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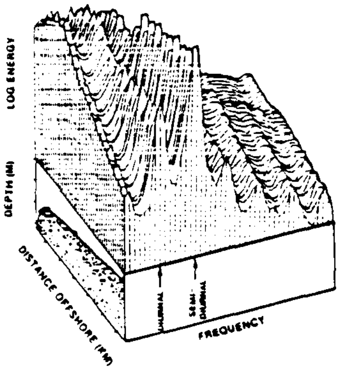
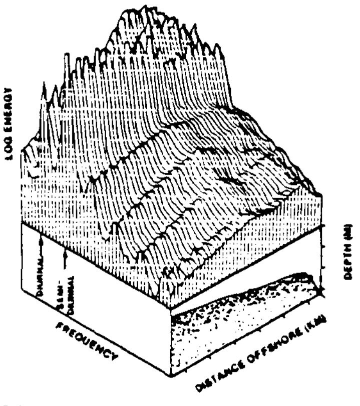
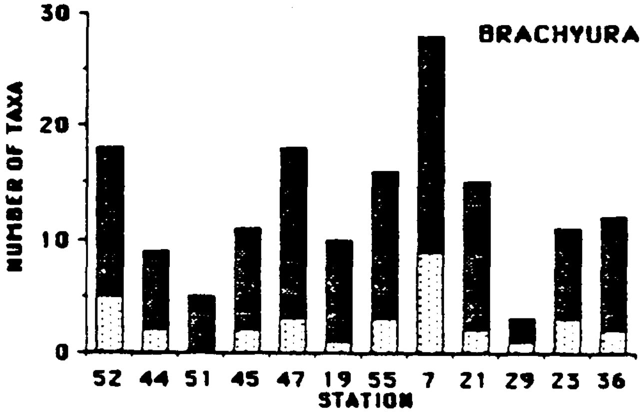
SOUTHWEST FLORIDA SHELF BENTHIC COMMUNITIES STUDY YEAR 5 ANNUAL REPORT

VOLUME I -- EXECUTIVE SUMMARY







U.S. Department of the Interior/Minerals Management Service

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SOUTHWEST FLORIDA SHELF BENTHIC COMMUNITES STUDY YEAR 5 ANNUAL REPORT

Volume I — Executive Summary

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Prepared for:
Minerals Management Service
Gulf of Mexico OCS Regional Office

Contract No. 14-12-0001-30211

September 1986

U.S. DEPARTMENT OF THE INTERIOR / MINERALS MANAGEMENT SERVICE

REPORT AVAILABILITY

This executive summary was prepared under contract between the Minerals Management Service and Environmental Science and Engineering, Inc. Extra copies may be obtained from:

Minerals Management Service
Gulf of Mexico OCS Regional Office
Attn: Public Information Section (OPS-3-4)
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394
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This volume should be cited as:

Danek, L. J., and G. S. Lebwel, editors. 1986. Southwest Florida Shelf Benthic Communities Study Year 5 Annual Report. A final report by Environmental Science and Engineering, Inc. and LGL Ecological Research Associates, Inc. (Contract No. 14-12-0001-30211) submitted to the Minerals Management Service, New Orleans, Louisiana. 3 vol.

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1.0 INTRODUCTION

The Southwest Florida Shelf Ecosystems Program began in 1980 and was originally designed as a 3-year, interdisciplinary study of the biogeochemical character and seasonal community patterns occurring in the region.

The overall objectives defined by the Bureau of Land Management (BLM) [now the Minerals Management Service (MMS)] for the Southwest Florida Shelf Ecosystems Program were as follows:

1. To determine the potential impact of outer continental shelf (OCS) oil and gas offshore activities on live-bottom habitats and communities, which are integral components of the southwest Florida shelf ecosystem.
2. To produce habitat maps that show the location and distribution of various bottom substrates.
3. To classify broadly the biological zonation across and along the shelf, projecting the percent of the area covered by live/reef bottoms and the amount covered by each type of live/reef bottom.

The first 3 years of investigations effectively addressed Objectives 2 and 3. However, it was determined that to assess the potential impacts of OCS oil and gas activities more must be known about the dynamics of the ecosystem and natural stresses that are imposed on the system by existing physical processes. Consequently, an additional 2-year study ("Southwest Florida Shelf Benthic Communities Study") was designed to investigate the biological and physical processes of the southwest Florida shelf that, in combination with the first 3 years of study, would provide the information needed to better assess potential impacts of offshore development. A final year (Year 6) was added for synthesis and interpretation of all available data, development of a conceptual model, and impact assessment of offshore oil development.

The overall Year 4 and 5 study objectives to investigate biological and physical processes and to provide information needed for impact assessment were defined as follows:

1. Compare and contrast the community structure of both live-bottom and soft-bottom fauna and flora to determine the differences and similarities between them and their dependence on substrate type.
2. Determine and compare the hydrographic structure of the water column and bottom conditions at selected sites within the study area.
3. Determine and compare sedimentary character at selected sites within the study area, and estimate sediment transport.
4. Relate differences in biological communities to hydrographic, sedimentary, and geographic variables.
5. Develop and conduct a research program which will 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.
6. Assemble and synthesize appropriate published and unpublished data with the results of this study, summarizing on a seasonal spatial basis all biological, habitat, and environmental observations and parameters. Relationships between biological and nonbiological factors would be delineated through illustrations (maps, diagrams, charts, etc.), as well as descriptive text. Appropriate statistical analyses would be performed to support the interpretations leading to the synthesis and conclusions.
7. Conduct an effective quality assurance and quality control program which ensures that all data acquired are accurate and repeatable within standards normally accepted for each type of observation, measurement, or determination.

8. Assess the need for and determine the type of studies to be conducted in future studies sponsored by MMS in the eastern Gulf of Mexico.

To address these objectives, a 2-year program (Years 4 and 5 of the overall program) was designed and implemented to provide seasonal data for selected live-bottom stations and supplemental data for soft-bottom stations. This annual report presents the results of this study.

The Year 4 field study included four seasonal cruises, with sampling conducted at two sets of stations (Figure 1-1). One set of stations (Group I stations: less than 20-m water depth) was sampled during fall 1983 and spring 1984, and consisted of the five hard-bottom and five of the 10 soft-bottom stations that were sampled during the winter 1982-1983 and summer of 1983 (Year 3 study). This sampling essentially completed the seasonal baseline descriptive study of the inshore area.

Ten replicate infauna samples were collected at each of the soft-bottom stations during both cruises. In addition, sediment samples and hydrographic measurements were made at each station to define the soft-bottom habitat. At the five hard-bottom stations, dredging, trawling, underwater television, benthic still photography, sediment sampling, and hydrographic measurements were completed during both cruises.

Seven other hard-bottom stations, as well as one Group I hard-bottom station, were selected for a more detailed study of biological and physical dynamics. During Year 4, five of these stations, designated Group II and each representing a separate epifaunal community type, were sampled during each of four seasons--fall 1983, winter 1983-1984, spring 1984, and summer 1984. These stations are at water depths greater than 20 m except for Station 52 (13 m). Station 52 was added to this group to provide one representative shallow-water station to this more intensely studied group of stations.

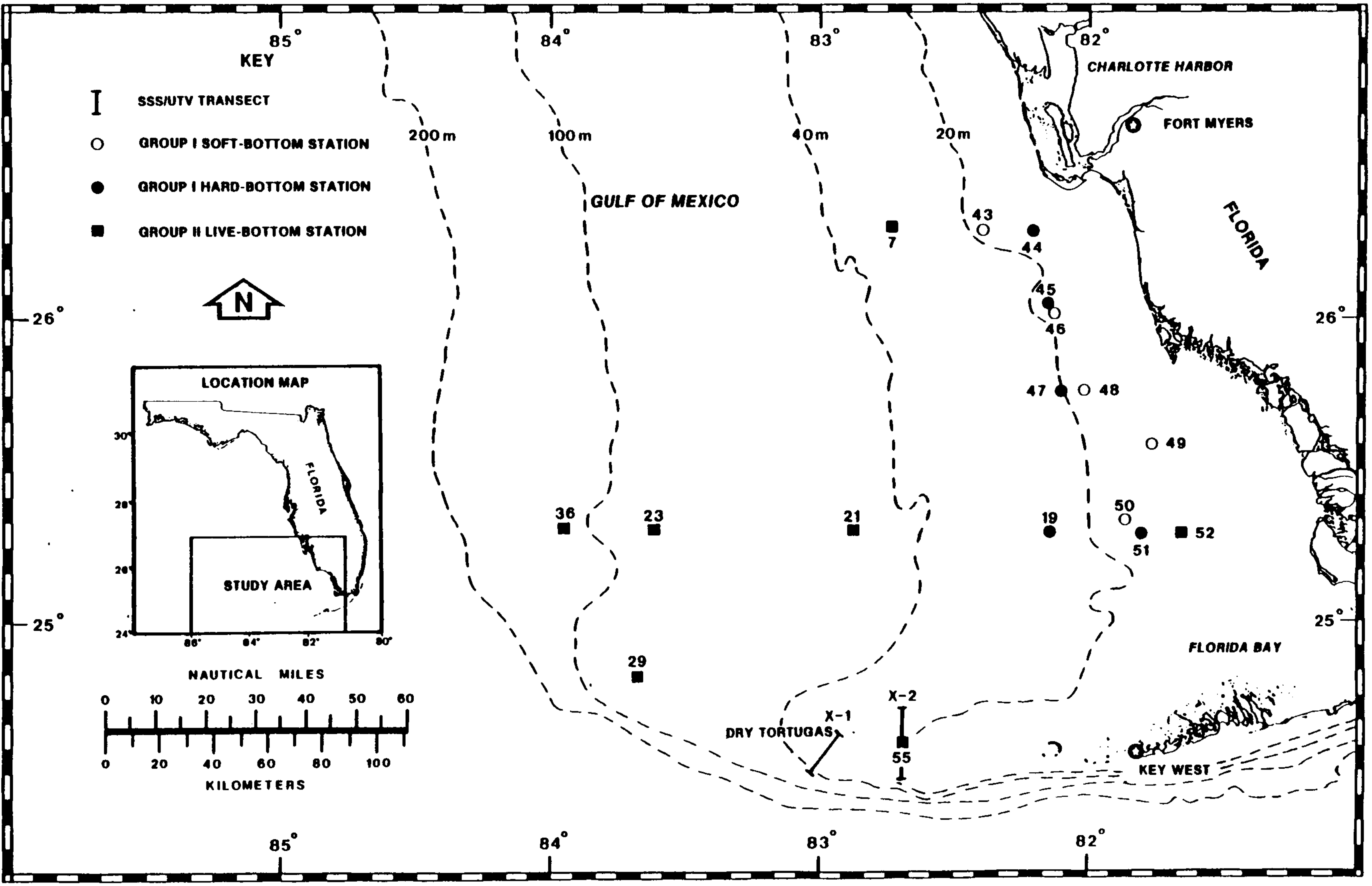

Figure 1-1 STATION AND INSTRUMENTED ARRAY LOCATIONS FOR YEARS 4 AND 5

During Year 4, sampling at the five stations consisted of dredging, trawling, underwater television, benthic still photography, sediments, and hydrography. In addition, in situ instrument arrays were installed with current meters that measured current speed and direction and temperature; 3 sets of sediment traps at elevations of 0.5 m, 1.0 m, and 1.5 m above the bottom; and 10 sets of settling plates that were scheduled to be retrieved at 3-month intervals over the 2-year study. Also, the arrays at Stations 52 and 21 each contained 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 quarterly sampling of the five Group II stations continued, and three other stations were added for intensive study (see Figure 1-1). Two of these stations (one was Year 4 Group I hard-bottom Station 44; the other, Station 7) had been sampled previously. The third station (Station 55) situated between the Dry Tortugas and the Marquesas was a new station established during 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.

