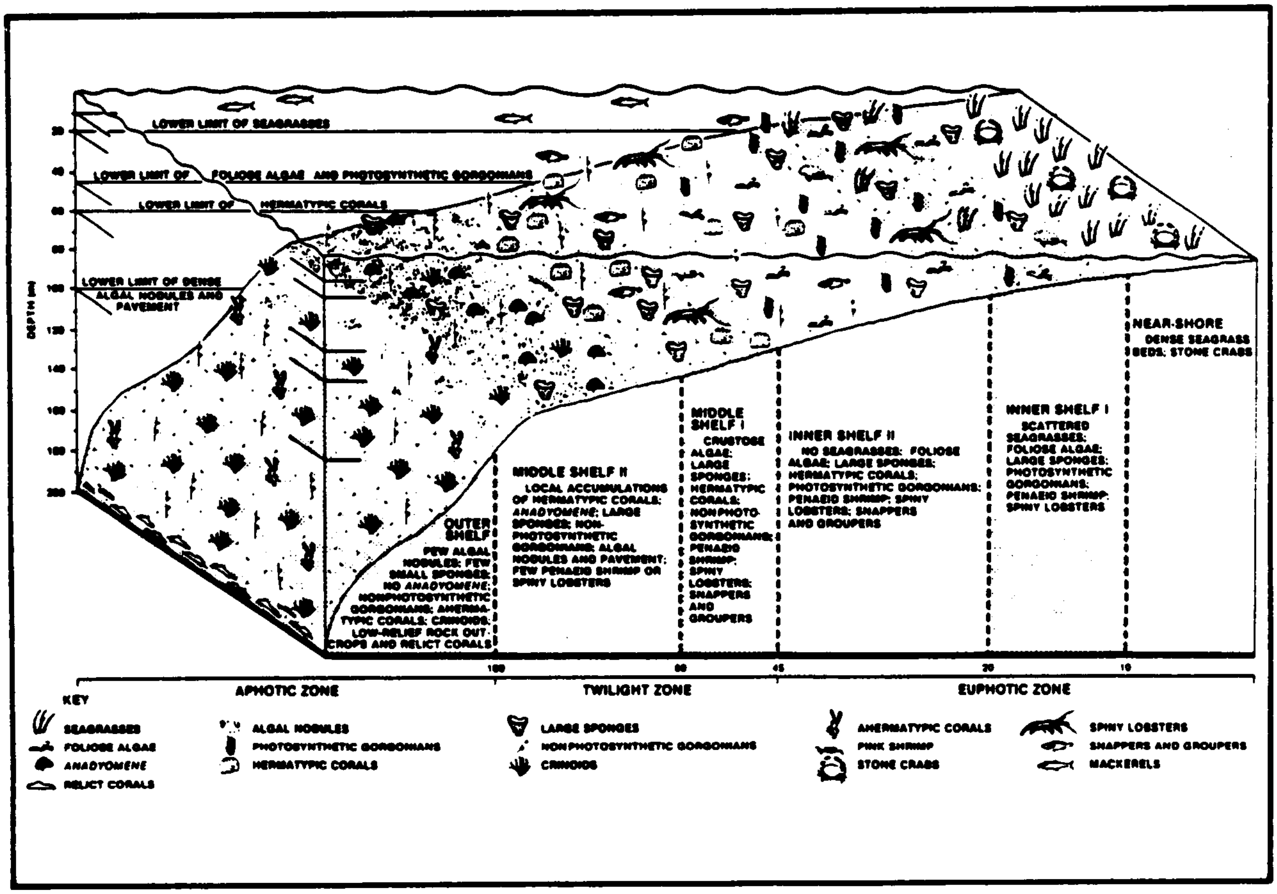
OCS Study
MMS 87-0022

Southwest Florida Shelf Ecosystems Study

Volume I: Executive Summary



U.S. Department of the Interior
Minerals Management Service
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Volume I: Executive Summary

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1.0 INTRODUCTION

The Minerals Management Service (MMS) has four priority goals for outer continental shelf (OCS) leasing: (1) orderly 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 program are 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 environmental study. 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 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 the 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 objective 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 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 (Figure 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.

The 6-year Southwest Florida Shelf Ecosystems Program began in 1980 as an interdisciplinary study designed to meet the objectives previously described. During Year 1 of the program, geophysical (bathymetric, seismic, and side-scan sonar) and underwater television surveys were conducted along Transects A through E (Figure 1-1) from the 40- to 200-m isobath and the 20- to 100-m isobath, respectively. Water column data [salinity, temperature, dissolved oxygen, transmissivity, light penetration, nutrients, chlorophyll, and Gelbstoff (yellow substance)] were collected at 30 cross-shelf stations (Figure 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 and sediment grain size, carbonate content, hydrocarbons, and trace metals data were collected at the 15 soft-bottom stations.

During Year 2, additional geophysical information was collected along a new north-south transect (Transect F, Figure 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

STATION	YEAR 1	2	3	4	5	STATION	YEAR 1	2	3	4	5
1	●	●				29	●	●		●	●
2	●					30	●				
3	●	●				31		●			
4	●	●				32		●			
5	●	●				33		●			
6	●	●				34		●			
7	●	●			●	35		●			
8	●					36		●		●	●
9	●	●				37		●			
10	●					38		●			
11	●	●				39		●			
12	●	●				40			●		
13	●	●				41			●		
14	●	●				42			●		
15	●	●				43			●	●	
16	●	●				44			●	●	●
17	●					45			●	●	
18	●					46			●	●	
19	●			●		47			●	●	
20	●	●				48			●	●	
21	●	●		●	●	49			●	●	
22	●	●				50			●	●	
23	●	●		●	●	51			●	●	
24	●	●				52			●	●	●
25	●	●				53			●		
26	●					54			●		
27	●					55					●
28	●	●									

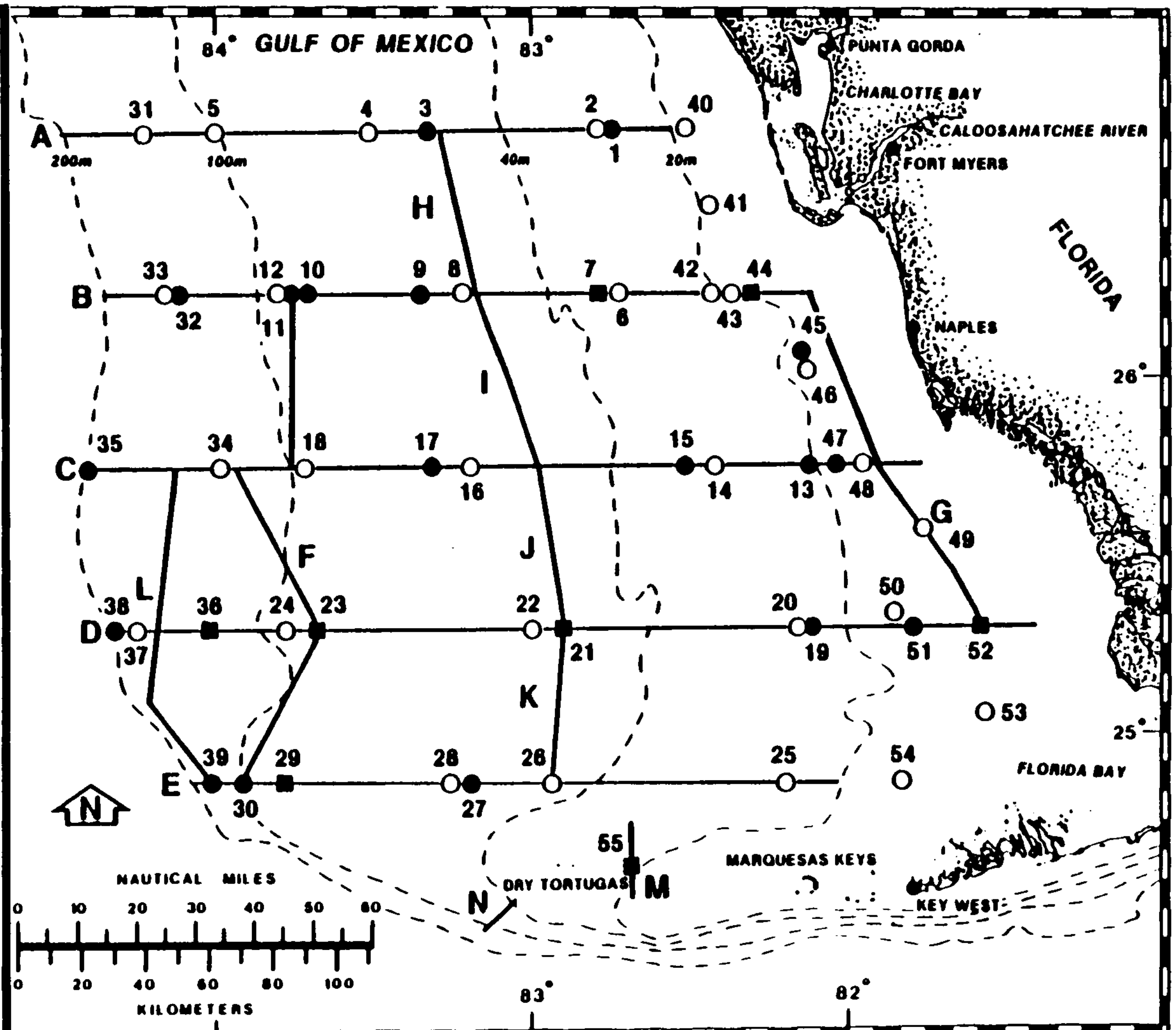

Figure 1-1 Southwest Florida Shelf Ecosystems Program study area with Years 1 through 5 geophysical and towed underwater television transects (A-N) and discrete stations (1-55) indicated. Inset indicates years during which stations were sampled: O = soft-bottom, ● = live-bottom, and ■ = intensively sampled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

Year 1 were resampled twice. 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) were established on Transects A through E, in water depths ranging from 100 to 200 m.

Under a Year 2 contract modification (which was essentially a separate, third year of studies), hydrographic cruises were conducted to yield higher resolution analysis of the temporal and spatial distribution of temperature, salinity, transmissivity, phytoplankton, chlorophyll, and nutrients. Primary productivity was measured during both cruises and correlated with nutrient and other physicochemical 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.

The expanded Year 3 program 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). Biological and hydrographic sampling was conducted at 10 new soft-bottom stations in the 10- to 20-m depth range 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.

In Year 4 of the program, five soft-bottom and five live-bottom stations (Figure 1-1) were sampled to complete the seasonal baseline descriptive study of the inshore area initiated during Year 3. 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. Five additional live-bottom stations (Figure 1-1) were selected for intensive study of physical and biological processes. Sampling at these stations, each representing a separate epifaunal community type, 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 of the 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, intensive sampling of the five Year 4 live-bottom stations continued, and three other stations were added for intensive study (Figure 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. 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 (Figure 1-1). These transects were added to supplement the habitat-mapping studies completed in previous years.

2.0 CHARACTERIZATION OF STUDY AREA

2.1 PHYSIOGRAPHY, GEOLOGY, AND SEDIMENTOLOGY

The southwest Florida continental shelf, as delimited by the 200-m isobath, is a broad (approximately 250 km), flat, westward sloping, limestone platform with relatively few areas of high relief (see Figure 2-1). Holmes (1981) suggested that, geomorphologically and geologically, the southwest Florida shelf can be divided into three units: southern banks, inner shelf, and outer shelf. 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). Woodward Clyde Consultants and Continental Shelf Associates (1983) divided the continental shelf into three depth zones: the inner shelf (shore to the 40-m isobath), the middle shelf (40-m isobath to the 100-m isobath), and the outer shelf (100-m isobath to the 200-m isobath). These three zones and the southern banks (including Florida Bay) are discussed in this section.

