations that appear acclimated to the noise associated with these structures.

As indicated in Figure 4.4-1, drilling fluid discharges in the water column may increase suspended sediment concentrations to the level that inhibitation of photosynthesis, reduction in food supplies or the ability to feed, or direct damage and mortality could be experienced by the biota if the discharges were prolonged. Massive discharges of drilling fluids, however, are typically episodic rather than prolonged. There is typically a prolonged, but small-scale, discharge of drilling fluids resulting from cutting washings, etc. The impacts of these discharges are exceedingly localized in scale.

Heavy sedimentation from the discharge of drilling fluids and cuttings is usually pronounced only in the immediate vicinity of the drilling rig and is of more concern in shallow than in deep water. Whereas the perceived impacts (Figure 4.4-1) can occur, they are typically restricted to a few hundred meters of the drilling structure (National Research Council, 1983).

The physical presence of oil-development-related structures (hard surfaces, vertical structures, and linear barriers in Figure 4.4-1) tends to either provide hard substrate for the settlement of biota and/or attract reef-associated organisms. Whereas the attraction response is well documented for most of the VECs (the attraction of sea turtles is probable, but not well documented), the suggested idea that pipelines and channels might represent linear barriers is entirely speculative. Whereas observation suggests that biota are attracted to pipelines, it is uncertain whether this attraction would ever interfere with a migration. Deep channels in shallow water areas are used as migration pathways and sometimes as a refuge in unseasonal weather. Animals that otherwise would have moved from shallow to deeper waters offshore, move into deep channels. But the presence of very thin sediment layers in the area would probably preclude deep channelization.

Mechanical bottom damage is an unavoidable impact of development but is restricted to the immediate area of the platform or other structure. Of most concern with regards to this impact are the live-bottom areas, particularly those having high relief. Live-bottom habitats cover only about 30% of the southwest Florida shelf and are distributed in a patchy fashion. Based upon the results of site-specific surveys, such areas can easily be avoided. Since many of the other impacts resulting from oil and gas development are also greatly restricted in a spatial sense, avoidance of high-relief areas for platform locations is an effective mitigative measure. If MMS continues to impose its Live-Bottom Stipulation, it is unlikely that exploration and development of the southwest Florida shelf will have significant adverse impacts on the associated ecosystem.

4.5 POSTPRODUCTION PHASE

Once offshore oil and gas fields become unproductive, present regulations require that the structures be removed to a depth at least 16 ft below the mud line, and the area swept clean by nets. Typically, at this stage, the platforms are well-developed artificial reefs having a full complement of attached organisms, reef fishes and invertebrates, snapper/groupers; in southwest Florida, resident sea turtles may also be characteristic.

Platform removal is usually accomplished using explosives implanted inside the platform pilings some 16 ft below the mud line. Most of the platform removals to date in the Gulf of Mexico have been accomplished using bulk charges, but there is a move toward the use of shape charges which release less total energy into the environment. The charges are sometimes detonated in a sequential fashion, also to reduce pressure peaks and impulses released into the environment. Other less destructive techniques for platform removal are being investigated.

The shock waves resulting from the explosives used in the platform removal process can result in mortality of resident marine organisms, especially in the immediate vicinity of the platform. Sea turtles may be rendered unconscious within a radius of up to 2000 m of the explosions (Edward Klima, National Marine Fisheries Service, paper presented at 1986 MMS Information Transfer Meeting in New Orleans, Louisiana).

Once the platform jacket is cut off below the mud line, it is removed and carried away on barges. This results in the complete mortality of the attached reef biota which, based upon results of studies in the northwestern Gulf of Mexico (Gallaway and Lewbel, 1982, and this study), might amount to one to several kilograms of organisms per square meter of subtidal platform surface.

Finally, the site is surveyed for debris using either nets or chains, side-scan sonar, or divers. The goal is to leave the bottom clean of any debris. Thus, the last vestige of the once-thriving reef is removed. In southwest Florida, the cleanup process would also have the potential to cause mechanical damage to the bottom. Care should be taken to avoid any high-relief habitat in the vicinity of the site being cleaned.

The impacts of platform removal will be to eliminate the reef communities associated with these structures, and endangered sea turtles may also be impacted, if they reside at the platforms. This possibility is suggested by observations of sea turtles at several of the _in situ_ instrument arrays used in this study. Whereas the impacts of platform removal are high, the communities associated with platforms would not have been present without the structure. If platforms are retained in place as artificial reefs, the removal impacts would not occur.