There was some modification to the sampling program during Year 5. Triangle dredge tows were discontinued at the five original stations, and were conducted at only two of the three additional stations (Stations 7 and 55). The third station (Station 44) was sampled only with the instrumented array and CSTD. A second modification was the transfer of the Station 21 wave gage to Station 55. In addition, seven of the eight arrays were equipped with time-lapse cameras; Station 36, the deepest station, was the only array not equipped with a time-lapse camera. Finally, during Year 5, two new transects were surveyed with underwater television and side-scan sonar. Transect X-1 ran from the Tortugas Shoals southwest to a depth of 100 m; Transect X-2 ran north-south through Station 55 at an average water depth of 27 m. These transects were added to supplement the habitat mapping studies completed in previous years.

2.0 PHYSICAL CHARACTERIZATION

A detailed and comprehensive description of the physico-chemical environment and the phenomena that affect this environment are essential to the understanding of an ecosystem. It is difficult to assess the impacts of man's activities, in this case offshore petroleum development, without first understanding the natural processes and perturbations that impact the ecosystem. The following discussion describes the physical characteristics of the individual stations and the dynamic physical processes that affect these stations.

2.1 GENERAL SITE DESRIPTIONS

The southwest Florida continental shelf is a broad (approximately 200 km), flat limestone platform with relatively few areas of high relief. The shelf slopes gently to the west. In most locations, low-lying, hard substrates either alternate with or are covered by a thin veneer of coarse sand. This sand is primarily calcareous, with percentages of calcium carbonate exceeding 90% in most locations, indicating that the sand is derived primarily from coral, calcareous algae, and the erosion of bedrock.

In general, hard substrates such as coral heads and bedrock project less than 2 m above the bottom, although larger depressions, pinnacles, and other more irregular geological features are found toward the outer edge of the shelf. Immediately beyond the shelf, the continental slope deepens rapidly, with the 1,000-m depth contour approximately 50 km seaward of the 200-m contour.

Currents along the bottom on the southwest Florida shelf tend toward the south. Bottom currents usually range from 10 to 30 cm/sec. Occasional intrusions of the Loop Current or eddies generated by it can cause abrupt changes in current direction and speed, especially along the outer portions of the shelf. These intrusions can produce bottom water velocities in excess of 80 cm/sec. Farther to the east, the average direction of flow of bottom water is more to the southeast, toward Florida Bay.

Wave action is variable on the shelf; the greatest mean wave height occurs between September and April. Passing tropical storms and fronts during the fall and winter produce the highest waves, usually in conjunction with winds from the west and northwest. Average wave height is less than 1.5 m (monthly means), but much higher waves are produced during storms. Under storm conditions, waves can resuspend and transport sand in shallow water, but during more normal weather and in greater depths, the effect of waves on bottom sediments is negligible. The wind on the shelf usually blows from the east or southeast, producing surface currents toward the west or southwest.

At most of the Year 4 and 5 stations, the substrate consisted of relatively smooth limestone covered with a shallow, shifting layer of calcareous sand. In many locations, bared limestone was visible, while in others, outcroppings projected a meter or two upward from flat bottom. In deeper water, loose and cemented calcareous algal nodules covered large patches between sandy areas.

2.2 STATION DESCRIPTIONS

A summary of individual station characteristics is presented in Table 2-1. This table includes a description of the station location, depth, substrate type, biological assemblage, years during which the station was studied, hydrographic and chemical oceanographic data, and dynamic physical oceanographic characteristics (current and wave data). In addition to this table, a brief description of each Year 5 station is presented (in order of increasing water depth).

TABLE 2-1. STATION DESCRIPTION SUMMARY

GENERAL STATION INFORMATION FOR THE YEAR 5 STATIONS

Station	Year*	Depth (m)	Latitude (N)	Longitude (W)	Lease Block**	Distance*** from Shore (km)	Substrate†	Assemblage††
44	3,4,5	13	26°17.71'	82°12.66'†††	CH 697	20	TS-HS	In-Live I
55	5	27	24°36.17'	82°41.96'	TLL	175	TS-HS	In-Live I
7	1,2,5	32	26°16.98'	82°43.66'	CH 686	58	TS-HS	In-Mid Live II
52	3,4,5	13	25°17.53'	81°39.82'	PR 655	48	TS-HS	In-Live I
21	1,2,4,5	47	25°17.26'	82°52.16'	PR 683	133	TS-HS	In-Mid Live II
23	1,2,4,5	74	25°16.89'	83°37.79'	PR 667	194	AN-S-D	Mid-Algal
29	1,2,4,5	60	24°47.51'	83°41.19'	DT 138	229	AN-S-D	<u>Agaricia</u>
36	4,5	126	25°16.50'	83°57.21'	PR 661	219	TS-HS-D	Out Crinoid

*Years during which data were collected.

**CH = Charlotte Harbor.
PR = Pulley Ridge.
DT = Dry Tortugas.
TLL = falls within Three League Line.

***Distance to nearest point of land excluding the Florida Keys.

†TS-HS = thin sand over hard substrate.
AN-S-D = algal nodules over sand with depressions.
TS-HS-D = thin sand over hard substrate with depressions.

††In-Live I = Inner Shelf Live-Bottom Assemblage I.
In-Mid Live II = Inner and Middle Shelf Live-Bottom Assemblage II.
Mid-Algal = Middle Shelf Algal Nodule Assemblage.
<u>Agaricia</u> = <u>Agaricia</u> Coral Plate Assemblage.
Out Crinoid = Outer Shelf Crinoid Assemblage.

†††Location of array.

SUMMARY OF NEAR-BOTTOM HYDROGRAPHIC AND WATER CHEMISTRY CHARACTERISTICS FROM 5-YEAR FIELD STUDY*

Station Number	Salinity (°/oo)	Temperature (°C)	DO (mg/l)	Transmissivity (%)	Light Pen. (K^1)	Chl. a (mg/m^3)	NO_3 - NO_2 (umole)	PO_4 (umole)	SiO_2 (umole)
44	34.8 - 36.0	20.3 - 29.6	5.6 - 10.1	77-100	0.14 - 0.38	ND	ND	ND	ND
55	35.8 - 36.5	22.0 - 28.0	5.9 - 9.3	83-94	0.11 - 0.19	ND	ND	ND	ND
7	35.6 - 36.5	19.1 - 27.8	7.7 - 9.4	90-99	0.08 - 0.17	0.1 - 0.9	0.1 - 0.3	<0.1 - 0.1	1.0 - 3.0
52	35.1 - 36.3	17.0 - 30.8	6.3 - 9.4	67-100	0.11 - 1.13	ND	ND	ND	ND
21	35.9 - 36.7	19.5 - 27.3	6.1 - 10.3	82-100	0.08 - 0.68	0.5 - 1.0	0.1 - 0.3	<0.1 - 0.1	1.0 - 2.0
23	36.1 - 36.7	17.5 - 24.3	6.1 - 9.3	87-97	0.06 - 0.11	0.3 - 0.6	0.8 - 4.0	0.1 - 0.4	1.0 - 3.5
29	36.1 - 36.6	17.5 - 26.0	6.4 - 8.6	86-98	0.07 - 0.19	0.1 - 0.6	2.0 - 4.0	0.2 - 0.3	1.0 - 2.0
36	36.1 - 36.7	15.0 - 23.8	4.4 - 6.6	88-98	0.06 - 0.08	<0.1 - 0.1	5.0 - 10.0	0.6 - 0.7	3.0 - 5.0

*Notes with respect to individual parameters:
Salinity—ranges are based on 4 to 12 data points collected during 1 to 5 years.
Temperature—Ranges are based on periodic measurements as well as continuous measurements over 1 to 2 years.
Dissolved Oxygen—same as salinity.
Transmissivity—same as salinity. Years 4 and 5 data adjusted by cruise so that the maximum was 100 percent.
Light Penetration—calculated using $1.7/D_s$, where secchi readings (D_s) were made during Years 4 and 5.
Chlorophyll <u>a</u>—ranges are based on 4 data points (Years 1 and 2) except for Station 36 (Year 2 only).
NO_3 - NO_2—same as Chlorophyll <u>a</u>.
PO_4—same as Chlorophyll <u>a</u>.
SiO_2—same as Chlorophyll <u>a</u>.

SUMMARY OF DYNAMIC PHYSICAL OCEANOGRAPHIC DATA FOR YEARS 4 AND 5

Station Number	Average Current Speed (cm/sec)	Modal Current Speed (cm/sec)	Modal Current Direction	Current Speed $\geq$20 cm/sec (%)	Net Current Speed (cm/sec)	Net Current Direction (°Ton)	Wave Orbital Velocity $\geq$20 cm/sec (%)
44	8.4	5 - 10	E	4.6	1.4	132	3.89*
55	10.4	0 - 5	NNE - SSW	13.3	1.4	176	1.86
7	5.2	0 - 5	E	0.6	1.0	182	1.91†
52	10.8	0 - 5	E - W	13.7	1.4	128	2.99
21	7.2	5 - 10	ENE - WSW	1.2	0.9	138	0.12†
23	7.5	0 - 5	ESE - WNW	1.8	3.1	253	0.01†
29	8.9	5 - 10	SW	4.6	3.0	175	0.05†
36	8.9	5 - 10	S	5.3	1.8	83	0.0†

*Estimated using Station 52 wave data.

Station 52, located in 13 m of water and 48 km from shore, was studied for 3 years. Station 52 was designated by Woodward Clyde Consultants/ Continental Shelf Associates (1983) as an Inner Shelf Live-Bottom Assemblage I with thin sand over a hard substrate. The sand was coarse [mean phi (ϕ) of 0.9], primarily calcium carbonate [($CaCO_3$) 94%], with an organic carbon content of 2.6%. The average near-bottom current speed was 10.8 cm/sec; a net current with an average speed of 1.4 cm/sec set consistently to the southeast. Currents and wave induced orbital velocities exceeded 20 cm/sec 14 and 3% of the time, respectively. With the exception of Stations 44 and 55, these values were at least a factor of two higher than the other stations. This was reflected in the higher average annual sediment deposition rate (estimated from sediment trap data) of 360 metric tons per square kilometer per day ($MT/km^2/day$). Sediment resuspension probably accounts for much of the turbidity in the water as recorded with time-lapse cameras, transmissometers and secchi disk readings. Transmissivity, was more variable than any other station ranging from 67 to 100%. Station 52 also exhibited the greatest variability in both salinity and temperature with ranges of 35.1 to 36.3 $^o/oo$ and 17° to 32°C. Other water quality parameters such as dissolved oxygen and pH were less variable. There were no nutrient or chlorophyll data available for Station 52.

Station 44 (studied for three years), also located in 13 m of water, was nearer to shore (20 km) than Station 52. Similar to Station 52, Station 44 was designated as Inner Shelf Live-Bottom Assemblage I with a thin sand over a hard substrate. The $CaCO_3$ (88%) sand was coarse (mean ϕ = 0.8) and had the lowest organic carbon content (1.8%) of all but one station. The highest average annual sediment deposition rate was measured at Station 44 (526 $MT/km^2/day$). This was reflected in transmissivity values as low as 77% and light extinction coefficients of 0.38 and was probably the result of wave orbital velocities that were estimated to exceed 20 cm/sec nearly 4% of the time. Current speeds exceeded 20 cm/sec less than 5% of the time; the average near-bottom current speed was 8.4 cm/sec. A net current speed of 1.4 cm/sec, setting to the southeast was measured. The variability in salinity and temperature was less than at Station 52 with salinity values ranging from 34.8 to 36.0 $^{o}/oo$ and temperatures ranging from 20.3° to 29.6°C. The second highest dissolved oxygen concentration (10.1 mg/l) observed during this study occurred at Station 44. There were no nutrient or chlorophyll data available for this station.