Florida Bay, formed by the juncture of the Florida Keys and the west coast of Florida, is a broad, shallow (depth less than 3 m), mud-bottom

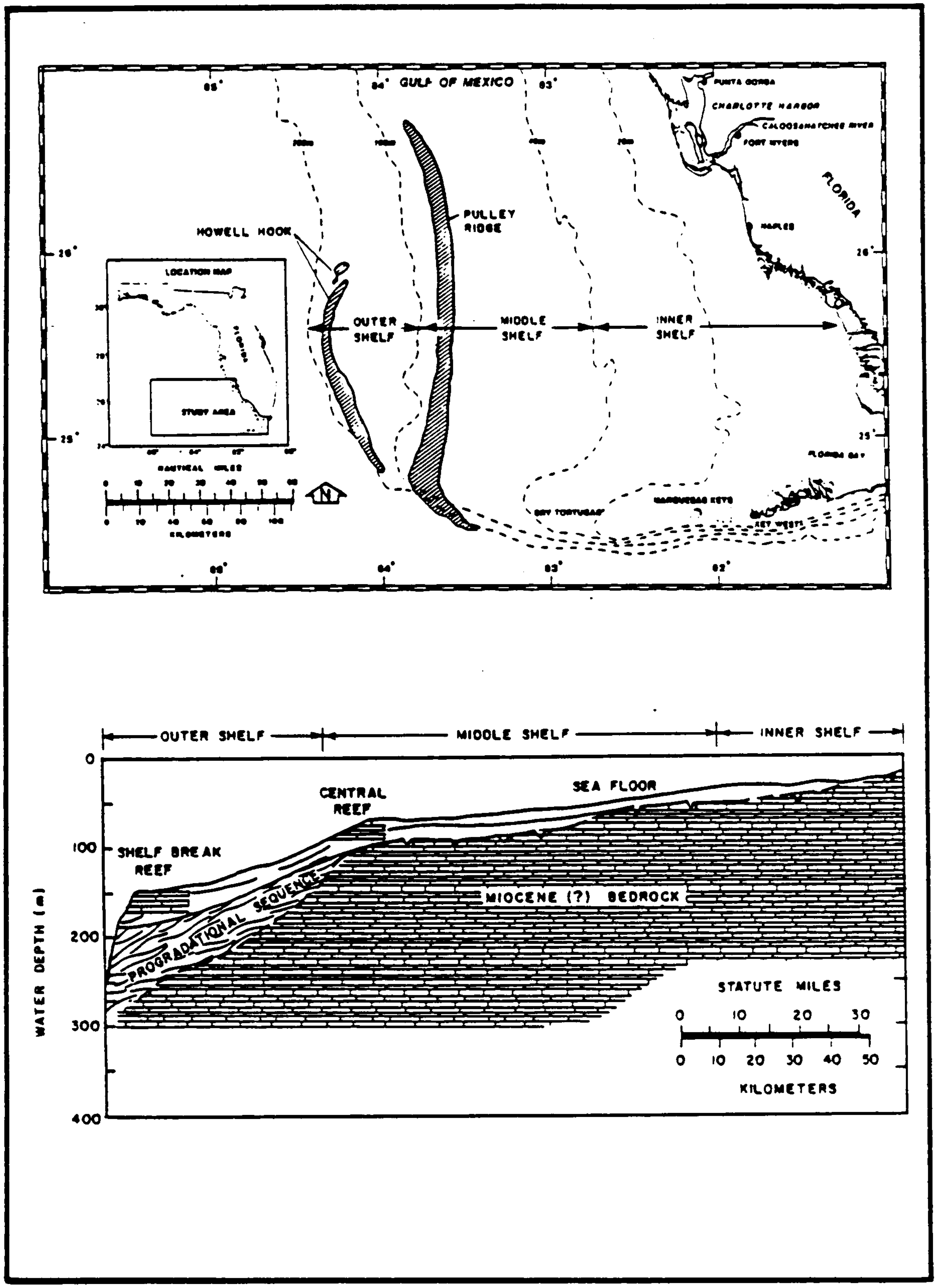

Figure 2-1 Locations of major reef features (top) and geologic cross section (bottom) on the southwest Florida shelf.

bay that is subdivided by mud banks, separated from the open sea by the Florida Keys (Uchupi, 1975), and encroached upon by mangroves (Boesch and Rabalais, 1985). 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 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.

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. 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. Holmes (1981) further suggests that some of these depressions may be undergoing modification by water flow from active subsea springs. 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, 1983). South of 25°N, the surficial sediment appears to be finer grained (i.e., silt), overlying Holocene and Pleistocene sediment, with no indications of bedrock outcrops.

The middle shelf is approximately 100 km wide. Between the 40- and 75-m isobaths, the relatively smooth seafloor of the middle shelf slopes to the west at 0.3 to 0.7 m/km; the slope increases slightly (1.4 to 1.7 m/km) with local zones of rough seafloor, depressions, and locally steeper slopes between the 70- and 100-m isobaths. This latter region corresponds to the partially buried, 10-km-wide Pulley Ridge reef complex (Figure 2-1), described by Holmes (1981) as a series of carbonate reef-like structures that drop the shelf step-wise from 70 to 90 m.

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 3.5 m/km, with locally steep slopes of up to 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, similar to those reported by Woodward Clyde Consultants and Continental Shelf Associates (1983) for the middle shelf, also are found on the outer shelf, primarily in water depths of 100 to 150 m. Holmes (1981) relates similar structures to the paleohydrology of southern Florida.

The seafloor on the outer shelf is generally covered with a sand veneer. Nevertheless, several outcrop areas are present. The shelf edge is marked by a double reef complex (Holmes, 1981), with the shallowest reef being described as a bioherm that appears to be partially exposed through thin sand cover. This bioherm contains many exposed pinnacles of dead coral that extend 1 to 3 m above the bottom (Woodward Clyde Consultants and Continental Shelf Associates, 1983).

The diagrammatic cross section of the southwest Florida shelf shown in Figure 2-1 was adapted from Holmes (1981) to show the relationship of the two reef complexes discussed previously (the middle shelf reef and the shelf-edge double reef complex) with other stratigraphic features in the area. Holmes suggests that the central shelf reef produced and impounded the sediment that was deposited landward on the inner shelf.

An examination of grain size distribution data for unconsolidated sediments of the southwest Florida shelf (Figure 2-2) suggests 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 coastal rivers, beaches, and older

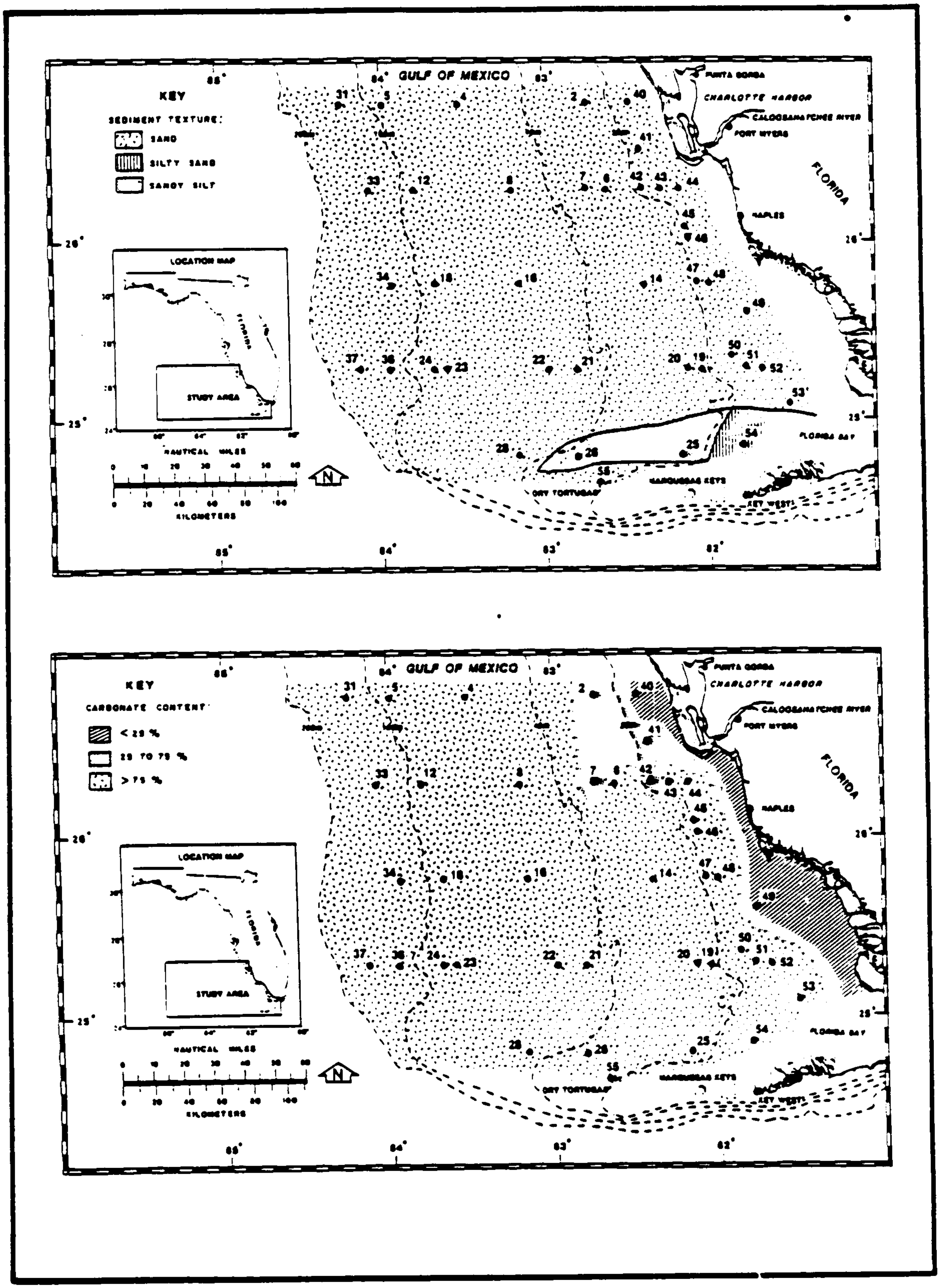

Figure 2-2 **Southwest Florida shelf sediment texture (top) and calcium carbonate content (bottom).**

coastal plain sediments, along with local accumulations of molluscan shell fragments (Figure 2-2). Seaward from this zone is a carbonate sand facies in which shell fragments, coralline algae, foraminifera, and oolites may be abundant at particular locations (Doyle and Sparks, 1980). Silt-sized sediments north of the Dry Tortugas are essentially carbonate muds probably consisting of comminuted algal and mollusc remains (Figure 2-2).

Sediment trace metal concentrations (chromium, iron, zinc, cadmium, copper, nickel, lead, barium, and vanadium) were measured at 15 stations during Year 1. The results indicated very low and spatially uniform trace metal levels. Some statistically significant correlations were noted by Woodward Clyde Consultants and Continental Shelf Associates (1983). 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 with concentrations significantly correlated with sediment grain size. Both copper and zinc tended to be present in higher concentrations in sediments of finer grain size.

Sediment may be transported along the seafloor as bed load, suspended load, or a combination of the two. Most of the bed load transport estimates (according to the methods of Sternberg, 1972) 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 of sediment transported due to currents, but the influence of waves cannot be quantified. Sediment transport as suspended load (determined from sediment traps and time-lapse camera records) was determined to be important and occurred as episodic events. Sedimentation rates following sediment resuspension ranged from 1 to 848 metric tons/km^2/day. The highest sedimentation rates were observed at the shallowest locations, and the lowest rates were noted at the deepest stations. 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 reflects the declining influence of surface waves. Nearshore, 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, but breaking internal waves near the shelf break could exert some influence on sediment movement (Danek and Lewbel, 1986).

The physiography, geology, and sedimentology of the southwest Florida shelf result in some distinct substratum types. Distribution of these substratum types along the survey transects are presented in Figure 2-3. Brief descriptions of the substratum types follow:

> Rock Outcrops/Hard Bottoms--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. Biological investigations conducted during this study have shown that sessile epifauna are attached almost exclusively where the veneer is thinner than 10 cm. The presence of sessile epifauna in these areas indicates that the underlying hard bottom must periodically be exposed as a result of sediment movement, since most of these organisms must originally attach to hard substratum.

> Coralline Algal Nodules--This designation refers to areas where the substratum consists of sand bottom covered by various thicknesses of coralline algal growth. Usually the growths occurred in the form of nodules a few centimeters in diameter.

> 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*.