5.0 SUMMARY OF SIGNIFICANT FINDINGS

5.0 SUMMARY OF SIGNIFICANT FINDINGS

This summary presents the significant observations and findings of the Southwest Florida Shelf Ecosystems Study Data Synthesis Program. The salient points are presented to provide a brief overview of the results and should not be viewed as a comprehensive abstract. For a more thorough abstract, the reader is referred to Volume I: Executive Summary.

<u>Physiography, Geology, and Sedimentology</u>

- The broad (250 km), westward sloping (0.3 m/km nearshore to 17 m/km offshore), southwest Florida shelf is a limestone platform with relatively few areas of high relief.
- Sand-sized particles predominate on the shelf; however, there are isolated areas (e.g., the Tortugas shrimp grounds) where the sediments are predominantly silt-sized.
- Shoreward of the 10-m isobath, sediments are predominantly detrital quartz; seaward of the 10-m isobath, the carbonate content of the sediments is generally in excess of 95%.
- Sediment resuspension, which occurs episodically as a result of waves and currents, can attain deposition rates as high as 1,000 metric tons/km^2/day in shallow water (13 m); however, seaward of the 50-m isobath, resuspension rates are very low.
- Sediment hydrocarbon analyses indicate that generally the area is relatively free of petrogenic hydrocarbons; hydrocarbons measured were primarily terrigenous and marine biogenic hydrocarbons.
- Concentrations of total extractable hydrocarbons were generally in the range of 0.5 to 2 ug/l, with values decreasing with distance offshore.
- A few of the deeper stations exhibited low levels of petrogenic hydrocarbons which were attributed to pelagic tars transported by the Loop Current, of which 50% are estimated to enter the Gulf through the Yucatan Straits.

Meteorology and Physical and Chemical Oceanography

- Generally, southwest Florida has a subtropical climate punctuated with tropical storms and hurricanes and, occasionally, by the passage of successive cold fronts; these phenomena can dramatically affect the ecosystem through increased wave activity and precipitation, upwelling, and, with the passage of cold fronts, water temperatures can decrease by as much as 10°C in 24 hours.
- Currents are dominated by the tides, with both diurnal and semidiurnal components, however, the latter decreases offshore.
- Residual currents are weak and variable with very little coherence across the shelf, thereby making it difficult to identify seasonal circulation patterns.
- The general flow on the shelf is to the south, with clockwise circulation in Florida Bay and water exiting the shelf to the west north of, and through, the Florida Keys.
- The Loop Current and its boundary phenomena dominate the circulation on the shelf; intrusions can cause a 2° to 4°C increase in water temperature, a two-fold increase in current speed, current direction reversals, and induce upwelling, which introduces nutrients to the nutrient-poor shelf waters.
- The major water masses in the study area are (1) Florida Bay water, (2) shelf water, (3) Loop Current water, and (4) Subtropical Underwater.
- The inner shelf light compensation depth (1% of surface intensity) ranged from 5 to 45 m, middle shelf compensation depth was about 50 m, and values ranged between 60 and 85 m on the outer shelf.

Soft-Bottom Ecology

- Infaunal densities on the shelf ranged from 1,000 to 14,000 individuals per square meter and generally declined with increasing water depth.

- Species composition of infaunal communities was controlled primarily by water depth and secondarily by grain size distribution (particularly silt content).
- Polychaetes were the most abundant group collected and comprised 64% of the individuals counted, followed by crustaceans (17%) and molluscs (10%).
- A total of 1,121 species were identified; 452 crustaceans (40%), 413 polychaetes (37%) and 231 molluscs (21%).
- The predominant motile epifauna associated with the soft bottoms include asteroids, echinoids, holothurians, portunid and calappid crabs, large hermit crabs, stone crabs (seagrass areas) and conchs.
- Predatory, cryptic fishes (e.g., lizardfishes and flatfishes) are the most frequently collected demersal species in the soft-bottom areas; other fish which school near high-relief features (e.g., snappers and grunts) during the day, feed over sand areas at night.