Station 55, located in 27 m of water and 175 km from mainland Florida, was studied for a single year (Year 5). This southernmost station was located between the Dry Tortugas and Marquesas on an important and little understood boundary of the southwest Florida shelf. This station, like the two previously described, was designated as Inner Shelf Live-Bottom Assemblage I with thin sand over a hard substrate. This coarse sand (mean ϕ = 1.2) had the highest $CaCO_3$ content (nearly 97%) and, along with Station 23, had the highest organic carbon content (3%). The third (of the eight stations) highest sediment resuspension value (278 $MT/km^2/day$) occurred at Station 55. This is the result of current speeds and wave induced orbital velocities exceeding 20 cm/sec 13 and 2% of the time, respectively. The average near-bottom current speed (10.4 cm/sec) was second only to Station 52; the net current speed of 1.4 cm/sec (identical to Stations 52 and 44) set due south. The water at Station 55 was clearer and the variability in salinity and temperature (35.8 to 36.5 $^{o}/oo$ and 22.0° to 28.0°C) was less than the two previously described stations. The dissolved oxygen concentrations ranged from 5.9 to 9.3 mg/l; there were no nutrient or chlorophyll data available.

Station 7 (studied for three years), designated as Inner and Middle Shelf Live-Bottom Assemblage II, was located in 32 m of water and 58 km from land. The thin sand overlying the hard substrate was unique in that the $CaCO_3$ content was only 53%. This may be most likely attributed to the influence of Caloosahatchee River. Station 7 was the last station where sediment resuspension exceeded 30 $MT/km^2/day$ (147 $MT/km^2/day$). The wave induced orbital velocities exceeded 20 cm/sec approximately 2% of the time; the current speeds exceeded 20 cm/sec less than 1% of the time. Because of the limited sediment resuspension the water was generally clear. The lowest recorded average current speed (5.2 cm/sec) occurred at Station 7; the net current was also low at 1.0 cm/sec (setting to the south). The variability in salinity and temperature closely paralleled the intermediate-depth stations with salinity values of 35.5 ± 0.5 °/oo and temperature values of 24° ± 5°C. Dissolved oxygen concentrations were the least variable of any of the stations (7.7 to 9.4 mg/l). The near-bottom water at Station 7 was typical of tropical waters being poor in nutrients and chlorophyll.

Station 21 (studied for four years), located in 47 m of water and 133 km from land, like Station 7, was designated as Inner and Middle Shelf Live-Bottom Assemblage II with thin sand over a hard substrate. The calcium carbonate (92%) sands at Station 21 were the finest (mean ϕ = 1.8) encountered at the eight stations and had an organic carbon content of nearly 3%. The average annual sediment deposition rate was 22 MT/km^2/day which was nearly an order of magnitude lower than the next highest station (Station 7). Because of limited sediment resuspension the water was clear and there was no evidence of turbidity on the time-lapse camera film. Current speeds exceeded 20 cm/sec slightly over 1% of the time; wave orbital velocities exceeded 20 cm/sec approximately 0.1% of the time. This, undoubtedly, accounts for the limited sediment resuspension. The variability in salinity and temperature was typical of the deeper stations with values of approximately 35.5 ± 0.5 °/oo and 23.5° ± 4°C, respectively. The dissolved oxygen concentrations were, however, more variable with values ranging from 6.1 to 10.3 mg/l (the highest dissolved oxygen concentration encountered during the 5-year study). The highest chlorophyll concentration also was measured at Station 21 (1.0 mg/m^3). Although this value was not comparable to concentrations measured in blooms in fertile coastal waters, it is above the concentrations normally encountered in temperate waters. The nitrate-nitrite concentration range 0.1 to 0.3 micromoles (um) was lower than the remaining deep water stations, but this could be the result of the increased productivity. Phosphate and silicate concentrations were low and typical for tropical waters.

Station 29 (studied for four years), along with Station 23, displayed the greatest variability in depth within a 1-km^2 station with an average depth of 64 m, but with depths as shallow as 59 m. Station 29 was designated as *Agaricia* Coral Plate Assemblage. The bottom was virtually continuous coral plate with little or no unconsolidated sediment exposed (thus precluding sediment sampling). There was virtually no sediment resuspension because of this continuous algal plate and the fact that wave orbital velocities rarely, if ever, exceeded 20 cm/sec (current speeds did, however, exceed 20 cm/sec approximately 4.5% of the time). The average near-bottom current speed was 8.9 cm/sec, and the net current, setting to the south, was 3.0 cm/sec. With respect to salinity, temperature, and dissolved oxygen, Station 29 showed the least variability of any station with values ranging from 36.1 to 36.6 ^{o}/oo 17.5° to 26.0°C, and 6.4 to 8.6 mg/l, respectively. The second lowest chlorophyll and the second highest nitrate-nitrite concentrations measured occurred at Station 29 at 0.1 to 0.6 mg/m^3 and 2.0 to 4.0 uM, respectively. These values would be expected for water depths greater than 50 m.

Station 23 (studied for four years), located 194 km from land, displayed variability in depth within a 1-km^2 station equivalent to Station 29 with an average depth of 74 m, but with depths as shallow as 69 m. Station 23 was designated as Middle Shelf Algal Nodule Assemblage with algal nodules over sand with depressions. The algal nodule layer accounted for 93% of the bottom; the remainder was a calcium carbonate sediment (96%) with 3% organic carbon (the highest encountered at all stations). The sediment grain sizes (excluding the nodules) at this station was the most variable encountered with mean ϕ values ranging from 2.3 to -1.1 (fine sand to fine gravel). Sediment resuspension was negligible at

Station 23. This was reflected by clear water and no incidence of turbidity as observed on the time-lapse camera. Current speed exceeded 20 cm/sec approximately 2% of the time; wave orbital velocities exceeding 20 cm/sec, however, were virtually nonexistent. The average current speed was the second lowest speed measured at 7.5 cm/sec. The net current, however, was the highest measured with a value of 3.1 cm/sec setting to the west-southwest. With the exception of Station 29, this value was nearly twice as high as the net current measured at all other stations. The salinity, temperature, and dissolved oxygen values were some of the least variable with values of 36.4 ± 0.3 ^{o}/oo, 21° ± 3.5°C, and 7.7 ± 1.6 mg/l, respectively. Chlorophyll concentrations (0.3 to 0.6 mg/m^3) were comparable to average temperate waters; the nutrient concentrations were comparable to the nutrient concentrations measured at the other stations.

Station 36, located 219 km from the nearest land, was the most remote and deepest station (125 m). This station (studied for three years) was designated as an Outer Shelf Crinoid Assemblage with thin sand over a hard substrate and interspersed with occasional depressions. The $CaCO_3$ sand (95%) contained approximately 3% organic carbon. The coarsest sediments (mean ϕ = 0.8) were found at this station and were classified as very coarse sand. This station is too deep for surface waves to initiate sediment resuspension, yet the absence of fine sediments on the bottom and small amounts of sediment in the sediment traps seem to suggest that sediment resuspension or transport from other areas does occur to some small degree. This sediment resuspension could be caused by currents (current speeds greater than 20 cm/sec occur slightly over 5% of the time) or possibly by internal waves breaking on the shelf break. The average near-bottom current speed was 8.9 cm/sec; the net current was 1.8 cm/sec and set to the east. The ranges of salinity, temperature, and dissolved oxygen were typical of the deeper stations, however, the highest salinity (36.7 ^{o}/oo), the lowest temperature

(15.0°C), and the lowest dissolved oxygen concentration (4.4 mg/l) were measured at this station. This, along with the lowest chlorophyll and highest nutrient concentrations would be expected for deeper stations.

2.3 PHYSICAL DYNAMICS

The principal objectives of the current and wave monitoring portion of this study are to further define the physical environment of the southwest Florida shelf and evaluate the interactions of the physical environment with the benthic community. Stresses may be imposed on the biota by water movement either directly or indirectly through sediment resuspension or the transport of plankton, larvae, nutrients, or pollutants across the shelf and throughout the water column.

The near-bottom currents of the shallower nearshore stations of the southwest Florida shelf are dominated by the semidiurnal component of the tides. This is evident from the nearly rectilinear motion of the water with a periodicity of approximately 6 hours (e.g., Station 52, Figure 2-1). The predominance of the semidiurnal component of the tides also is evident as a pronounced energy peak in the three-dimensional power spectra presented in Figure 2-2. These energy spectra also reveal that the semidiurnal component becomes less important farther offshore in deeper waters, and that the diurnal component begins to predominate (at the latitude of the study area, however, the local inertial frequency is at nearly the same frequency as the diurnal component, therefore, it is difficult to separate the two energy bands). In Figure 2-1 the predominance of the diurnal (and inertial) frequencies is demonstrated by the speed-direction plots for Station 7 where the current direction is more evenly distributed (suggesting a more elliptical, rather than rectilinear, motion) and the major peaks in current speed occur every 12 hours with only small peaks at the 6-hour interval.

The power spectra for the summer currents and the winter currents were similar. The differences are illustrated in Figure 2-2. Energy levels

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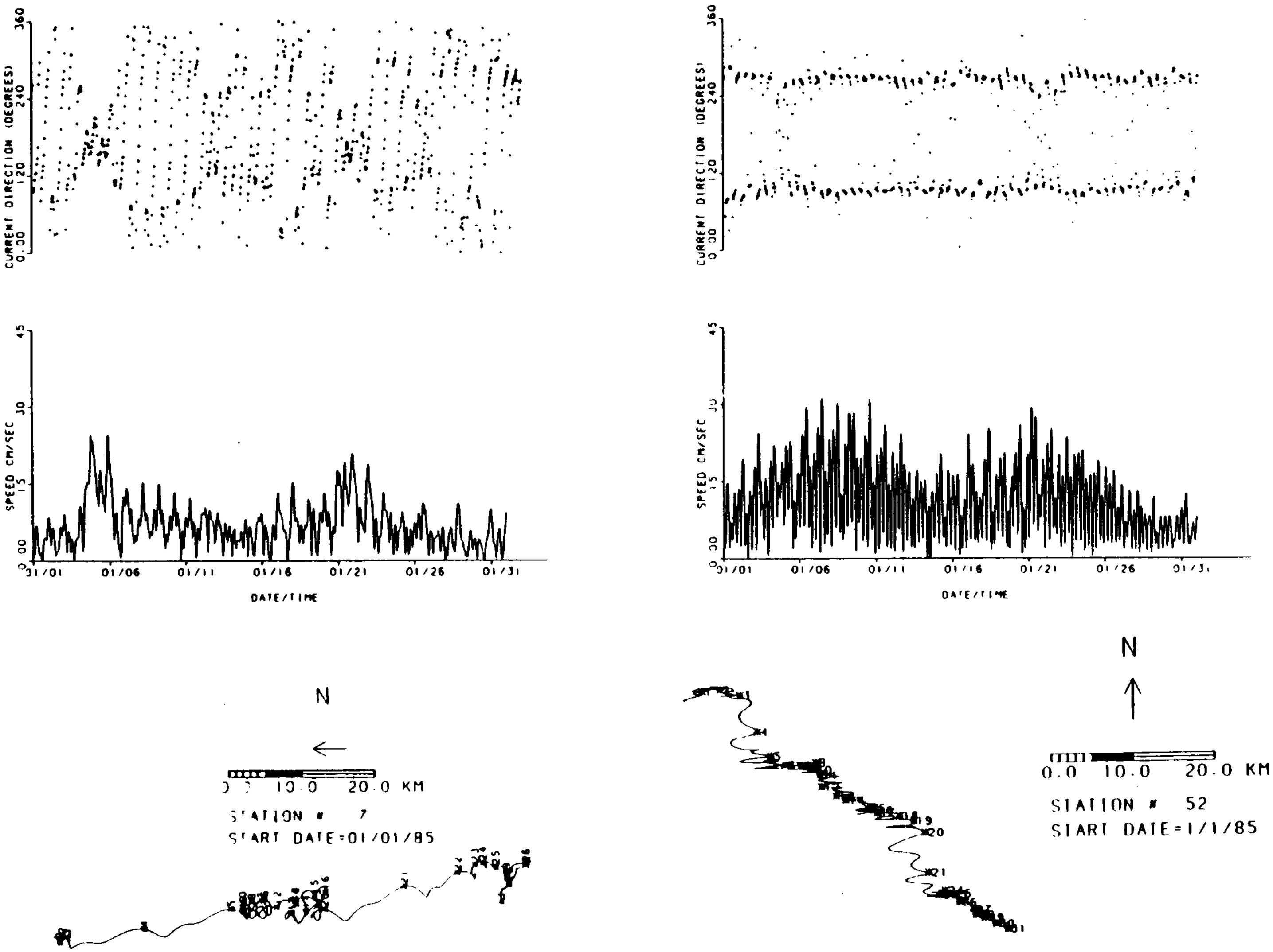