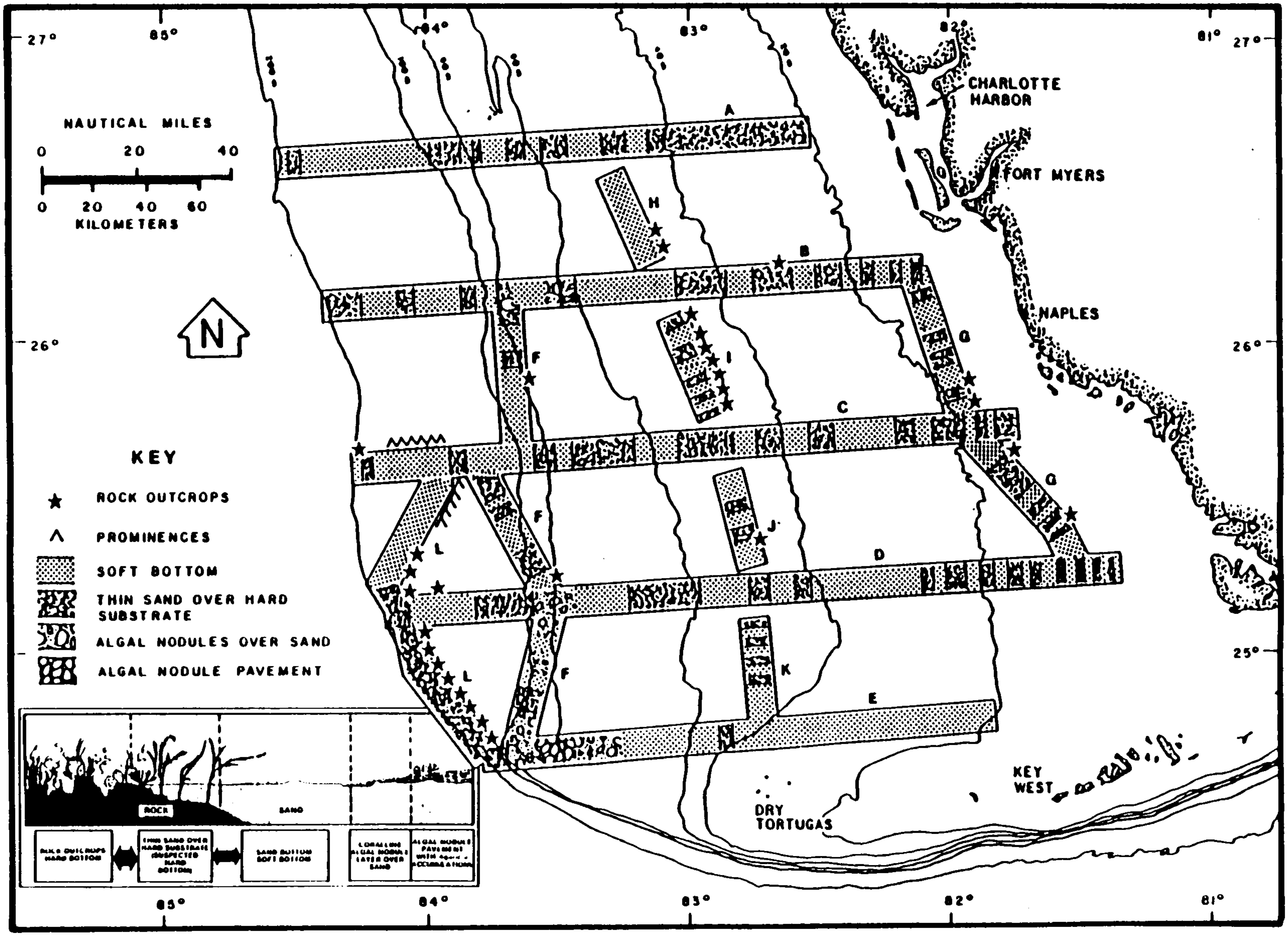

Figure 2-3 Substratum types (see inset) and distribution along study transects.

Sand Bottom/Soft Bottom--Sand bottom was the most widely distributed substratum type on the shelf. This includes thick sand, silt, or mud bottoms. Several morphological forms were observed, including areas of sand waves and ripples, bioturbated areas, and sandy bottoms covered with algae.

2.2 METEOROLOGY AND PHYSICAL OCEANOGRAPHY

Mean monthly air temperatures range from 18°C (winter) to 29°C (summer) with the offshore and southern portions of the study area generally warmer [National Climatic Data Center (NCDC), 1983, 1986a, 1986b]. The air temperatures over the open gulf (compared with overland air temperatures) exhibit narrower limits of variations on both a daily and seasonal basis (MMS, 1983). The average annual precipitation values range from 97 cm at Key West to 136 cm at Fort Myers. According to NCDC (1986a, b), the greatest precipitation occurs during different seasons at the two locations: at Fort Myers 49% of the total annual precipitation occurs during the summer, and at Key West 43% of the total annual precipitation occurs during the fall. 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).

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 coastal stations (Key West and Fort Myers, 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). Offshore, the average annual windspeed of 5.6 m/s is higher than the onshore stations (NCDC, 1983); the mean monthly windspeed ranged from 3.9 to 7.1 m/s, and the highest windspeed recorded was 34 m/s. The winds offshore are from

from the north to northeast in late fall and early winter and switch to the east for the remainder of the year (NCDC, 1983).

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 mph) is 2 to 3%. These storms can generate winds in excess of 110 m/s, storm surges as high as 4.5 m, surface waves in excess of 10 m, and rains that exceed 50 cm in 24 h. In addition, Leipper (1967) reported that hurricanes can induce upwelling that can cool the surface waters of the Gulf of Mexico by 5°C, and the effects can last for weeks.

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 and northwest, especially in the fall and winter, tend to have greater heights than those from other directions. The waves measured offshore [National Data Buoy Center (NDBC) Buoy No. 42003) were generally larger than those measured nearshore because of the virtually unlimited fetch. The mean monthly significant wave height ranged from 0.7 to 1.5 m, with the highest values occurring between November and March. The largest significant wave height recorded by the buoy between 1976 and 1985 was 10.7 m (Danek and Lewbel, 1986) during Tropical Storm Kate (November 1985). Nearshore (Stations 52 and 55), waves were smaller, with the highest recorded wave height never exceeding 5 m. 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.

Estimates of wave orbital velocities in excess of 10 cm/s indicated that virtually no surface wave energy penetrated to a depth of 125 m, and at depths greater than 50 m, wave orbital velocity exceeded 10 cm/s less than 0.5% of the time. At bottom depths less than 30 m, wave orbital velocities exceeded 10 cm/s more than 5% of the time (10% of the time at a bottom depth of 13 m). Consequently, wave energy is less important at deeper stations and probably contributes only to sediment resuspension during extreme weather conditions.

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]. Offshore, the tides are mixed; closer to shore the tides are predominantly semidiurnal. The tidal range on the southwest Florida shelf is approximately 1.5 m during spring tides and 0.7 m during neap tides, and tidal ranges are smaller offshore.

Plots of near-bottom current speed and direction at a relatively shallow shelf station (Station 52--13 m) and deeper shelf stations (Station 7--32 m) illustrate the gradual change in tides from semidiurnal to diurnal and from nearly rectilinear motion in the east-west direction to more elliptical motion with increasing depth (see Figure 2-4). The fortnightly spring and neap tides are also apparent in these plots. Near-bottom average current speeds across the shelf ranged between 5 and 11 cm/s. Generally, the average current speed was highest nearshore, decreasing 2 to 3 cm/s at mid-shelf and increasing 1 to 2 cm/s (from the mid-shelf value) on the outer shelf region. The percentage of the time near-bottom current speeds exceeded 20 cm/s followed this same basic trend, with values as high as 14% nearshore, the lowest values (less than 2%) occurring mid-shelf, 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.

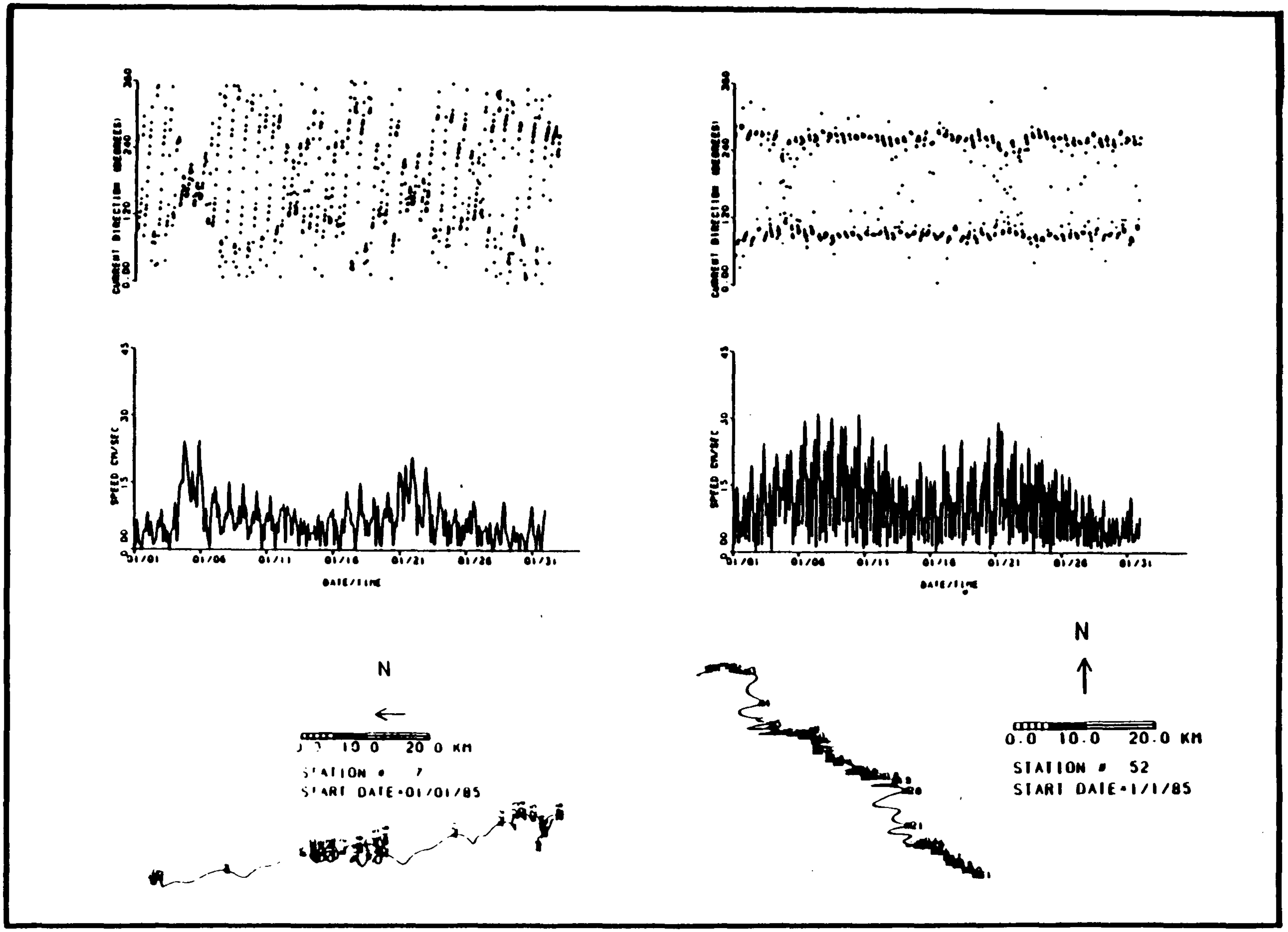

Figure 2-4 Example of the change in current velocity characteristics from elliptical to rectilinear motion and diurnal to semidiurnal periodicity as depth decreases from 32m (Station 7) to 13m (Station 52).

Power spectra analysis was conducted to examine energy frequency concentration and identify how the water current energy changes across the southwest Florida shelf. These analyses 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 deeper water, current motion was more elliptical, whereas in shallow water, the motion was more rectilinear in the east-west direction;
7. 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;
8. Power spectra for the summer and winter currents were generally similar;
9. 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
10. Intrusions related to the Loop Current frequently contributed to the low-frequency energy in the north-south component, particularly at the offshore stations.

The 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 <u>annual</u>, residual, near-bottom, and near-surface currents on the southwest Florida shelf (Figure 2-5). This pattern represents the residual currents averaged over an entire year and, therefore, should not be considered as an instantaneous representation of currents at any single time. Because of intrusions of the Loop Current and Loop Current boundary perturbations, the currents at

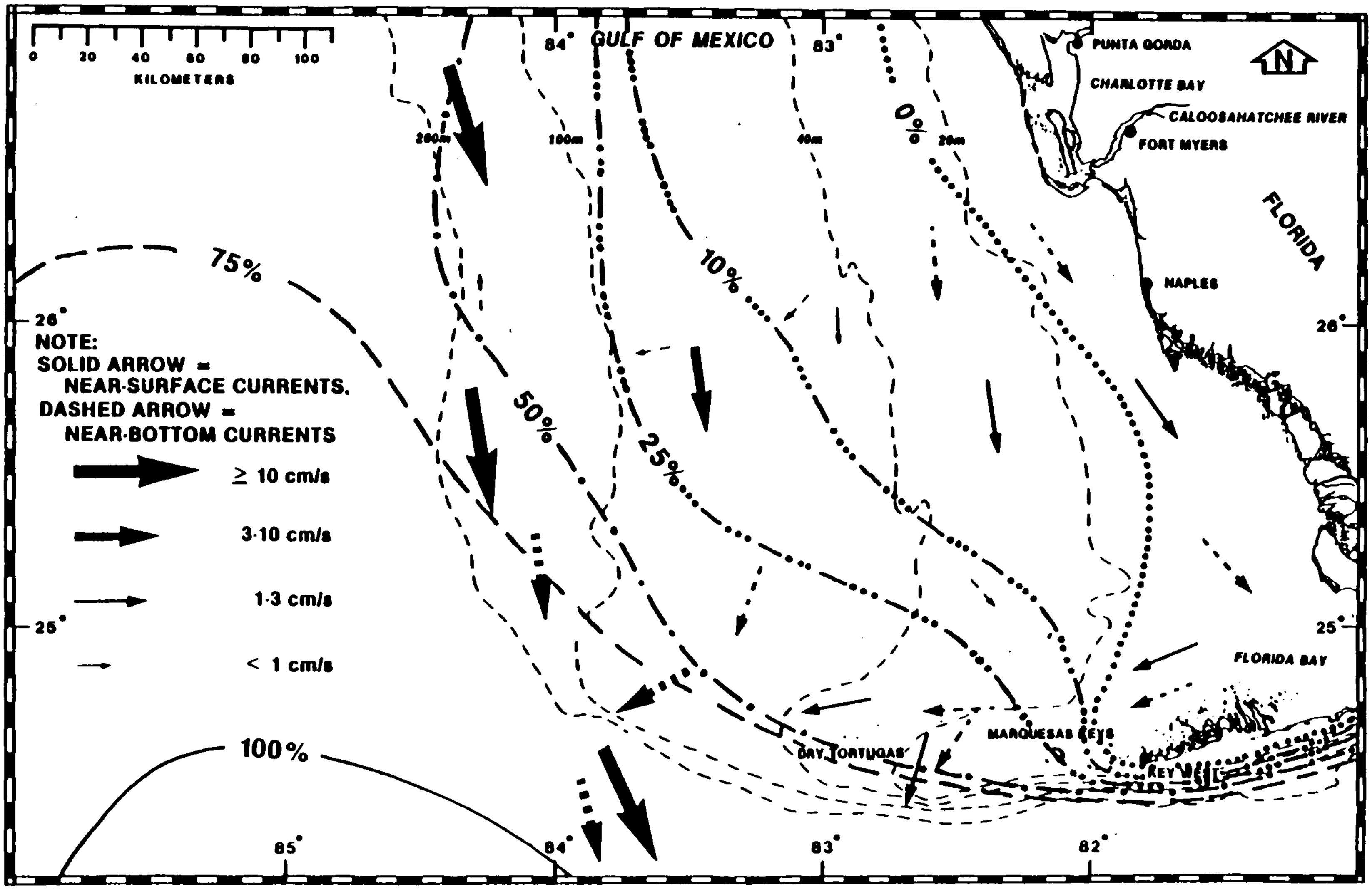

Figure 2-5 Estimated annual residual current pattern based upon Eulerian current data collected by ESE and LGL (1986) and SAIC (1986) as well as historical Lagrangian current data. Also shown is the probability of Loop Current maximum boundary phenomena incursion (April, according to Vukovich *et al.*, 1979).