<u>Live-Bottom Ecology</u>

- Live-bottom communities cover approximately 30% of the shelf and include a variety of substrate types, including: high- and low-relief limestone outcrops, coralline algal nodules and pavement, agariciid plate corals, and sand.
- Substrate type, exposure to sand scour and burial, and light (as a function of depth) are considered the most important factors influencing species abundance of habitat-forming sessile benthic organisms that determine community composition.
- Where thin or transitory sands cover hard substrates, gorgonians, algae, antipatharians, large sponges, scleractinian corals, and other large, sessile organisms are abundant; thick, more permanent sands favor soft-bottom communities.
- Motile species associated with the larger sessile species found in areas not subject to sand inundation include brachyuran and

anomuran crabs, bivalves, spiny and slipper lobsters, ophiuroids, echinacean echinoids, and gastropods.

- Many of the sessile live-bottom organisms exhibit pronounced depth zonation apparently in response to decreasing light levels with increasing depth; epibiotic and smaller motile species associated with these sessile forms show the same depth zonation.
- Photosynthetic scleractinians and gorgonians, hydroids, tunicates, sponges, bivalves, sabellid and serpulid polychaetes, and large algae are associated with inner shelf (<40 m) high-profile outcrops; also common near these outcrops are puffers, damselfishes, groupers, jacks, grunts, triggerfishes, wrasses, and butterflyfishes.
- Within the inner shelf, low-profile hard substrates, often covered with thin sand, are much more common; dense (150,000 individuals per hectare) beds of zooxanthellate gorgonians, sponges, foliose algae, and low-lying scleractinian corals, grunts, snappers, scrawled cowfishes, and porgies are common, and where the sand is thicker, seagrasses and algae predominate.
- Within the middle shelf (45 to 100 m), as the depth increases, photosynthetic corals and gorgonians are replaced with non-photosynthetic varieties; also found are large sponges (e.g., loggerheads, shoreward of the 70-m isobath), agariciid plate corals and Anadyomene menziesii (abundant on southern middle shelf), sea basses, squirrelfishes, scorpionfishes, damselfishes and bigeyes.
- The aphotic outer shelf (100 to 200 m), covered with thick sand, includes many small hexactinellid (glass) sponges, antipatharians, azooxanthellate scleractinians and gorgonians, and crinoids (most abundant large benthic organism), searobins, small sea basses, bigeyes, and bothid flatfishes.

Potential Impact Projections and Considerations

- To examine the effects of oil development, a list of 15 valued ecosystem components (VECs) were selected to represent all trophic levels and areas of special concern. Conceptual modeling techniques were used to qualitatively project the potential impacts of the various aspects of oil development on these ecosystem components.
- The impacts examined were typical for offshore development, with the primary considerations being oil spills, drilling fluid discharges, drill cuttings, mechanical disturbance from platform and pipeline installation, increased vessel traffic, and impacts from platform removal.
- The southwest Florida shelf ecosystems differ from other Gulf of Mexico ecosystems in that live-bottom areas are not associated with significant topographic highs and the distribution of the live bottoms are more patchy; therefore, mitigative strategies such as shunting and exclusion zones may not be effective. Nevertheless, remote sensing surveys of the individual sites and optimal location of oil and gas structures will mitigate many adverse effects.
- Particularly sensitive areas include: Florida Bay, mangroves, Florida reef tract, and live-bottoms (e.g., *Anadyomene*, *Agaricia*, or grass beds).
- Offshore oil and gas development activities, should they occur, will cause measurable impacts, but the impact radius will generally be substantially less than 2,000 m.
- The impacts resulting from a major oil spill (>1,000 bbl) could be severe, particularly if the spill occurred near shore; however:
  - -Less than one major spill is expected for MMS Scenario M (0.06 billion bbl over assumed 18-year production life);
  - -There is less than a 10% chance of a spill impacting southwest Florida within 10 days, if it occurs;

- Spills that occur on the middle shelf are unlikely to impact the western shore of Florida (this study does not address the potential for oil impacting the eastern shore of south Florida or the southern side of the Florida Keys); and
- The prevailing winds and currents would have a tendency to transport the oil away from southwest Florida.

o Currently enforced MMS regulations and mitigative measures are adequate to minimize the impacts on the ecology of the southwest Florida shelf. MMS imposed biological stipulations (requirement of surveys prior to platform installation, etc.) identified in the EISs should mitigate many of the potential impacts of offshore development.

6.0 LITERATURE CITED

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