Figure 2-1 STATIONS 7 AND 52 CURRENT SPEED, DIRECTION AND PROGRESSIVE VECTOR PLOTS – JANUARY 1985

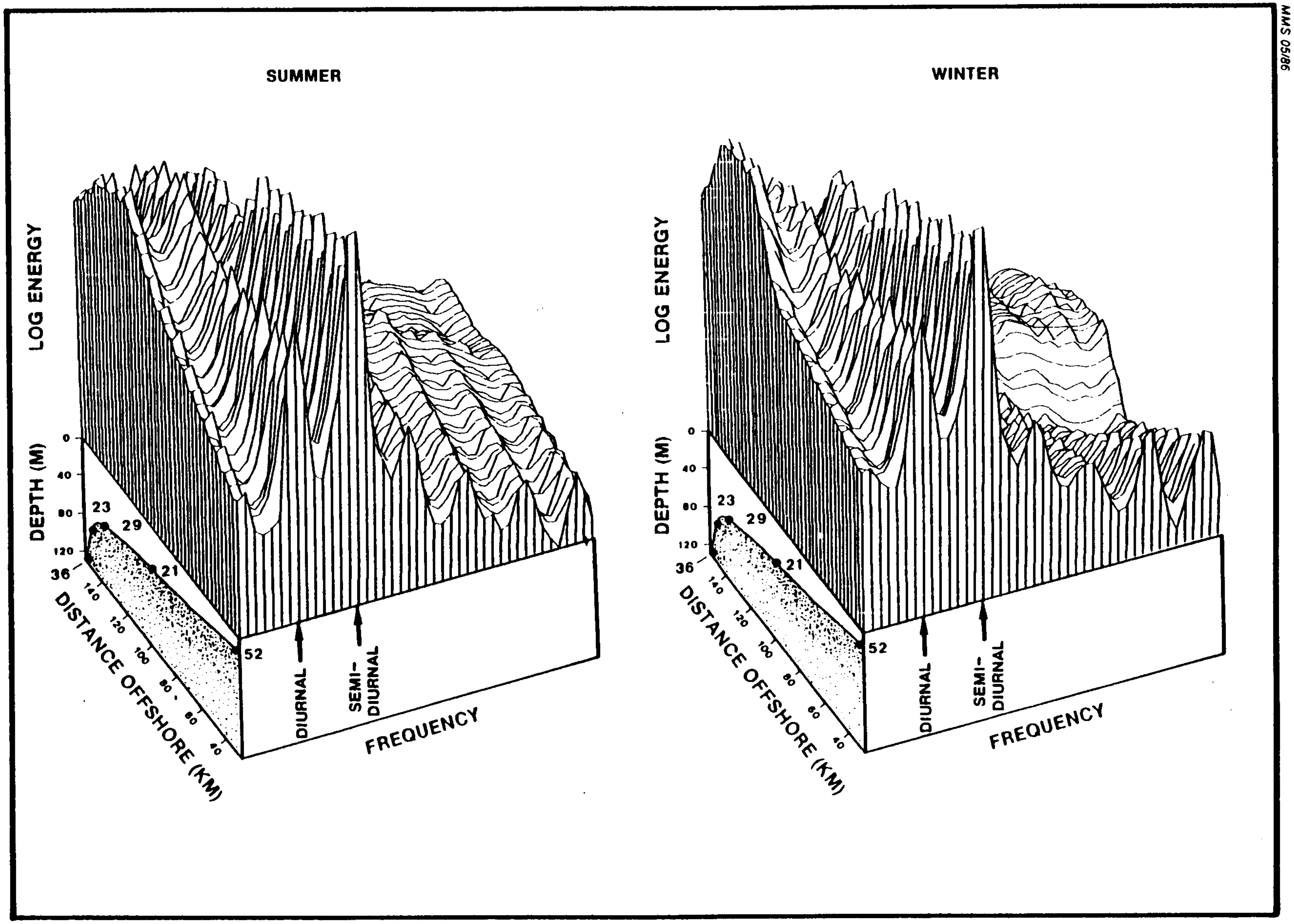


Figure 2-2 3-D SUMMER (1984) AND WINTER (1983-84) ENERGY SPECTRA, EAST-WEST COMPONENT in the diurnal component in deeper water were higher in the summer than in the winter, probably as a result of increased energy at the inertial frequency because inertial currents generally are much stronger in the summer when there is a thermocline. The winter spectra, however, had higher energy levels at the low-frequency components. This was a direct result of the higher average current speeds in the winter that were produced by the stronger winter winds.

Progressive vector diagrams (examples of which are presented in Figure 2-1) were used to estimate the net currents for each station. These net currents (summarized in Table 2-1) provide some indication of the speed with which materials (sediment, plankton, nutrients, or pollutants) are transported into and out of the study area. Generally, the deeper stations had less consistent net currents (with respect to direction) while the net currents at the shallower stations exhibited considerable constancy, usually setting to the south or southeast at less than 2 cm/sec.

At least two short-term phenomena significantly affect the current regime on the southwest Florida shelf. The first phenomenon involves the intrusion of Loop Current eddies onto the shelf. These intrusions are characterized by a noticeable increase in current speed, a tendency for the current direction to become constant, and an increase in the near-bottom water temperature of 2° to 4°C. An example of the effects of two typical intrusions (at Station 36) is shown in Figure 2-3. The effects of an intrusion may extend nearly across the shelf, but generally stay outside of the 20-m isobath. The second phenomenon to affect the current regime is the passage of major storms (tropical or hurricanes). The effects of the passage through the study area of Tropical Storm Bob in July 1985 are shown in Figure 2-4. The most severe effects were at Stations 7 and 44 nearest the center of the storm. The current speeds increased from an average of less than 10 cm/sec to peak speeds of approximately 60 cm/sec. The effects decreased with distance from the