any given time can be considerably more complicated. In addition, the aperiodic intrusions of the Loop Current or its boundary phenomena preclude representations of the seasonal residual currents.

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. According to Cooper (1982), the Loop Current dominates the circulation of the eastern Gulf of Mexico and clearly affects the southwest Florida shelf (Figure 2-6). The Loop Current's boundaries fluctuate considerably both spatially and temporally. Various investigators have suggested that maximum intrusion occurs during different seasons of the year; nevertheless, all investigators concede that the periodicity of the intrusions could vary between 8 and 17 months.

Loop Current boundary perturbations and subsequent intrusion on to the southwest Florida shelf are important short-term phenomena. The intrusion of a warm filament (see Figure 2-6) 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 in current direction (Figure 2-7). In addition, upwelling (see Figure 2-6) is frequently associated with these perturbations; this upwelling is an important mechanism for importing nutrients onto the southwest Florida shelf. These events typically last for approximately 5 to 10 days and can extend across nearly the entire shelf, although they rarely intrude beyond the 20-m isobath.

Another Loop Current phenomenon is the shedding of large anticyclonic eddies or rings of warm water (see Figure 2-6). These rings are thought to contribute significantly to the transfer of temperature and dissolved constituents (and presumably organisms entrained in the rings) in the Gulf of Mexico (Science Applications International Corporation, 1986). Although these rings are an important phenomenon in the Gulf of Mexico, they do not impact the southwest Florida shelf.

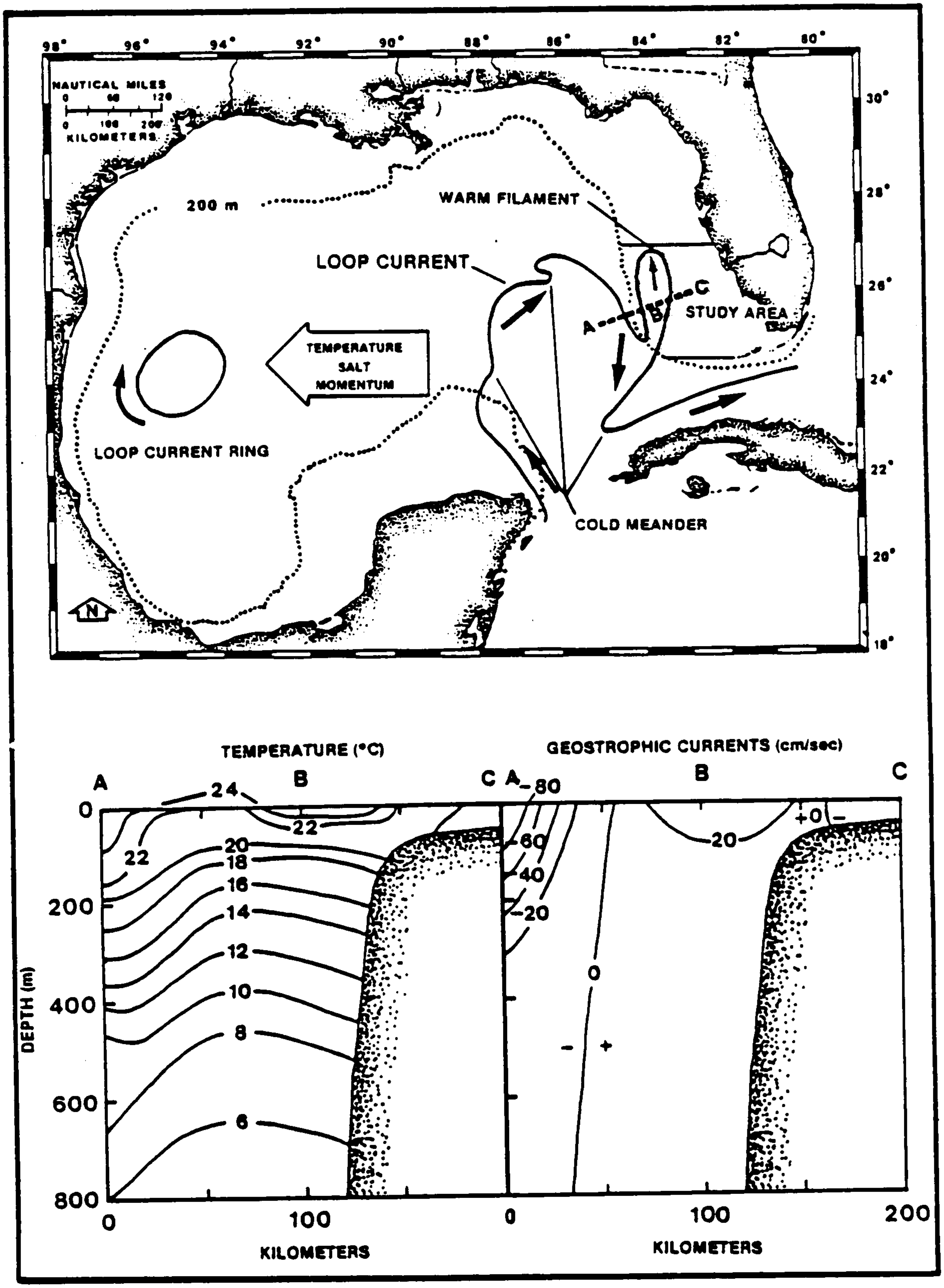

Figure 2-6 Schematic representation of Loop Current features and dynamic processes (top) and a cross section through a warm filament (bottom) showing distribution of temperature (note upwelling between Stations A and B) and current velocity (– denotes southward and + denotes northward).

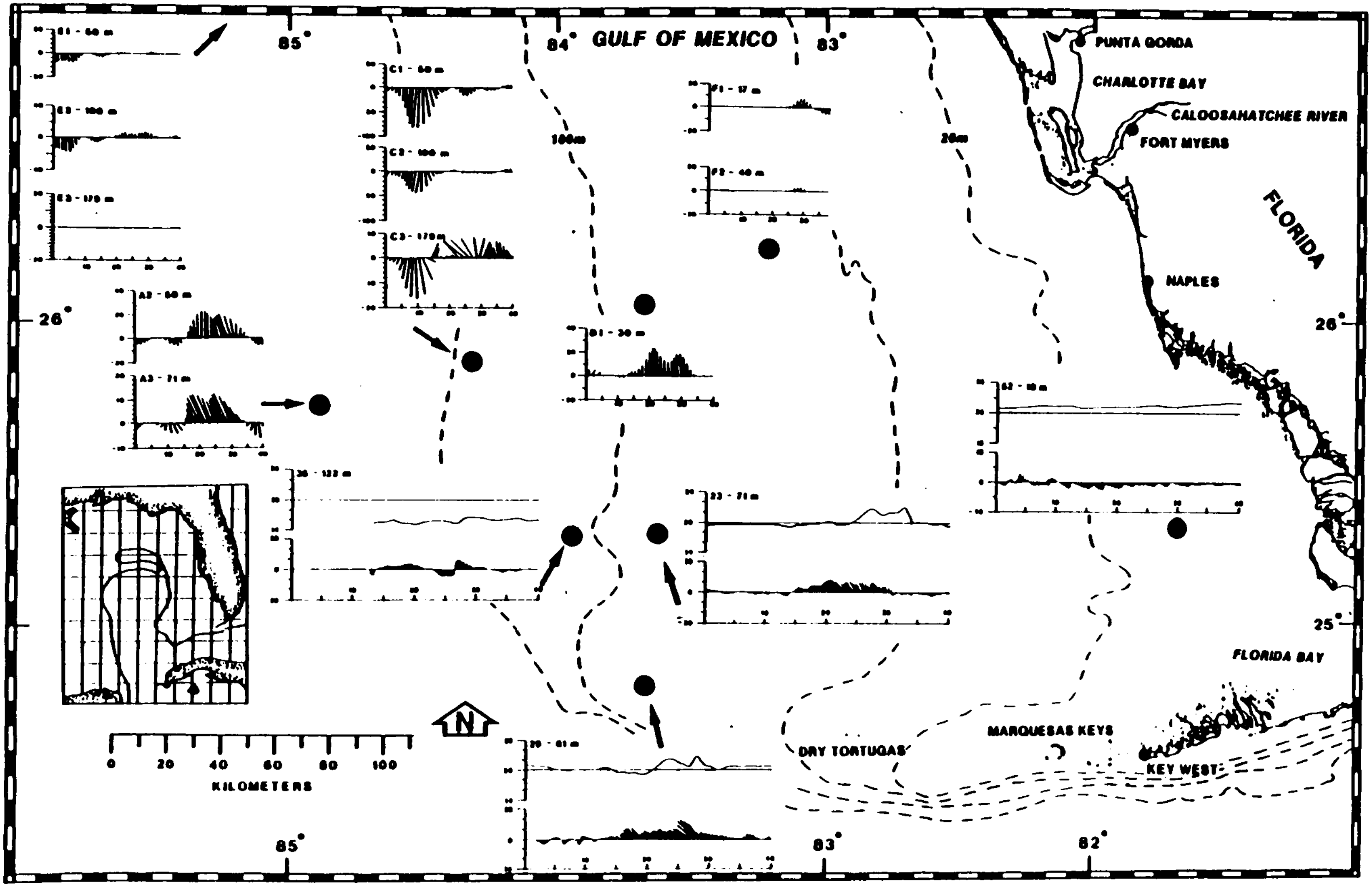

Figure 2-7 The effects of Loop Current intrusions and boundary perturbations on current velocity (cm/s) and temperature (°C). This particular intrusion, presented as mean monthly plot of the Loop Current boundary (inset), occurred in May 1984.

The passage of a hurricane or tropical storm across the southwest Florida shelf is another important short-term phenomenon. As an example, the passage of Tropical Storm Bob (Figure 2-8) in July 1985 increased mean daily current speeds at some stations from 5 to 35 cm/s. The farther a station was from the storm, the less pronounced were the effects of the storm on current speed. The effects were also greater at shallower, rather than deeper, stations. A 3 to 4°C change (both increases and decreases) in near-bottom temperature accompanied the passage of the storm. Temperature changes of the same magnitude have been reported by Leipper (1967) during the passage of Hurricane Hilda (1964).