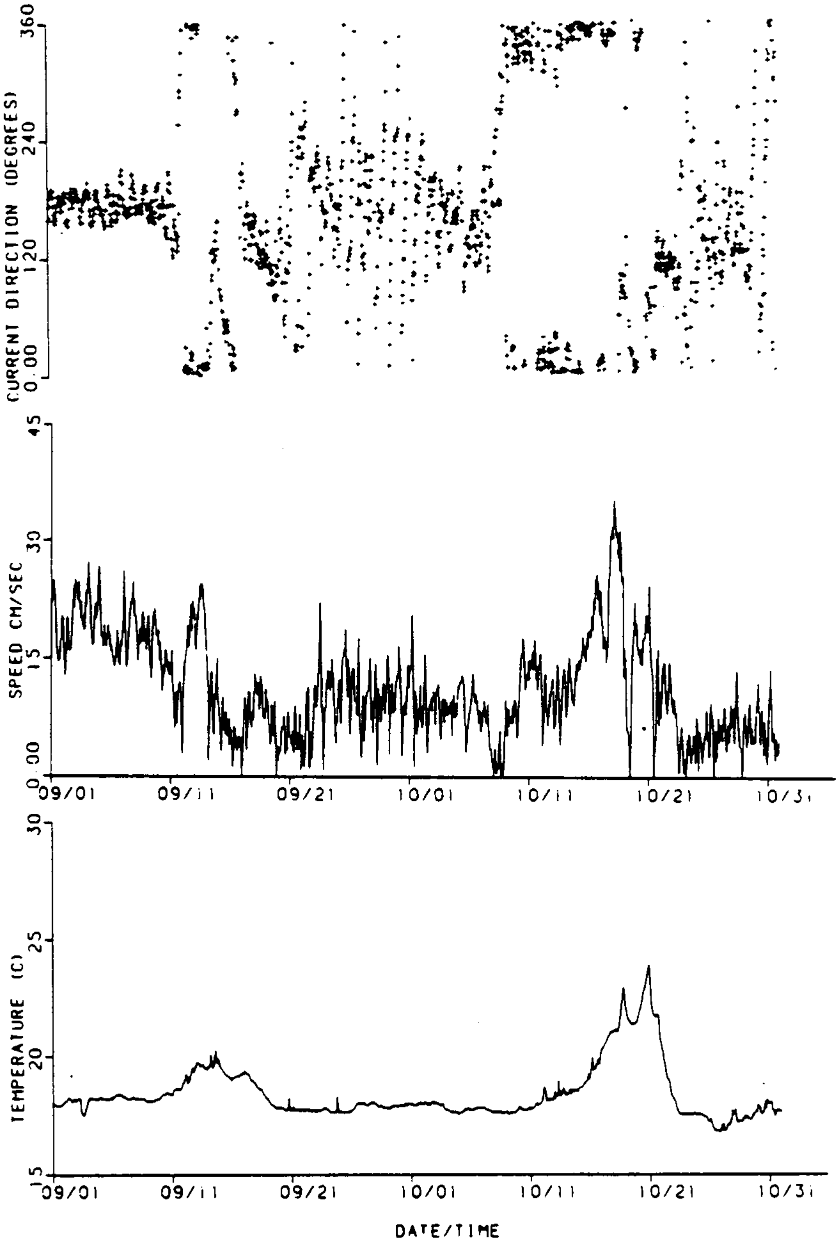


Figure 2-3 STATION 36 CURRENT AND TEMPERATURE DATA SHOWING LOOP CURRENT INTRUSION

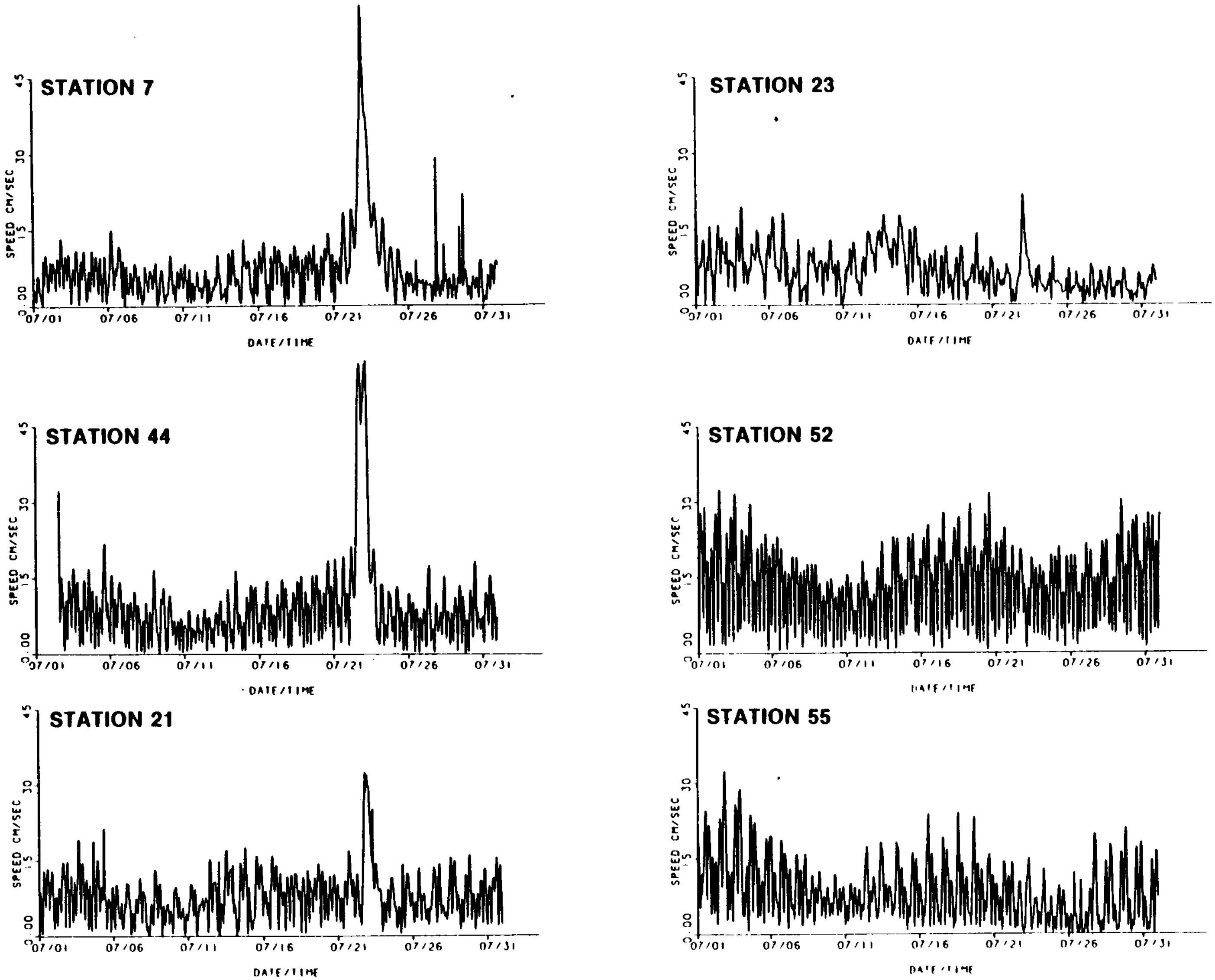


Figure 2-4 CURRENT SPEEDS RESULTING FROM TROPICAL STORM BOB -- JULY, 1985

MMS 05/86

center (e.g., Stations 55 and 52). Storms such as this also had some effect on the waves and tides in the region. The change in water level resulting from a storm, although detectable, was usually less than 0.5 m. The effect of a storm passage on the wave regime was considerably more evident with waves exceeding 5 m.

Based on Year 4 and 5 results, it appears that the wind-driven currents, tidal currents, and surface wave-induced bottom orbital velocities operate in concert to resuspend and transport significant quantities of sediment in the study area. Further, it appears that routinely recurring weather patterns do not cause significant quantities of sediment resuspension and transport at depths exceeding 50 m. This is supported by the sediment trap data presented in the station descriptions and the percentage of the time current speeds or wave induced orbital motion exceeded 20 cm/sec. Those stations with the greatest sediment resuspension were also the stations where wave induced motion exceeded 20 cm/sec more often (i.e., the shallower stations). The speed of 20 cm/sec was used as a criterion because that is the approximate current speed that can initiate motion in unconsolidated ocean sediments (Wimbush and Lesht, 1979). At Stations 52 and 55, the currents exceeded 20 cm/sec more than 13% of the time, indicating that these areas are more susceptible to sediment movement. The current speeds at Station 36 (125 m) exceeded 20 cm/sec 5.6% of the time; however, only minute quantities of sediment were collected in the sediment traps because virtually no wave energy penetrated to the bottom. Consequently, the currents may have been strong enough to initiate sediment movement in the form of bed load transport but were not strong enough to resuspend the sediments. Wave motion probably plays the most important role in sediment transport at those stations in water less than 50 m in depth.

During the 5-year program an extensive data base was collected describing the physical environment on the Southwest Florida Shelf.

A summary of these data and information collected from literature sources is presented in Figure 2-5 for the five major Group II Stations. This figure is presented not only to provide a description of the physical environment as it changes with depth, but also to illustrate the stresses or ranges in the physical parameters that help determine the composition of the biological communities. The parameters that are summarized in the figure include:

1. Bottom description: including characteristic biota, sediment characteristics, biological assemblage type, substrate type, and euphotic zone limit;
2. Energy penetration: including light intensity, sediment deposition (measured in sediment traps), turbidity obscurations (from time-lapse camera data), wave orbital velocities at the bottom, average current speeds, and percent of time the current speed was greater than 20 cm/sec; and
3. Water quality parameters: including ranges of salinity, temperature, dissolved oxygen, and nutrients.

3.0 BIOLOGICAL CHARACTERIZATIONS

3.1 STATION DESCRIPTIONS

Station 52 (depth 13 m) was located in a low-relief, flat area dominated by patches of algae (21% average cover), sponges (8% cover), and very dense stands of gorgonians (over 28,000/ha). Large sponges such as *Ircinia campana* were prominent benthic features (over 400/ha). These sessile organisms projected upward either from exposed limestone or through a thin sand veneer covering the hard substrate, and provided shelter for other invertebrates and fishes. More than 100 different invertebrates and 22 benthic algae were identified in dredge samples from Station 52.

Fish were abundant at Station 52--40 fishes were identified in underwater television transects and 38 were collected in trawl samples. Trawls collected an average of 71 individuals per 10-minute tow, with the most

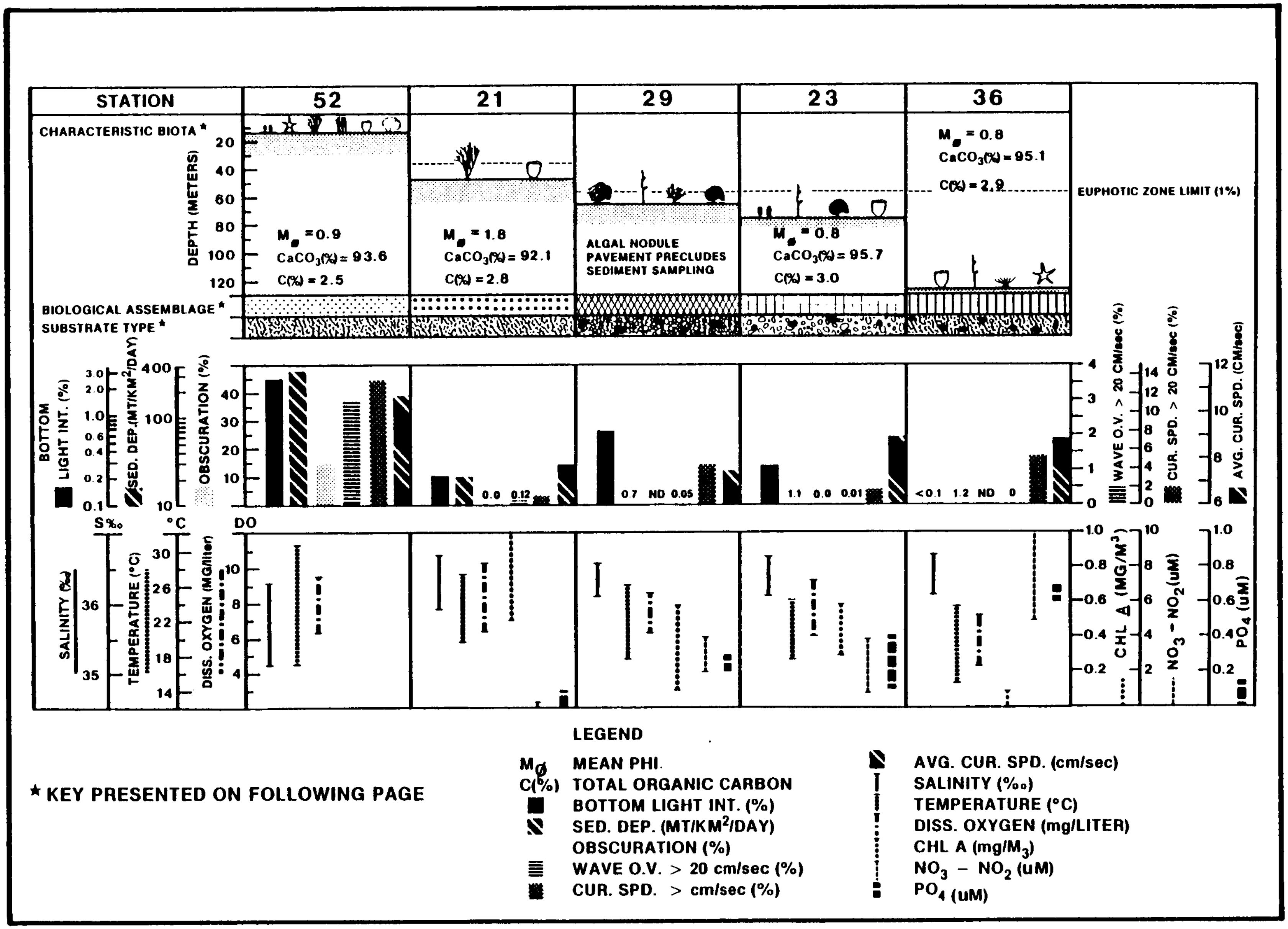
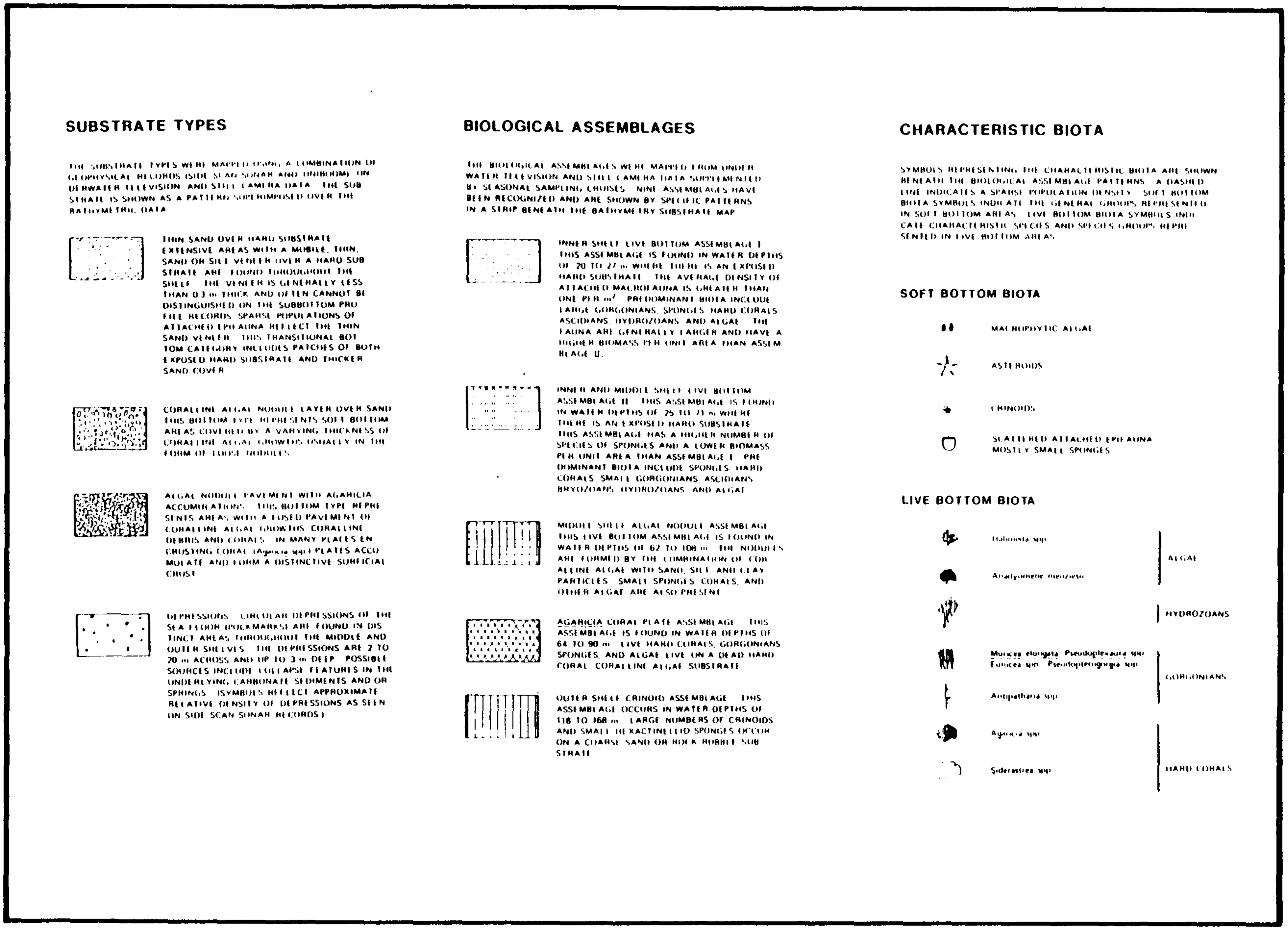


Figure 2-5 CROSS-SHELF BIOLOGICAL, PHYSICAL, AND CHEMICAL STATION CHARACTERIZATION OF SELECT GROUP II STATIONS



SUBSTRATE TYPES

THE SUBSTRATE TYPES WERE MAPPED USING A COMBINATION OF GEOPHYSICAL RECORDS (SIDE SCAN SONAR AND UNIBOOM), UNDERWATER TELEVISION AND STILL CAMERA DATA. THE SUBSTRATE IS SHOWN AS A PATTERN SUPERIMPOSED OVER THE BATHYMETRIC DATA.

THIN SAND OVER HARD SUBSTRATE. EXTENSIVE AREAS WITH A MOBILE, THIN, SAND OR SILT VENEER OVER A HARD SUBSTRATE ARE FOUND THROUGHOUT THE SHELF. THE VENEER IS GENERALLY LESS THAN 0.3 m THICK AND OFTEN CANNOT BE DISTINGUISHED ON THE SUBBOTTOM PROFILE RECORDS. SPARSE POPULATIONS OF ATTACHED EPIFAUNA REFLECT THE THIN SAND VENEER. THIS TRANSITIONAL BOTTOM CATEGORY INCLUDES PATCHES OF BOTH EXPOSED HARD SUBSTRATE AND THICKER SAND COVER.

CORALLINE ALGAL NODULE LAYER OVER SAND. THIS BOTTOM TYPE REPRESENTS SOFT BOTTOM AREAS COVERED BY A VARYING THICKNESS OF CORALLINE ALGAL GROWTHS USUALLY IN THE FORM OF LOOSE NODULES.

ALGAL NODULE PAVEMENT WITH AGARICIA ACCUMULATIONS. THIS BOTTOM TYPE REPRESENTS AREAS WITH A FUSED PAVEMENT OF CORALLINE ALGAL GROWTHS, CORALLINE DEBRIS AND CORALS. IN MANY PLACES ENCRUSTING CORAL (*Agaricia* spp.) PLATES ACCUMULATE AND FORM A DISTINCTIVE SURFICIAL CRUST.

DEPRESSIONS. CIRCULAR DEPRESSIONS OF THE SEA FLOOR (POCKMARKS) ARE FOUND IN DISTINCT AREAS THROUGHOUT THE MIDDLE AND OUTER SHELVES. THE DEPRESSIONS ARE 2 TO 20 m ACROSS AND UP TO 3 m DEEP. POSSIBLE SOURCES INCLUDE COLLAPSE FEATURES IN THE UNDERLYING CARBONATE SEDIMENTS AND/OR SPRINGS. (SYMBOLS REFLECT APPROXIMATE RELATIVE DENSITY OF DEPRESSIONS AS SEEN ON SIDE SCAN SONAR RECORDS.)

BIOLOGICAL ASSEMBLAGES

THE BIOLOGICAL ASSEMBLAGES WERE MAPPED FROM UNDERWATER TELEVISION AND STILL CAMERA DATA SUPPLEMENTED BY SEASONAL SAMPLING CRUISES. NINE ASSEMBLAGES HAVE BEEN RECOGNIZED AND ARE SHOWN BY SPECIFIC PATTERNS IN A STRIP BENEATH THE BATHYMETRY SUBSTRATE MAP.

INNER SHELF LIVE BOTTOM ASSEMBLAGE I. THIS ASSEMBLAGE IS FOUND IN WATER DEPTHS OF 20 TO 27 m WHERE THERE IS AN EXPOSED HARD SUBSTRATE. THE AVERAGE DENSITY OF ATTACHED MACROFAUNA IS GREATER THAN ONE PER m^2. PREDOMINANT BIOTA INCLUDE LARGE GORGONIANS, SPONGES, HARD CORALS, ASCIDIANS, HYDROZOANS AND ALGAE. THE FAUNA ARE GENERALLY LARGER AND HAVE A HIGHER BIOMASS PER UNIT AREA THAN ASSEMBLAGE II.

INNER AND MIDDLE SHELF LIVE BOTTOM ASSEMBLAGE II. THIS ASSEMBLAGE IS FOUND IN WATER DEPTHS OF 25 TO 71 m WHERE THERE IS AN EXPOSED HARD SUBSTRATE. THIS ASSEMBLAGE HAS A HIGHER NUMBER OF SPECIES OF SPONGES AND A LOWER BIOMASS PER UNIT AREA THAN ASSEMBLAGE I. PREDOMINANT BIOTA INCLUDE SPONGES, HARD CORALS, SMALL GORGONIANS, ASCIDIANS, BRYOZOANS, HYDROZOANS, AND ALGAE.

MIDDLE SHELF ALGAL NODULE ASSEMBLAGE. THIS LIVE BOTTOM ASSEMBLAGE IS FOUND IN WATER DEPTHS OF 62 TO 108 m. THE NODULES ARE FORMED BY THE COMBINATION OF CORALLINE ALGAE WITH SAND, SILT, AND CLAY PARTICLES. SMALL SPONGES, CORALS, AND OTHER ALGAE ARE ALSO PRESENT.

AGARICIA CORAL PLATE ASSEMBLAGE. THIS ASSEMBLAGE IS FOUND IN WATER DEPTHS OF 64 TO 90 m. LIVE HARD CORALS, GORGONIANS, SPONGES, AND ALGAE LIVE ON A DEAD HARD CORAL, CORALLINE ALGAE SUBSTRATE.

OUTER SHELF CRINOID ASSEMBLAGE. THIS ASSEMBLAGE OCCURS IN WATER DEPTHS OF 118 TO 168 m. LARGE NUMBERS OF CRINOIDS AND SMALL HEXACTINELLID SPONGES OCCUR ON A COARSE SAND OR ROCK RUBBLE SUBSTRATE.

CHARACTERISTIC BIOTA

SYMBOLS REPRESENTING THE CHARACTERISTIC BIOTA ARE SHOWN BENEATH THE BIOLOGICAL ASSEMBLAGE PATTERNS. A DASHED LINE INDICATES A SPARSE POPULATION DENSITY. SOFT BOTTOM BIOTA SYMBOLS INDICATE THE GENERAL GROUPS REPRESENTED IN SOFT BOTTOM AREAS. LIVE BOTTOM BIOTA SYMBOLS INDICATE CHARACTERISTIC SPECIES AND SPECIES GROUPS REPRESENTED IN LIVE BOTTOM AREAS.

SOFT BOTTOM BIOTA

MACROPHYTIC ALGAE

ASTEROIDS

CRINOIDS

SCATTERED ATTACHED EPIFAUNA
MOSTLY SMALL SPONGES

LIVE BOTTOM BIOTA

Halimeda spp.
Anadyomene menziesii
ALGAE

HYDROZOANS

Muricea elongata, *Pseudoplexaura* spp.
Eunicea spp., *Pseudopterogorgia* spp.
Antipatharia spp.
GORGONIANS

Agaricia spp.
Siderastrea spp.
HARD CORALS

Figure 2-5 (cont'd)

abundant species being the white grunt, *Haemulon plumieri* (19/tow); the hogfish, *Lachnolaimus maximus* (11/tow); and the scrawled cowfish, *Lactophrys quadricornis* (7/tow). The most abundant species seen with the underwater television were the white grunt (278/ha); the hogfish (39/ha); and the red grouper, *Epinephelus morio* (19/ha).

The instrument array and settling plates at Station 52 were rapidly overgrown with sessile organisms, including the octocoral, Telesto; barnacles, *Balanus trigonus*; oysters, *Isognomon radiatus*; bryozoans; ascidians; and other sessile forms. The array was visited by many fishes, such as jewfish, *Epinephelus itajara*, which took up residence along with schools of gray snappers, *Lutjanus griseus*; porkfish, *Anisotremus virginicus*; and tomtates, *Haemulon aurolineatum*. Loggerhead sea turtles, *Caretta caretta*, and a leatherback turtle, *Dermochelys coriacea*, were also attracted to the array.

Station 44 (depth 13 m) was located in an area primarily covered with carbonate sand, with scattered dense gorgonian beds (about 4,500/ha), and large sponges (*Ircinia campana*, 51/ha). Overall sponge coverage was low (2%). The tracks of burrowing echinoids were often seen in the sand during underwater television transects, and melittid echinoids (sand dollars) and asteroids were abundant (approximately 600 and 50/ha, respectively).

Fifty kinds of benthic invertebrates were identified in dredge samples, including both soft-bottom or grass-bed species such as the flat sea biscuit, *Clypeaster subdepressus*; and the spiny beaded sea star, *Astropecten duplicatus*; and sessile forms such as ark shells (*Anadara nobilis*, *Barbatia candida*), scleractinian corals (*Solenastrea hyades*, *Siderastrea siderea*), and gorgonians.

The fish community at Station 44 was relatively sparse, averaging 12 individuals per 10-minute tow, or 12 individuals/ha in underwater television transects. The most abundant fishes seen with the television were the round scad, *Decapterus punctatus* (24/ha) and the tomtate, *Haemulon aurolineatum* (10/ha). The most common fishes collected by trawling were unidentified engraulids (7/tow).

The array at Station 44 was heavily colonized by sessile organisms such as ascidians; barnacles, *Balanus trigonis*; oysters, *Isognomon radiatus*; and hydroids. The array attracted many fishes; those most often observed in time-lapse films from the array included sand perch, *Diplectrum bivittatum* or *D. formusum*; the jackknife-fish, *Equetus lanceolatus*; and juvenile tomtates, *Haemulon aurolineatum*. Jewfish, *Epinephelus itajara*, were also recorded by the time-lapse camera.

Station 55 (depth 27 m) was located in a relatively flat area, with alternating patches of sand and exposed limestone substrate. A large proportion of the bottom was covered with large benthic organisms. The most conspicuous species in underwater television surveys at Station 55 were gorgonians in very dense patches (average abundance over 54,000/ha); various sponges (17% cover); and algae (21% cover). Low-profile sponges hid many small scleractinian corals such as *Solenastrea hyades* that were visible to divers. Larger sponges such as *Ircinia campana* and *Ircinia strobilina* were also common (144 and 142/ha, respectively).

Triangular dredge samples from Station 55 confirmed the existence of a complex benthic community. More invertebrates (121 taxa) were collected at Station 55 than at any other station. Of the 50 gorgonians identified in this study, 36 were collected at Station 55, including 20 species not found at other stations. Eighteen scleractinian corals were also taken by the dredge, including many tropical species such as *Solenastrea hyades*, *S. bournoni*, *Meandrina meandrites*, *Dichocoenia stokesii*, and various agariciids. Many other invertebrates and plants associated with hard substrates and coral communities were collected.