2.3 HYDROGRAPHY, CHEMICAL OCEANOGRAPHY, AND HYDROCARBONS

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 water of the Florida Keys, temperature changes as great as 8°C can occur within 24 h. Water 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. Surface water temperatures ranged from 20°C during the winter to 30°C during the summer. The variability observed in bottom temperatures (13 to 30°C) was more a function of depth of measurement than time of the year. Thermal stratification (approximately 0.1°C/m) was evident during the summer. Generally, the surface and bottom temperatures were 2 to 4°C warmer from north to south. The surface water

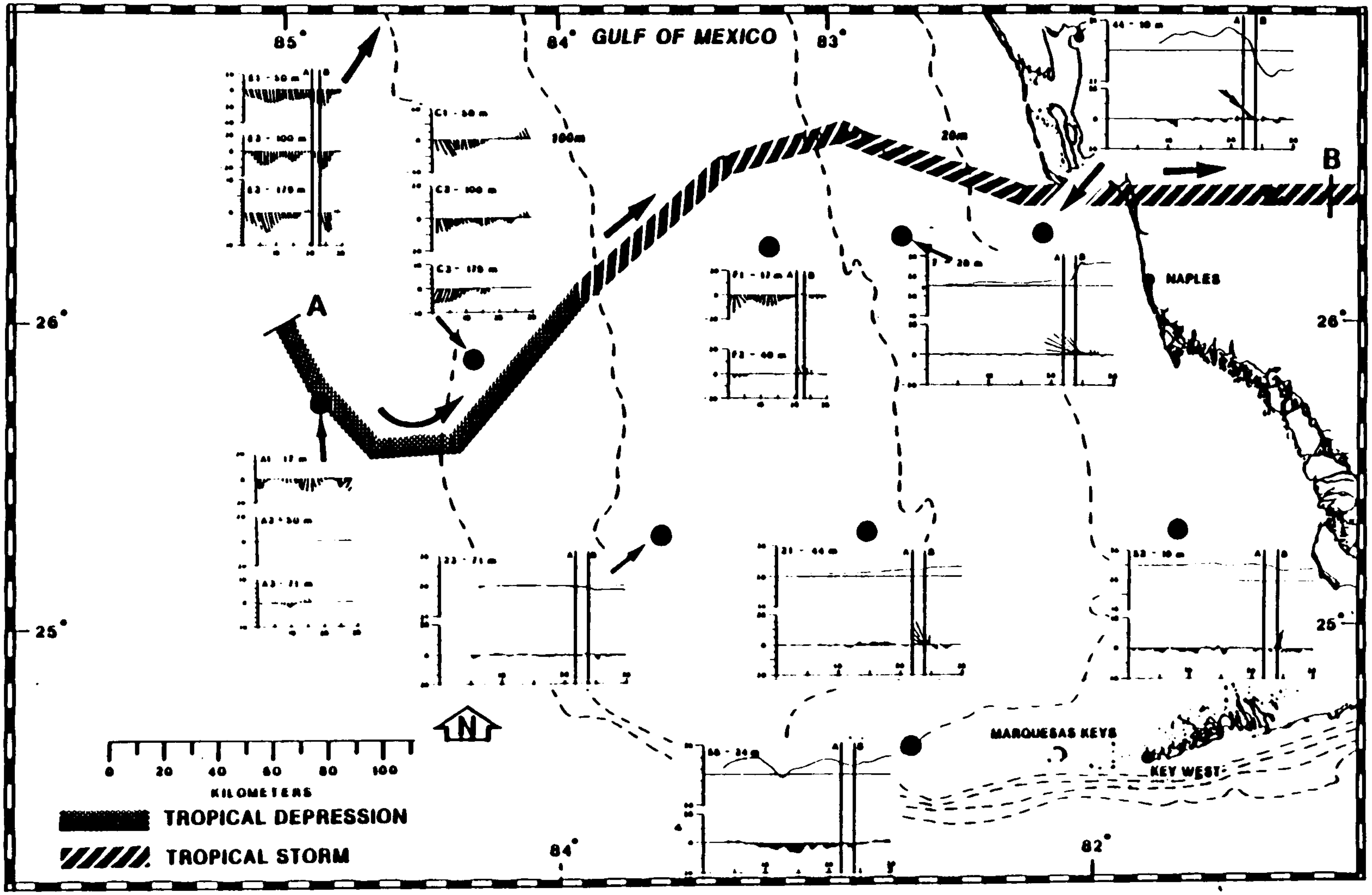

Figure 2-8 The effect of the passage of Tropical Storm Bob on current velocity and temperature during July 1985.

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.

The overall shelf salinity values for all seasons were within ±1 °/oo; however, within Florida Bay, Schomer and Drew (1982) reported salinity values as low as 13 °/oo and as high as 66 °/oo during periods of high precipitation and high evaporation, respectively. Generally, the salinity distribution did not reflect the vertical stratification that was apparent in the summer temperature distribution. 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 °/oo) except during the fall, when it decreased by approximately 0.2 °/oo.

Beyond the inner shelf zone (i.e., beyond the 45-m isobath), water on the southwest Florida shelf is comparable to values observed in the open ocean (1-m beam transmissivity values in excess of 90%). According to the data summarized by Woodward Clyde Consultants (1983), 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% (presumably even lower values would be encountered within Florida Bay)]. According to these investigators, there was progressively more structure or variability in water clarity southward across the study area.

The compensation depth or lower limit of the euphotic zone (defined as that depth at which only 1% of the surface incident radiation is received) is a function of water clarity (transmissivity) and color. According to Pickard and Emery (1982), the compensation depth can range from between 3 and 4 m for turbid coastal waters to approximately 100 m for the clearest ocean water. Across the southwest Florida shelf, the estimated compensation depth ranged between 5 and 100 m. Stations located in 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 when photosynthesis would be retarded because of reduced light levels. At the mid-shelf locations (water depths between 40 and 70 m), the average compensation depth (50 m) probably was rarely greater than the bottom depth. Nevertheless, algae such as Anadyomene not only exist, but apparently thrive, at depths of 65 m, probably relying on the deeper penetrating blue-green light almost exclusively. The outer shelf compensation depths ranged from 60 to 85 m, with values of 100 m occasionally observed.

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 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 collected along a cross-shelf transect by Marvin (1955) revealed a distinct trend toward lower dissolved oxygen concentrations in the estuaries and nearshore zone, with values 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.

El Sayed et al. (1972) reported that the upper 100 m of water in the Gulf of Mexico were nutrient poor, with phosphate, nitrate, and silicate values less than 0.4, 2.0, and 2.0 micromoles (uM), respectively. Nitrate-nitrite nitrogen concentrations on the southwest Florida shelf ranged from less than 0.1 to 19 uM; however, the concentrations rarely exceeded 1 uM at depth 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). 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.

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. Physical oceanographic investigations conducted by Science Applications International Corporation (1986) suggest that upwelling resulting from Loop Current boundary perturbations [e.g., warm filaments (upwelling is evident by doming of isotherms in Figure 2-6)] would bring up the more nutrient-rich Subtropical Underwater onto the southwest Florida shelf.

Riley and Chester (1971) report that fertile coastal water in bloom may exhibit chlorophyll values from 10 to 40 mg/m^3. According to Woodward Clyde Consultants (1983), chlorophyll values on the southwest Florida shelf range from less than 0.1 to 1.5 mg/m^3. The highest value is approximately six times higher than the average gulfwide value reported by El Sayed et al. (1972), but still considerably lower than the values for fertile coastal water. There was 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

Skidaway Institute of Oceanography (1983) are low and should be considered conservative when estimating the productivity of the shelf water or comparing this productivity with worldwide values.

There are many sources of hydrocarbons that may result in ultimate deposition in the marine environment: (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, resulting from petroleum drilling, production, and use (anthropogenic) and from natural seeps. A 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 were dominated by biogenic and diagenetic compounds; however, analysis of select polynuclear aromatic hydrocarbons revealed small amounts of petrogenic and pyrogenic input.

The distribution of hydrocarbons in surface sediment of the southwest Florida shelf according to source characteristics is shown in Figure 2-9. Three major source regimes were observed: (1) predominantly marine biogenic, found primarily in the mid-shelf 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. Hydrocarbon analysis of sediment on the southwest Florida shelf indicates the area is relatively free of petrogenic hydrocarbons. Concentrations of total extractable hydrocarbons generally fell in the range of 0.5 to 2 ug/l, with values decreasing with distance from shore. The source of petrogenic hydrocarbons is attributed to pelagic tars transported by the Loop Current, 50% are estimate to enter the Gulf of Mexico through the Yucatan Straits.

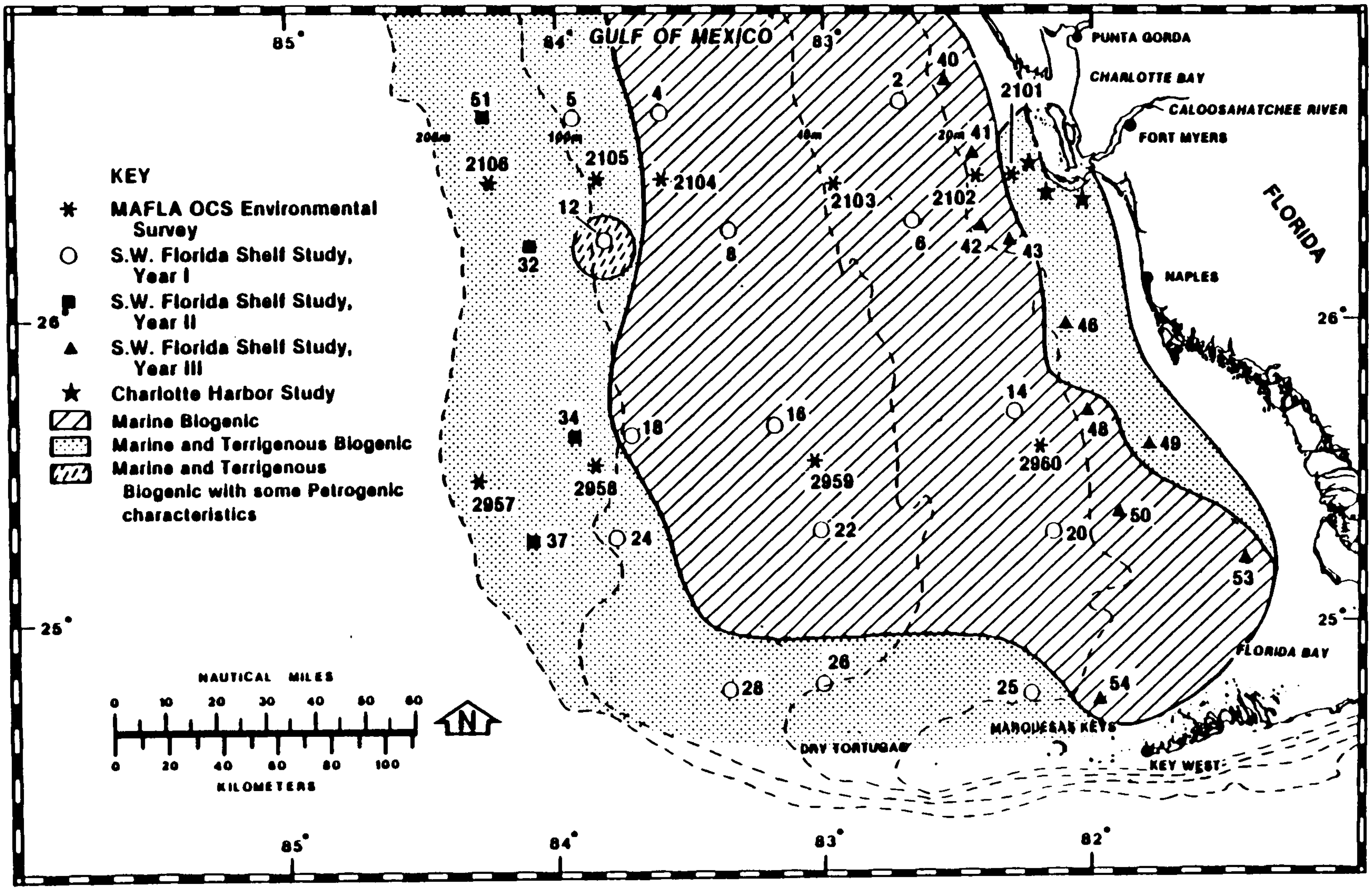

Figure 2-9 Surface sediment sample stations and hydrocarbon source characteristic distribution.

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). The lack of petrogenic contamination in biota indicates the absence of petrogenic hydrocarbons in the water column as well as in sediments.

Studies of pelagic tar (anthropogenic or, less likely on the southwest Florida shelf, from natural seeps) in the eastern Gulf of Mexico 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). Although most pelagic tar in the Loop Current 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).

The distribution of dissolved and dispersed petroleum hydrocarbons in the water column of the eastern Gulf of Mexico follows the distribution of pelagic tar. Highest values observed were 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.

2.4 INFAUNA AND SESSILE EPIFAUNA

Infaunal densities on the shelf range from about 1,000 to 14,000 individuals per square meter and generally decline with increasing water depth. Some species, especially spionid polychaetes such as *Paraprionospio pinnata* and *Prionospio cristata*, fluctuate widely in abundance. Polychaetes account for about 64% of the individuals collected and 37% of the species (Table 2-1). Polychaete biomass is typically <20 g wet weight/m^2 and decreases with increasing water depth.

Most of the infaunal individuals collected are deposit feeders. The polychaete families *Paraonidae* (burrowing, subsurface deposit feeders) and *Spionidae* (tubicolous, surface deposit feeders and/or suspension feeders) are well represented in the list of most abundant species. Species composition of infaunal communities varies primarily in relation to water depth and, secondarily, grain size composition of sediments (particularly silt content; see Figure 2-10).

The southwest Florida shelf is characterized by a diverse sessile epifauna. Schematic representations of the biotic zonations for hypothetical northern and southern transects across the southwest Florida shelf are presented in Figures 2-11 and 2-12, respectively. The subtropical climate and the widespread occurrence of various hard substrates favor colonization by species of scleractinian corals, gorgonians, and sponges typically associated with Caribbean and south Florida reefs.

Most of the inner and middle shelf (to a depth of about 70 m) consists of a mosaic of sand bottom and hard bottom covered by a thin sand veneer, with occasional low-relief rock outcrops. Hard-bottom areas near shore (<20 m depth) are typified by dense populations of gorgonians, large sponges, and small scleractinian corals. Areas of open sandy bottom in the same depth range are colonized by various species of macroalgae and seagrass (*Halophila decipiens*). The gorgonians and seagrass become much

Table 2-1. 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.

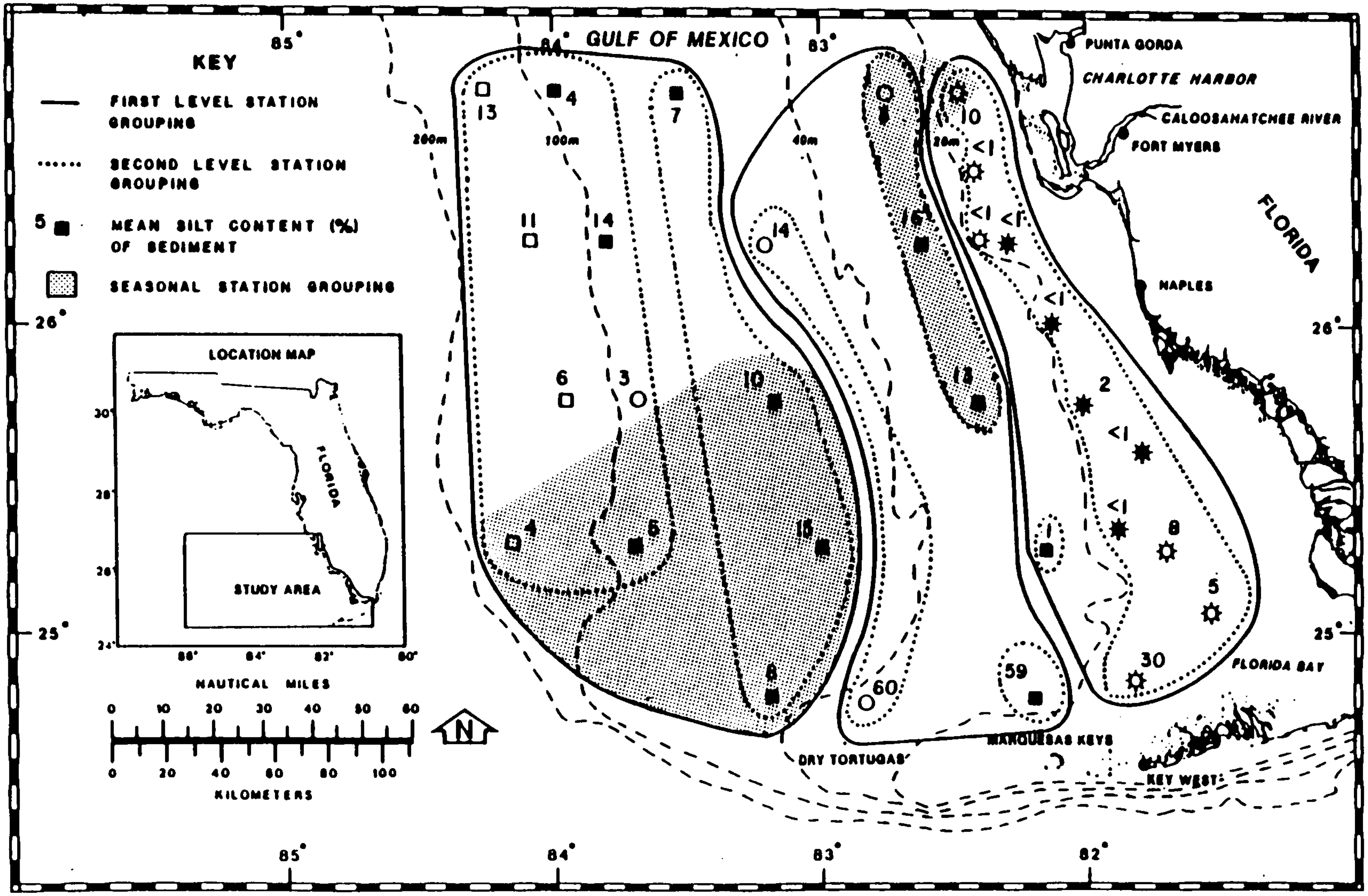

Figure 2-10 **Station groupings from normal classification analysis of infaunal data.**

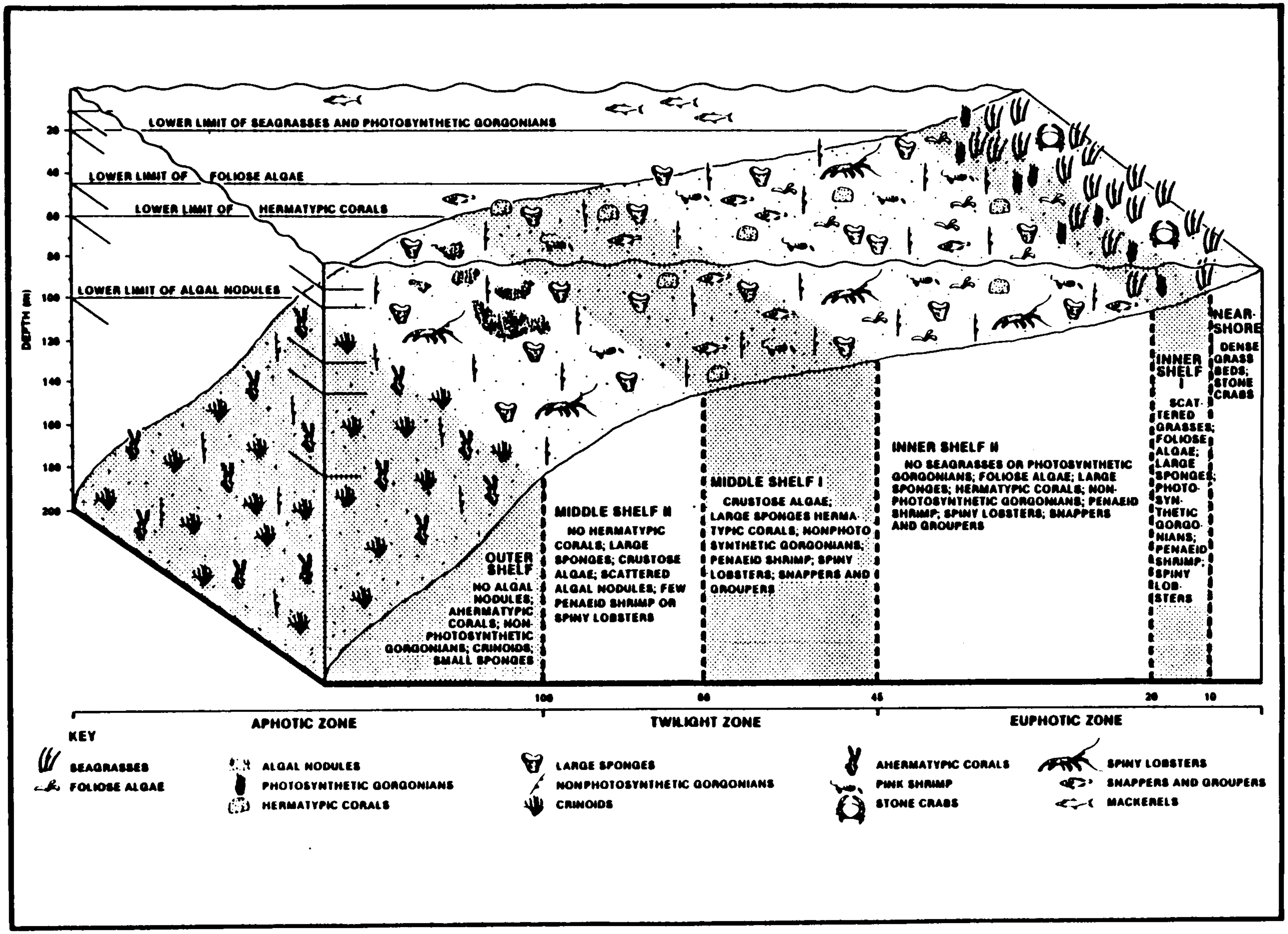

Figure 2-11 Biotic zonation of the southwest Florida continental shelf (northern transect, e.g., Transect A) showing general distribution patterns of major components of the flora and fauna.

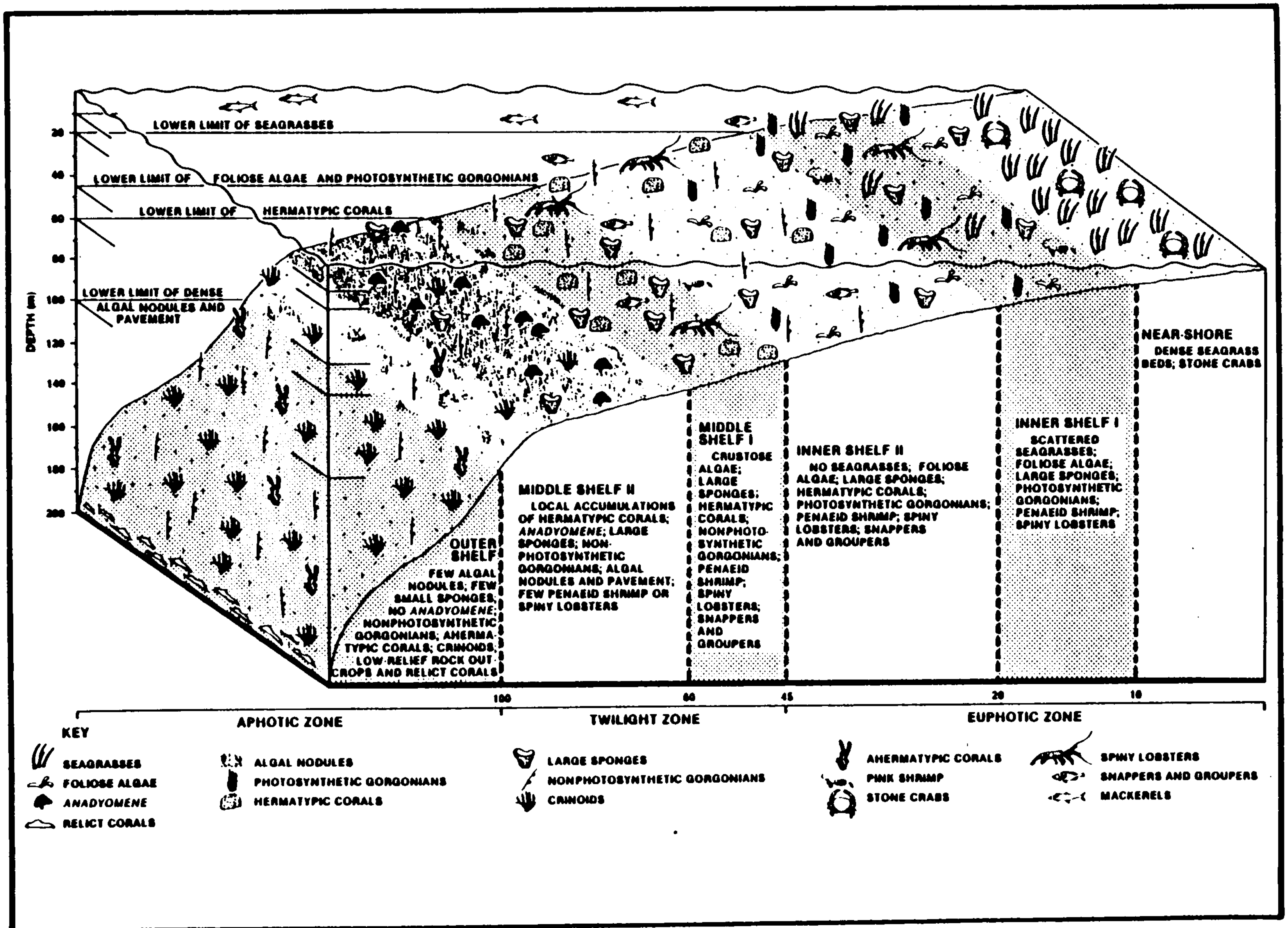

Figure 2-12 Biotic zonation of the southwest Florida continental shelf (southern transect, e.g., Transect E) showing general distribution patterns of major components of the flora and fauna.

less common with increasing water depth seaward of the 20-m isobath, but many other elements of the sessile epibiota extend across much of the inner and middle shelf.