Twenty-five fishes were present in trawl samples from Station 55, which averaged 17 individuals per 10-minute tow. The most common species were the scrawled cowfish, *Lactophrys quadricornis* (three/tow); the gray snapper, *Lutjanus griseus* (two/tow); and the red grouper, *Epinephelus morio* (one/tow). The gray snapper was observed most frequently through the underwater television camera (six/ha), along with the longsnout butterflyfish, *Chaetodon aculeatus* and an unidentified porgy (five/ha); and the white grunt, *Haemulon plumieri*.

Bacterial mats, hydroids, the oyster *Isognomon radiatus*, bryozoans, ascidians, and other fouling organisms grew on the array and its settling plates. The wet weight of the sessile community on plates was approximately 25% of that found on equivalent plates at shallower stations.

More fishes were observed with the time-lapse camera at the array at Station 55 than at any other station. The most frequently sighted fishes were the jewfish, *Epinephelus itajara*; the white grunt, *Haemulon plumieri*; the gray angelfish, *Pomacanthus arcuatus*; and the blue angelfish, *Holocanthus bermudensis*. The time-lapse camera at Station 55 also revealed various dynamic processes, such as drastic seasonal changes in the abundance of benthic foliose algae, diurnal periodicity of gorgonian polyp extension and retraction, rates of movement of sea stars, and resuspension of sediment by the spotted goatfish, *Mulloidichthys maculatus*.

Station 7 (depth 32 m) was located in a sandy, flat area with scattered rock outcrops and patches of calcareous shell hash. The most abundant benthic organisms seen in underwater television surveys were gorgonians (566/ha), low-lying sponges (15% cover), and algae (24% cover).

Samples collected with triangular dredges included 96 invertebrates and 25 algae. Many soft-bottom forms [clams (*Chione*, *Tellina*, *Semele*), scallops, penaeid shrimps, and many crabs] were taken. No gorgonians were collected with the dredge, but 14 scleractinian corals were found in samples even though they were not visible with the underwater television.

Twenty-four fishes were collected by trawling at Station 7, averaging 37 per ten-minute tow. The most abundant species in trawls were the dusky flounder; *Syacium papillosum*, the offshore lizardfish, *Synodus poeyi* (8 each/tow); the inshore lizardfish, *Synodus foetens*; the sand perch, *Diplectrum formosum*; and the jackknife-fish, *Equetus lanceolatus* (all 4/tow). Fishes most often observed in underwater television transects included the blue goby, *Ioglossus calliurus* (41/ha); the jackknife-fish (16/ha); and the tomtate, *Haemulon aurolineatum* (14/ha).

The settling community that settled on the array and plates at Station 7 was similar in biomass to the community at Station 55, located at an equivalent depth. Hydroids, ascidians, bryozoans, and oysters (*Isognomon bicolor*) were common. The time-lapse camera on the array revealed major periods of growth and regression for hydroids. The camera recorded much bioturbation of the sandy sediment by echinoids. Many fishes were attracted to the array, including the Atlantic spadefish, *Chaetodipterus faber*; the greater amberjack, *Seriola dumerili*; the lane snapper, *Lutjanus synagris*; and the tomtate, *Haemulon aurolineatum*. Loggerhead sea turtles, *Caretta caretta*, and a nurse shark, *Ginglymostoma cirratum* also took up temporary residence beneath the array.

Station 21 (depth 47 m) was located in an area of coarse carbonate sand. The most common benthic organisms observed through the underwater television camera at Station 21 were algae (36% cover) and sponges (23% cover). Large sponges such as *Ircinia campana* and *Ircinia strobilina* were frequently observed (62 and 69/ha, respectively). Gorgonian beds were not often encountered, but were dense in some spots, as evidenced by their high abundance (500/ha) on one cruise only.

Sixty-seven invertebrates and 18 plants were identified in dredge samples from Station 21. No gorgonians were collected, confirming the highly patchy nature of their distribution at this station. Seven scleractinian corals were found, including common tropical reef forms such as *Siderastrea siderea*, *Mussa angulosa*, and *Stephanocoenia michelini*. Most invertebrates were typical of soft bottoms, such as conchs, cone shells, murexes, cockles, portunid crabs, sea stars (e.g., *Astropecten duplicatus*, *A. nitidus*), and burrowing echinoids (e.g., *Clypeaster subdepressus* and *C. rosaceus*).

Fish were numerous at Station 21. Trawl hauls averaged 49 individuals per 10-minute tow, and 69 taxa were collected. The most common species were the dusky flounder, *Syacium papillosum*; the twospot cardinalfish, *Apogon pseudomaculatus*; and the tattler, *Serranus phoebe* (all averaged 5/tow). Fishes most often seen in underwater television transects were the blue goby, *Ioglossus calliurus* (41/ha); the jackknife-fish, *Equetus lanceolatus* (16/ha); and the tomtate, *Haemulon aurolineatum* (14/ha). Many of the fishes present at Station 21 were collected at that station, including many apogonids and other deep-water or cryptic forms.

A community of hydroids, oysters (*Isognomon radiatus*, *I. bicolor*, *Spondylus americanus*), ascidians, and bryozoans settled on the array and settling plates at Station 21. Fewer settling organisms accumulated there than at shallower stations; for example, biomass on plates at Station 21 was usually one-fifth to one-tenth of that on plates at Station 52 for equivalent exposure times. Jewfish (*Epinephelus itajara*) took up residence at the array, but relatively few other fishes were observed by the time-lapse camera. The spotfin butterfly fish, *Chaetodon ocellatus*, was observed occasionally, along with various groupers.

Station 29 (depth 64 m) was located in an area of algal nodules and plate corals, *Agaricia*. Underwater television surveys revealed dense cover by the green alga *Anadyomene menziesii* (23% cover); deep-water gorgonians (*Ellisella*) were common (11/ha). The substrate was a combination of living and dead agariciid plate corals and fused coralline nodules (84% cover). There were many small cavities and irregularities in the bottom; these provided hiding places for cryptic species.

Dredge samples were dominated by coralline rubble and by *Anadyomene*, and included 48 invertebrates and 6 algae were identified. Twelve scleractinian corals were recorded, including four agariciid species and various other tropical reef forms such as *Montastrea cavernosa*, *Manicina areolata*, and *Madracis decactis*. An especially diverse ophiuroid community was present--13 species were collected by dredging.

Trawl hauls for fishes at Station 29 averaged 26 individuals per 10-minute tow. The most abundant species were damselfishes and included the purple reef fish, *Chromis scotti* (11/tow) and the yellowtail reef fish, *Chromis enchrysurus* (7/tow). *Chromis enchrysurus* and *Chromis scotti* were frequently observed in underwater television surveys (518 and 133/ha, respectively), along with various smaller serranids such as *Hemanthias* (295/ha), and *Serranus phoebe* and/or *S. annularis* (47/ha).

Station 23 (depth 74 m) was located in a flat area of loose and lightly consolidated algal nodules on a base of carbonate sand which was exposed in patches. The most visible benthic organisms in underwater television transects--other than the nodules themselves--were the green algae *Anadyomene menziesii*, small sponges (8% cover), and other algae (8% cover).

There were 59 invertebrates and 4 algae identified in triangular dredges. Dredges primarily contained nodules and *Anadyomene*. One scleractinian coral, *Madracis asperula* and one gorgonian, *Nicella schmitti* were collected. An assortment of asteroids (seven species) and ophiuroids (eight species) were present at Station 23. Many gastropods were collected at Station 23, including a rare abalone, *Haliotis pourtalesii*, which was found on the underside of one of the nodules.

There were 35 fishes observed with the underwater television camera. Species seen most frequently were the round scad *Decapterus punctatus*, and the yellowtail reef fish, *Chromis enchrysurus*, (912 and 221/ha) respectively. *Chromis enchrysurus* and the tattler, *Serranus phoebe* (17/ha), were seen on every cruise at Station 23. The trawl collected 30 species of fishes, with an average density of 82 individuals per 10-minute tow. The tattler, *Serranus phoebe* (36/tow) was most abundant, but the blackear bass, *Serranus atrobranchus*, and the fringed filefish, *Monacanthus ciliatus* (both 9/tow) were also common.

A few sessile organisms were found on the array or its plates at Station 23; the main settling organisms were serpulid polychaetes, which accounted for 25% or less biomass than that collected by settling plates at Station 29. Time-lapse equipment observed mainly *Chromis enchrysurus* and *C. scotti*, and a loggerhead sea turtle, *Caretta caretta*, also was sighted once.

Station 36 (depth 125 m) was located in a sandy area with low relief. Much of the bottom was bare sand with ripple marks. There were a few rocky outcrops and shallow depressions which harbored more animals than did the surrounding sand flats. Comatulid crinoids (23,681/ha) and the sea whip *Ellisella* (2,613/ha) were the most conspicuous benthic fauna observed with the underwater television camera. Asteroids, ophiuroids, hydroids and other benthic invertebrates were also observed, but at low densities.

Fifty-three invertebrates were identified in triangular dredge hauls at Station 36, including many anomuran and brachyuran crabs, echinoids, and ophiuroids. Dredges usually contained comatulid crinoids of the genus

Comactinia. Eight species of ahermatypic corals were taken in dredge hauls, confirming the presence of exposed hard substrate at the station. None of these corals were taken at any other station.

Fishes most often seen in underwater television transects were mainly serranids, such as unidentified anthinids [streamer basses (130/ha)] and the tattler, *Serranus phoebe* (11/ha). Lizardfishes and the bank butterfly fish, *Chaetodon aya* were also seen frequently at low densities. Trawl samples at Station 36 yielded 21 fishes, and averaged 117 individuals/10-minute tow. The most abundant species were the blackear bass, *Serranus atrobranchus* (33/tow); the offshore lizardfish, *Synodus poeyi* (24/tow); and the shortwing searobin, *Prionotus stearnsi* (10/tow).

The settling plates and array emplaced at Station 36 remained almost bare of sessile organisms; a few serpulid polychaetes, hydroids, and other species settled on the artificial substrates.

3.2 BIOLOGICAL ASSESSMENT

3.2.1 Ecological Considerations

The southwest Florida shelf is a mosaic of biological communities that reflects the extremely patchy nature of the substrate. Where sand is present, animals such as starfish, conch, and sand dollars are abundant. Large sponges, corals, and other organisms project through the sand. These larger organisms provide habitat and shelter for thousands of other species of smaller animals and plants, as well as focal points for many fishes.

On hard substrate in shallow water, sessile animals dependent upon sunlight (e.g. corals, and gorgonians) and sponges are dominant. Low-lying coral reefs that include many Caribbean species can be recognized. In deeper water, organisms that can tolerate lower light levels are abundant (e.g. agariciid corals, crinoids, the alga *Anadyomene*, and red algal nodules). The plate corals and algal nodules harbor cryptic or rare species, such as abalones. Virtually all of the areas of the shelf that are not covered with deep sand--and those areas that have large animals such as sponges anchored on hard substrate and projecting through the sand--can be considered to fall within the current MMS definition of "live bottom."

Several hundred different fishes have been identified on the southwest Florida shelf, including grunts, snappers, groupers, and other species of potential commercial and recreational interest. Much of the area is unsuitable for trawling due to outcrops of hard substrate, masses of sponges, or other bottom features, and must be fished either with traps or by hook and line. There also are several deep (perhaps 1000+ m) "holes" (subsidence or solution holes) near the edge of the shelf; these deep holes are reported to harbor large numbers of fish, especially snappers, and may be of great commercial and scientific interest.

Artificial high-relief structures such as petroleum platforms are likely to attract and concentrate many fishes, sea turtles, and fishermen, based on all three having been attracted to our research equipment. Artificial structures will also provide habitat for many sessile organisms, such as oysters and barnacles. These fouling or settling species will settle primarily in shallow water (less than 50 m), and will provide food and shelter for hundreds of additional species.