A different suite of sessile epibiota is found in the 60- to 100-m depth range in association with coralline algal nodules, which occur in greatest density south of 25.5°N latitude. Sparse populations of sessile epifauna such as sponges, nonzooxanthellate gorgonians, scleractinian corals, and crinoids are present in the nodule areas, but the most conspicuous epibiota are species of algae (Anadyomene menziesii, Peyssonnelia rubra, and P. simulans). At the southern shelf edge in the 64- to 80-m depth range, the coralline algal growth forms a continuous pavement, and dense accumulations of plate corals (Agaricia) are seen. Biotic coverage in this area is the highest on the shelf (64 to 90%), with most due to the algae cited previously.

Much of the outer shelf is covered by a sand veneer; scattered rock outcrops occur, but most are concentrated along two partially buried north-trending reef features. The most important is Howell Hook, which was observed in a water depth of about 150 m in the form of steep-walled rock prominences protruding several meters above the surrounding sandy bottom. Common sessile epifauna on the outer shelf, both in association with rock outcrops and with areas of coarse shell rubble, are comatulid crinoids, hexactinellid (glass) sponges, antipatharian sea whips, and nonzooxanthellate gorgonians.

The availability of suitable substratum is an obvious influence on the occurrence and species composition of sessile epifaunal communities. Many species can colonize only bare rock or areas where the sand veneer is thin enough to allow intermittent exposure of hard bottom. Several environmental variables related to water depth are also influential, the most important being light. Many species of hard coral, gorgonian, and sponge harbor symbiotic algae and are light limited in their distribution.

2.5 MOTILE EPIFAUNA AND FISHES

The depth zonations presented in Figures 2-11 and 2-12 are generally appropriate for sessile epifauna; however many motile epifauna may be found at most locations. 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.

For motile invertebrates, it is perhaps more appropriate to define only two benthic habitats: 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 are certainly important. However, many of these motile invertebrates are closely associated with the surrounding sand, also.

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.

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 punctualata*, and *Eucidaris tribuloides*).

Many of these species are more abundant in shallow water (e.g., less than 60 m deep), due to herbivorous diets and the greater availability of plants in shallow water.

Low-relief bottom refers to areas of partially buried limestone, coral or algal debris, and sandy substrates. Seagrass beds are included in the definition. 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. and 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 a broad depth range 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 asteroid included the Middle Shelf Algal Nodule Assemblage 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.

Larger holothurians (sea cucumbers) 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 range. Stone crabs, Menippe mercenaria, are common only in the inshore portion of the study area.

Within the study area, the Tortugas grounds and the Sanibel grounds are Florida's most productive areas for pink shrimp (Penaeus duorarum). 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. Pink shrimp are dependent on these 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 water 4 to 48 m deep throughout the year. The 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.

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.

Like motile epifauna, the distribution of fish does not fall easily into established assemblages or biotic zones. 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. Nevertheless, it should be remembered that fishes are capable of moving rapidly between habitat types and that apparent boundaries of zones are not absolute barriers. Continental Shelf Associates (1986) 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 that follows.

Within the inner shelf zone (approximately 10 to 45 m), considerable variability was present between different habitat types. Fishes associated with coral reefs--some of which are numerically dominant 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 (lane snapper), Haemulon plumieri (white grunt), and H. aurolineatum (tomtate), ranged across the zone. Others were more common toward the outer edge of the inner shelf zone, such as Ioglossus calliurus (blue goby).

The 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 [bigeyes, etc. (Pristigenys alta, Priacanthus spp.)], and butterflyfish (chaetodontids). According to Continental Shelf Associates (1986), Middle Shelf II was a special category for algal nodule and algal pavements (some bearing Agariciid plate corals); areas between 60 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 yellowtail reeffish (Chromis enchrysurus), purple reeffish (C. scotti), and sunshinefish (C. insolatus); anthids and other serranids, such as saddle bass (Serranus notospilus), tattler (S. phoebe), orangeback bass (S.

annularis), and chalk bass (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, none of the sampling methods used to date are 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.

Characteristic fishes from the outer shelf zone (100 to 200 m) included the tattler (Serranus phoebe) and other small serranids such as the roughtongue bass (Holanthias martinicensis), offshore lizardfish (Synodus poeyi), searobins [e.g., the shortwing searobin (Prionotus 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 the fringed filefish (Monocanthus ciliatus), sand diver (Synodus intermedius), dusky flounder (Syacium papillosum), blackedge moray (Gymnothorax nigromarginatus), jackknife-fish (Equetus lanceolatus), red grouper (Epinephelus morio), scrawled cowfish (Lactophrys quadricornis), gray angelfish (Pomacanthus arcuatus), and reef butterflyfish (Chaetodon sedentarius).

2.6 FISHERIES/SOCIOECONOMICS

Commercial and recreational saltwater fishing activities are important elements of the economy in southwest Florida. The diversity of offshore and coastal habitats supports a variety of economically important species of fish and shellfish.

Recreational fishing is a substantial component of Florida's economy, and southwest Florida is one of the most active areas in the state for anglers. More than 625,000 saltwater anglers in southwest Florida spent over 10 million man-days fishing during 1980-1981. Most fishing days were spent on surf, shore, pier, jetty, or bridge fishing. Offshore fishing also is important, with charter and party boats operating primarily out of Fort Myers, Marathon, and Key West.

In 1985, Florida's marine commercial fishery was ranked fifth nationally in value of dockside landings ($171,073,000) and ninth in poundage (182,577,000 lbs). Within the study area, Monroe County leads in volume and value of fish and shellfish landing, and Lee County is ranked second (see Figure 2-13). Key West and Fort Myers are the primary ports for landings.

Economically valuable finfish species can be grouped by habitat. Inshore species include red drum, spotted sea trout, snook, striped or black mullet, tarpon, pompano, black drum, and sheepshead; although some are harvested commercially, all but sea trout and mullet are sought primarily by recreational anglers. Coastal pelagic fishes, which traverse coastal and inner shelf water during their life spans, are represented by Spanish, cero, and king mackerels; bluefish; little tunny; and cobia. Economically, the Spanish and king mackerels are most important; both are sought by commercial and recreational fishermen alike. Valuable reef fishes include snappers, groupers, grunts, porgies, barracudas, and jacks. Groupers (Epinephelus spp., Mycteroperca spp.) and snappers (Lutjanus spp., Ocyurus chrysurus, Rhomboplites aurorubens) are the most sought-after reef fishes and have been subject to intense fishing pressure. Other reef species are becoming increasingly important as snapper and grouper stocks decline.

Shellfish harvested in the area include pink shrimp (Penaeus duorarum), spiny lobster (Panulirus argus), and stone crab (Menippe mercenaria). The pink shrimp fishery is the most valuable on the southwest Florida

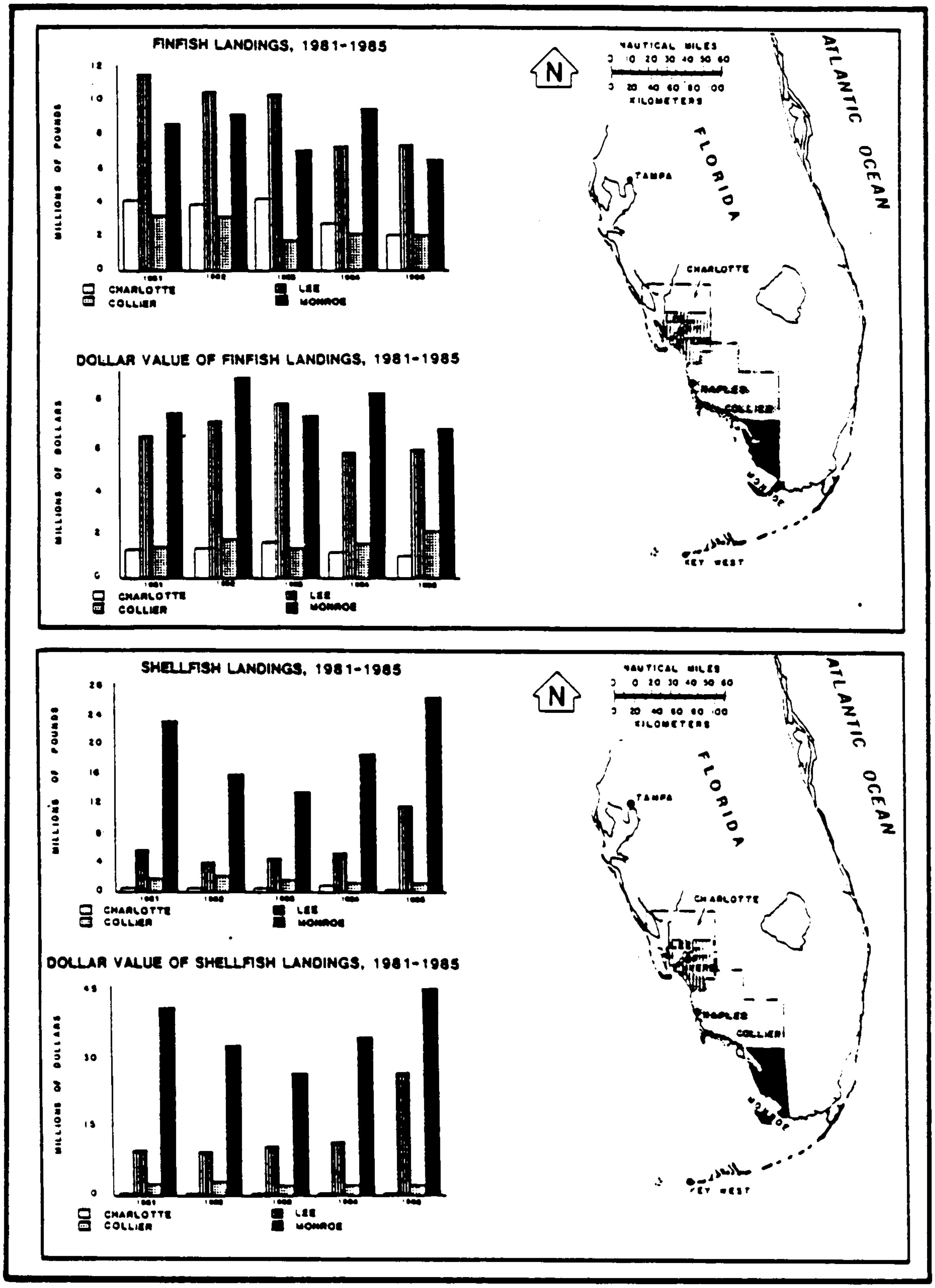

Figure 2-13 Commercial Finfish (top) and shellfish (bottom) landings in millions of pounds and millions of dollars by county.

shelf in terms of volume and value; Monroe County landings in 1985 were more than 20 million pounds, valued at $32 million. About 48% of the harvest comes from the Tortugas grounds; the Sanibel grounds off Charlotte Harbor account for another 28%. The second-ranking spiny lobster fishery is concentrated in Monroe County (1985 value of $8 million). Adult spiny lobsters, which congregate under rock ledges and coral heads during the day and emerge at night to forage over adjacent sand bottom or seagrass flats, are taken mainly by wooden slat traps and divers. Stone crabs are abundant in coastal seagrass beds off southwest Florida; the crabs are caught in wooden slat traps, declawed, and returned to the water. Fishing effort is concentrated in shallow water from northern Florida Bay and west of the Ten Thousand Islands from Cape Romano to Cape Sable; over 50% of the state catch is landed in Collier and Monroe Counties.

2.7 ENDANGERED SPECIES AND AREAS OF SPECIAL CONCERN

Florida's geographic position, geologic history, and habitat diversity favor the existence of vertebrates and plants having specific habitat requirements. As habitat degrades or disappears, such species become in danger of extinction. The most recent federal listing of endangered species includes six mammals, four birds, and five reptiles that may occur over or in water of the study area.

The endangered mammals are five species of whales (fin, blue, humpback, right, and sei) and the West Indian manatee. The whales are open-ocean mammals that might enter the study area during annual movements. The manatee population, estimated at 350 to 400 animals, is restricted to coastal waters. Most of the manatees are located in the brackish water of Everglades National Park and the Ten Thousand Islands region.

Everglades National Park and the Ten Thousand Islands region are also known nesting and roosting havens for many water bird species, four of which--the brown pelican, the southern bald eagle, the least tern and the peregrine falcon--are endangered. Both the brown pelican and the bald eagle nest in mangrove trees. Peregrine falcons have been reported in the Dry Tortugas.

The endangered reptiles are four species of sea turtle (green, Kemp's ridley, hawksbill, and leatherback) and the American crocodile. Of the sea turtles, only the green turtle is expected to occur commonly in the study area, where it migrates to nesting sites on the beaches of southwest Florida. The American crocodile, an inhabitant of coastal rivers and swamps, occurs in Dade and Monroe Counties, where the population is estimated at 200 to 400 individuals. Nesting is apparently restricted to eastern Florida Bay and southern Biscayne Bay and takes place in April.

In addition to endangered species, several areas of special concern occur within the study area. These areas are considered biologically valuable and/or particularly sensitive to impacts from continental shelf oil- and gas-related activities. The areas discussed include the Tortugas and Sanibel pink shrimp grounds, seagrass meadows, mangrove forests and tidal marshes, and coral reefs (Figure 2-14).

Pink shrimp are the most important commercial fishery species on the southwest Florida shelf, and most of Florida's pink shrimp catch comes from the Tortugas grounds (48%) and the Sanibel grounds (28%). The importance of coastal areas in Florida Bay as nursery habitat led the State of Florida and the U.S. Department of Commerce to establish the Tortugas Sanctuary in 1981 as an area closed to shrimp trawling.

Seagrass beds provide food and habitat for many species of fishes and invertebrates. Extensive seagrass meadows consisting of mixed associations of turtle grass (*Thalassia testudinum*), Cuban shoalgrass (*Halodule wrightii*), and manatee grass (*Syringodium filiforme*) occupy most of Florida Bay to a depth of 10 m. Seagrass cover within this area is estimated to be about 550,000 ha. Between Cape Sable and Tampa Bay, seagrasses are confined mostly to inshore lagoons.

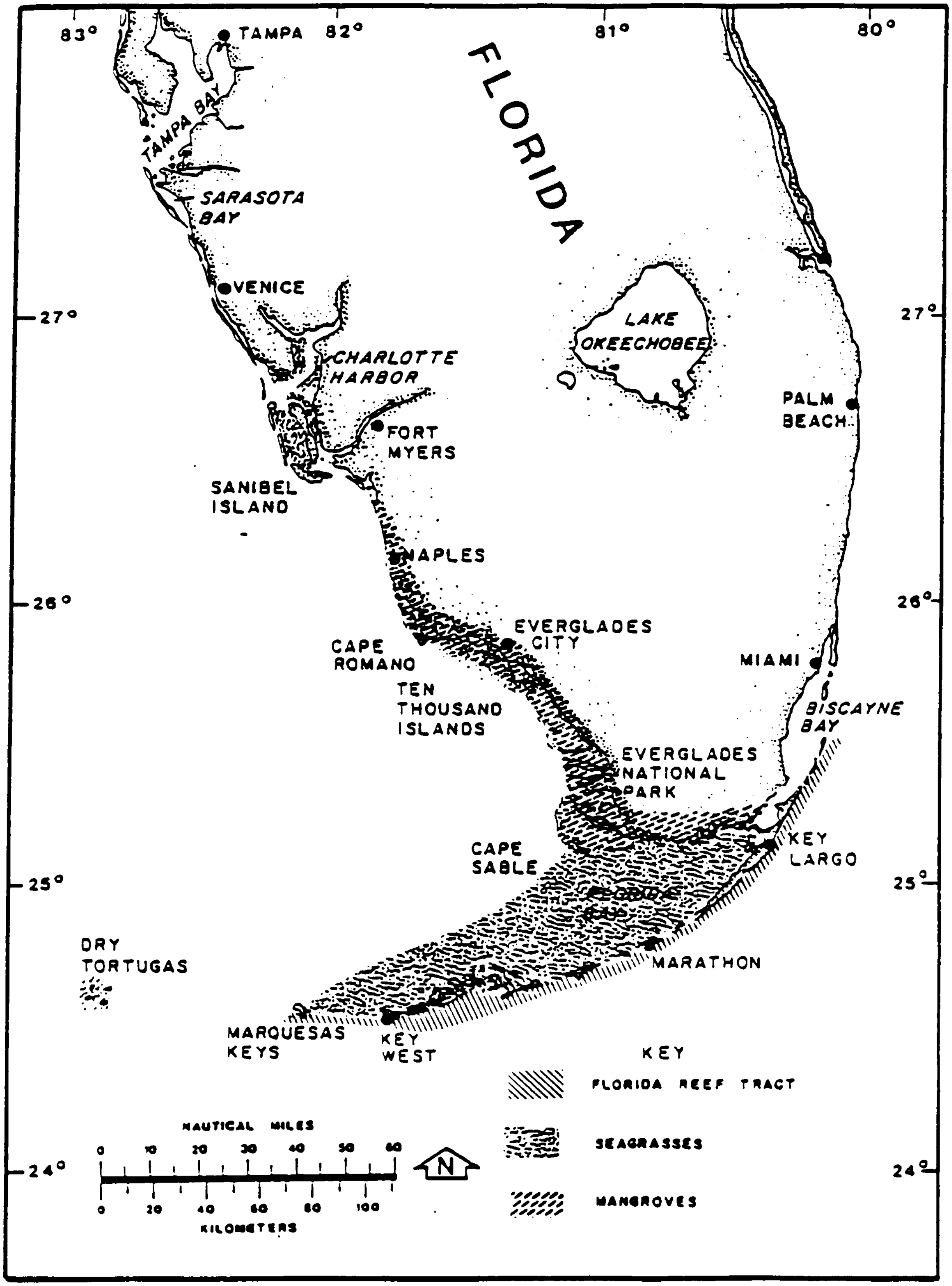

Figure 2-14 Locations of environmentally sensitive coastal habitats in Southwest Florida.

Mangrove forests consisting of red, black, and white mangroves occur interspersed with tidal marsh vegetation along most of the coast in the study area. Over 75% of the mangrove acreage in Florida occurs in the coastal counties of the study area (greater than 200,000 ha). Mangrove forests are considered important as wildlife habitat and as producers of detrital carbon. Tidal marshes occur along some 13,000 ha of shoreline in the study area.

The Florida reef tract forms a 200-km, 6-km-wide arc parallel to the east coast of the Florida Keys from Fowey Rocks to the Dry Tortugas. Four coral community types have been recognized within the reef tract: live bottom, patch reefs, transitional reefs, and bank reefs. Similar reef development occurs in a 22,000-ha area around the Dry Tortugas. Various species of scleractinian corals, octocorals, sponges, and algae occur in these reef areas.

3.0 POTENTIAL OIL AND GAS DEVELOPMENT 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).

The delineation and distribution of distinguishable biological communities and the physical factors that determine the distribution of these communities are discussed in Section 2.0; the distribution of the live-bottom communities is summarized schematically in Figures 2-11 and 2-12. In this section, the potential impacts of oil and gas development on the southwest Florida shelf habitats, ecosystems, and valued ecosystem components will be discussed in light of the information presented in Section 2.0.

The first step in the projection of potential impacts resulting from oil- and gas-related operations involves identification of specific activities resulting from each phase of these operations. The phases (exploration, development, production, and transport and storage) and the activities and potential habitat impacts associated with these activities are presented in Table 3-1.

Potential ecosystem impacts associated with oil- and gas-related activities (summarized in Table 3-2) are derived largely through habitat impacts. Although much information is included in Table 3-2, the potential ecosystem impacts could be expanded several times to include all known potential effects of all known agents (particularly the chemical species associated with oil and gas operations) on various biological components.

The deficiencies of tables such as these 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 may have on each component. A more useful approach, and the one used for this study, is to select a discrete and manageable number 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. The VECs for this study were selected by representatives from the U.S. Department of the Interior (MMS and USFWS), Department of Commerce (NMFS), the State of Florida (Office of the Governor), and the project team. The list of VECs selected for the southwest Florida shelf includes the following:

Table 3-1. 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 3-2. 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.
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.
	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.

Table 3-2 (Cont.).

Factor	Potential Ecosystem Effects and Considerations
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.
	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.

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

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.

Analyses of the potential impacts of oil- and gas-related activities were conducted for each VEC; an example of the analysis conducted for snappers and groupers is presented in Figure 3-1. Each analysis is presented as a flow diagram connecting the initial activities of oil and gas development, through intermediate steps, to the final presumed impacts.

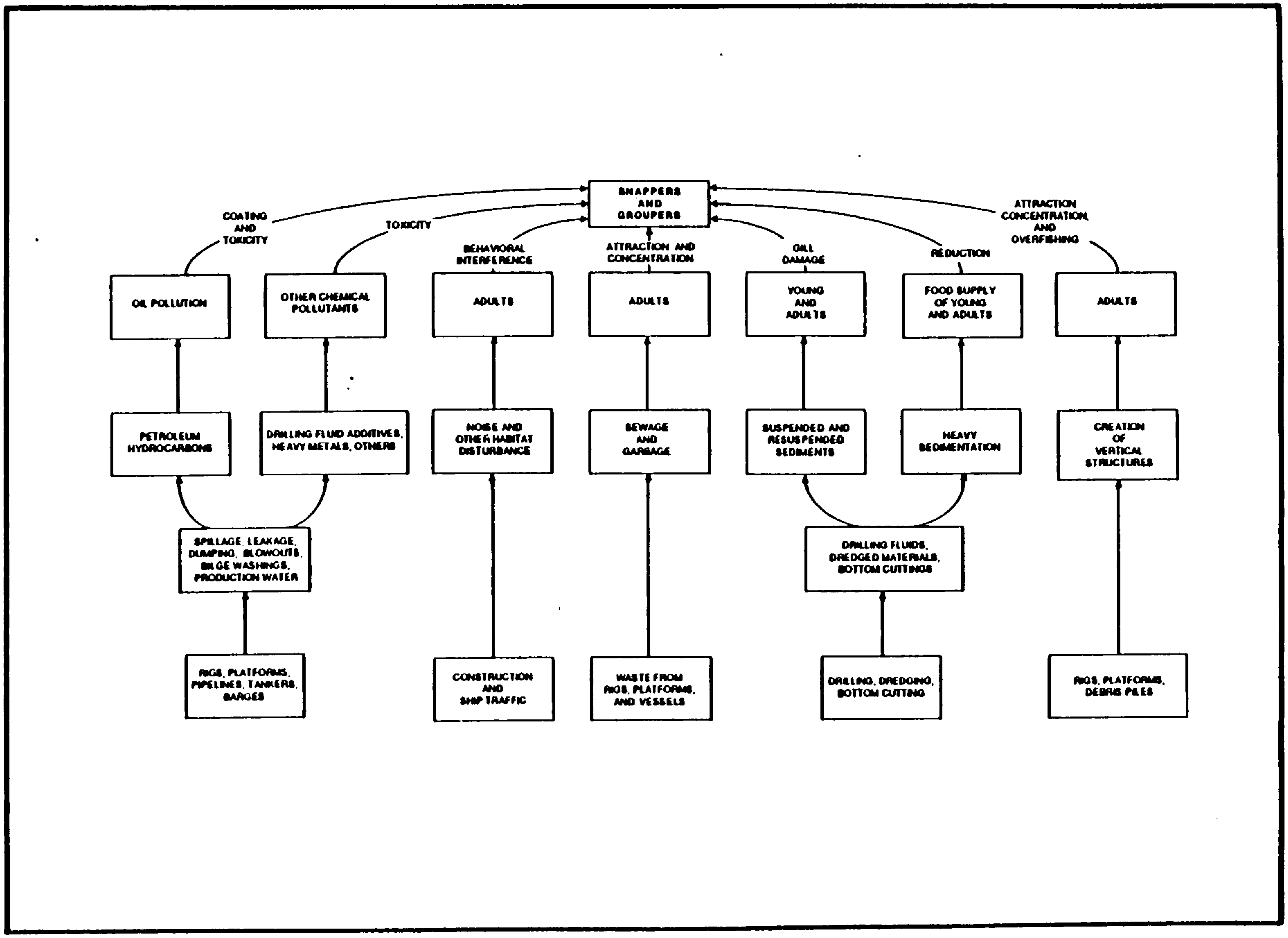

Figure 3-1 Example of a conceptual submodel of potential impacts of oil- and gas-related activities on a valued ecosystem component (snappers and groupers).

All pathways should be carefully considered. Snappers and groupers of the southwest Florida shelf extend through all 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. 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 3-1). 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 result in increased time of exposure in areas where contaminant levels might be elevated. Other impacts that were considered included noise, oil pollution, garbage, and sewage.

Each of the potential impact factors were then examined to estimate effects on the remainder of the 15 VECs in a manner similar to that for snapper and grouper. Figure 3-2 is a matrix summarizing the potential impacts on all VECs resulting from this analysis. 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 3-2). 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 probabilistic

VALUED ECOSYSTEM COMPONENT

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

POTENTIAL IMPACT OF OIL- AND GAS-RELATED ACTIVITIES

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 3-2 **Matrix summary of potential impacts of oil- and gas-related activities on valued ecosystem components.**

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) estimated that the total number of expected oil spills occurring within the Eastern Planning Area for MMS volume Scenario M (Most Likely Find 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 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% (MMS, 1984). 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 3-2).

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 in 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 currently prohibited, so smothering is unlikely. The attraction to organic garbage does occur, but on a localized basis.

Drilling and production rigs and platforms are generally noisy. 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 3-2, drilling fluid discharges in the water column may increase suspended sediment concentrations to the level that inhibition 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 3-2) 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 3-2) 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 migration. Deep channels in shallow water areas are used as migration pathways and sometimes as a refuge in severe 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.

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 be 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, and 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 2,000 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 impact of platform removal will be to eliminate the reef communities associated with these structures. 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.

The preceding impacts were conceptualized in terms of a given structure (platform, pipeline, etc.) or activity (exploration, production, etc.); 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 historical stipulations, the envisioned impacts presented, especially those concerning live bottoms, could be greatly reduced.

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