Light is one of the primary controlling factors in the distribution of large benthic organisms on the shelf, as described above. The other primary controlling factors are probably the availability of suitable hard substrate for recruitment of larvae and the movement of sand. How much hard substrate is exposed, and how long it is exposed, depend upon topography as well as sand movement in response to currents. The shelf ecosystem has probably evolved in the face of episodic benthic "wipeouts," particularly in shallow water. The benthic organisms there are well adapted to survive unpredictable, occasionally heavy, sand movement. In many areas of the shelf, hard substrate is alternately exposed and then covered by a thin layer of sand. Depressions are probably always filled with sand, while ridges and promontories are scoured at their bases but rarely or never covered.

Sand movement appears to be episodic in nature, rather than a slow, gradual process. This conclusion is confirmed by time-lapse camera evidence, which showed little change in sand depth except during major storms. A second line of evidence also supports this conclusion indirectly. Gorgonians, sponges, corals, and other large, sessile fauna were present at most sites, usually projecting through a layer of sand rather than attached to exposed limestone. Although they must have been able to withstand sand scour at their bases, these animals must first have settled on hard substrate, and then grown to a sufficient size to resist burial by the time the sand returned and prevented further recruitment. Their communities may be considered mature, and have probably taken years to develop.

On hard substrate exposed only for a short time, or eventually buried deeply by sand, newly settled and smaller organisms (e.g., settling species such as barnacles and hydroids) are probably killed. These settling species depend upon rapid settlement, growth, and reproduction on bare substrate. They probably include many of the organisms that grew on settling plates and arrays during this study.

Activities adversely affecting settling species will probably be inconsequential (or undetectable) at most sites in the long run, since these species are transitory by nature, and can repopulate on anything from buoys to oil rigs in short order. Few such species were actually collected from the natural bottom, perhaps because of differences in sampling methodology. However, other species such as Telesto are uncommon on natural bottoms despite their prominence on arrays and plates. This implies that community development on artificial substrates may not parallel natural community development.

Activities that alter the distribution or abundance of habitat-formers such as gorgonians, sponges, and algal nodules would have local consequences for many other species. Whether or not those consequences would adversely affect any biological parameter would depend upon the species and the scale of the activity, of course. Damaging a gorgonian bed, for example, would reduce fish densities locally, and reduce or eliminate many other motile and sessile species that normally find refuge in that bed. However, since most of the shallow shelf has huge gorgonian beds, it is also likely that many of these organisms would find suitable habitat nearby.

Damage to corals is likely to have long-term effects, since coral growth rates are typically low. Damaging or killing corals on projections above the bottom would also undoubtedly destroy a number of other benthic invertebrates associated with corals. Eliminating corals from any given area might have little effect upon many fishes, though. Fishes use both natural projections (outcrops) and relatively bare, artificial structures (arrays) as orientation aids and gathering spots, rather than as food sources. For example, most fishes censused in this study feed at night on sand flats away from arrays or coral heads where they aggregate in the daytime.

Algal nodule beds exist in deep, clear water, where there is relatively little light present. They may already be near their compensation depth, and any reduction of light by burial or prolonged increased turbidity might be harmful to them. However, no specific information is available on this subject. Sediment trap data indicate sedimentation is very low at these depths, and the existing biota currently are not under stress from sediment burial.

3.2.2 Management Implications

Management implications of these findings are discussed below, each followed by a summary of the rationale used to reach conclusions. These conclusions will be subject to further examination, modification, and refinement during the Year 6 synthesis, and should be considered working hypotheses at this point.

1. Mechanical damage (e.g., from offshore construction) is likely to be ecologically unimportant in the long run in many low-relief areas, such as patches of sand and hard bottom populated by sponges and gorgonians. Most so-called "live bottom" stations shallower than 50 m fit this description.

Rationale: Shelf organisms routinely re-populate areas exposed by shifting sand, and there is an extensive amount of similar bottom covered with organisms whose offspring can aid the repopulation process. In addition, disturbance of the sand community (e.g., echinoids, and tube-dwelling polychaetes) routinely occurs due to bioturbation, as evidenced by time-lapse camera results. Furthermore, several examples of very rapid sponge growth were recorded with high-resolution benthic photography, and some sponges may be capable of repair and regrowth in a short period of time.

2. Mechanical damage may be long-lasting in high-relief areas in either shallow or deep water, or where scleractinian corals, algal nodules, or other unusual benthic features are abundant. Stations in the outer portion of the middle shelf fit this description.

Rationale: Mechanical damage can cause short- and long-term losses in corals. Corals tend to be very slow-growing, and may be permanently damaged by abrasion or impact. In shallow water, corals were most abundant on high-relief spots, where they may not be subject to periodic inundation by sand. In deeper water, agariciid corals and algal nodules form extensive beds whose ecological importance is virtually unknown. Furthermore, coral and algal nodule beds provide attraction and shelter for many fish and invertebrates. Special concern is probably appropriate for areas of high relief, since the corals and other organisms on them differ from those on flat, sandy bottom.

3. The disposal of drilling fluids (mud and cuttings) will probably not have any major effects on shallow areas of the shelf, unless unusually widespread, toxic, or chronic.

Rationale: Previous studies of mud and cuttings have shown that toxic effects of offshore disposal are usually rather limited in spatial extent (e.g., Fischel, 1983), although they may adversely affect scleractinian corals and other organisms due to their toxicity, even in low concentrations (cf. Thompson and Bright, 1980; Parker _et al._, 1984). A discussion of toxicity is beyond the scope of this project. However, some comments on sedimentation are pertinent.

Drilling effluents suspended in the water can reduce light levels on the bottom, and may be deposited on benthic organisms. At shallow sites, neither of these effects is considered likely to be of sufficient magnitude to be detrimental, except possibly on a short-term, localized basis. Throughout most of the shelf, bottom water velocities are usually high enough to keep fine particulates in suspension, and in shallow water are frequently high enough to resuspend even calcareous sand. During winter, daily resuspension rates due to wave action and currents at a shelf station 13 m deep have been measured up to 1,000 MT/km^2/day, over 100 times the daily mud and cuttings discharge rate of a typical drilling rig. As a result, little or no buildup of drilling mud components should take place--at least in shallow water--unless discharges are permitted during periods of slack water. There may, however, be some accumulation of cuttings.

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

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

Whether or not sediment from drilling fluids would accumulate in deeper water is another matter. Water velocities are relatively low there, and it is possible that particulate matter could build up on the bottom immediately adjacent to discharge points. However, the depth of the water and the slow settling velocity of drilling muds suggest the muds will be dispersed over a large area before reaching the bottom. The sensitivities of deep-water benthic organisms to drilling effluents have not been examined. To reduce the chances of damage, it may be appropriate to require any offshore discharges to be near the surface and during high current periods at platforms located in deeper water. Because the water is deeper, the drilling muds will be dispersed over a much larger area before settling to the bottom. Cuttings, however, will probably accumulate in the proximity of the drill rig.

4. Petroleum platforms and other structures will almost certainly concentrate settling species, fishes, turtles, and other organisms. Offshore structures will provide outstanding fishing and recreational diving. Some species (e.g. VEC's and species already protected by law)

may require legal and/or educational measures to prevent their being caught or injured, since they will be more accessible to fishermen and divers at platforms.

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

5. Residential species on offshore structures may be exposed to high levels of discharged materials (e.g. produced water), if such discharges take place.

All sessile forms and some residential motile species may be exposed to comparatively high levels of contaminants if they are discharged from platforms. Turtles and groupers were reluctant to leave established sites at arrays. Their behavioral responses to most contaminants are unknown, as are their abilities to detect those contaminants. That these animals may not readily leave structures should be a source of concern, especially with regard to benthic discharges or high-density fluids that may sink rapidly to the bottom.

6. Routine platform operations other than discharges are unlikely to have any detrimental effects on most residential species, with the possible exception of turtles, which may be vulnerable to boat injury on the surface.

Rationale: Servicing the arrays with divers did not dissuade turtles or fishes from living beneath them. Given the large number of fishes and other species living beneath most platforms in the Gulf of Mexico, routine disturbances such as noise, light, and boat traffic will probably have little effect on most residential species. Turtles may have an increased risk of being hit by boats, however, since turtles have a habit of basking on the surface and increased boat traffic near rigs is a virtual certainty.

7. If corals and their associated species are exposed to spilled oil, they are likely to suffer physiological damage or death. The extent of the damage will depend upon the size, nature, and location of the spill. Turtles and other resident species are also likely to suffer from such events, which may have long-lasting ecological and economic consequences.

Rationale: The effects of spilled oil on shelf communities cannot be predicted without specific accident scenarios (quantity and type of oil spilled, sea state, wind and current direction, etc.). Spilled oil which sinks below the surface is likely to have a trajectory toward the south or southeast. Although surface currents and winds during most weather conditions across the shelf are from the southeast, weather fronts usually bring strong winds from the north or northwest, which would move a surface slick to the south or southeast. Spill components with a southward trajectory could be swept onto or around the western Florida Keys, or into the Florida Current and Gulf Stream, possibly impacting the eastern seaboard. Spilled oil from the inner portions of the shelf could be carried into Florida Bay and the eastern/northern Keys. Spilled oil may be damaging to suspension feeders such as oysters and sponges, as well as corals, and may taint fish or shellfish, destroying their marketability.

Admittedly, the responses to petroleum of most species on the Florida shelf are unknown. However, those few species of corals for which petroleum exposure has been studied appear to be sensitive to low concentrations, and suffer detrimental metabolic effects, and long-term retention of hydrocarbons (e.g. Loya and Rinkevich, 1980; Vandermeulen and Gilfillan 1984). Sea turtles have also been described as particularly sensitive to oiling (see Fritts _et al_., 1983), and may be exposed both to surface slicks and oil settling on the bottom.

8. If spilled oil contacts the sediment, it is likely to become incorporated and moved downward by the action of burrowing animals, where it may remain for a long time, and is likely to have detrimental effects.

Rationale: Bioturbation was intense at soft-bottom stations, as shown by time-lapse camera results. Burrowing echinoids reworked surface sediments to a depth of several centimeters at least, while other animals excavated large mounds of sand, presumably derived from much deeper levels in the bottom. Such activities are known to cause the migration of oil into subsurface layers, where they may be retained in essentially undegraded form, and interfere with the activities of infaunal species (Clifton _et al_., 1983).

The environmental concerns listed above are the most likely to be of importance on the southwest Florida shelf. Numerous studies have amassed information concerning potential environmental hazards from oil- and gas-related activities including Darovec _et al_. (1975); Darnell, Defenbaugh, and Moore (1983); Darnell and Kleypas (1986); Jaap (1984); McCoy (1981); Schomer and Drew (1982); Wolfenden (1983); and Zieman (1982). A listing of potential hazards indentified in these studies, their causative activities and agents, and potential effects are summarized in Table 3-1. These hazards and potential are in general agreement with those identified for the southwest Florida shelf.

4.0 RECOMMENDATIONS FOR FURTHER WORK

In some senses, making recommendations is premature at this stage in the project. Once the Year 6 synthesis is complete and an overview of the

Table 3-1. Preliminary listing of environmental hazards potentially resulting from oil and gas related activities on the Southwest Florida Shelf, their causes, and their valued ecosystem component effects

Potential Hazards	Causative Activities and Agents	Valued Ecosystem Component Effects
o Reduction in water clarity	o Excess suspended material resulting from dredging and drilling operations.	o Elevation of aphotic zone; elimination of deeper water populations of each group of photosynthesizers. Enhancement of nepheloid layer.
		o Interference with feeding, esp. by filter and mucous feeders.
		o Gill damage in some fishes and invertebrates.
		o Avoidance of area by mobile fishes, esp. sight-feeders.
		o Reduction in phytoplankton production.
o Reduction in water quality due to chemical pollutants	o Petroleum hydrocarbons from spills, blowouts, wrecks, bilge washing, pipeline leaks, etc.	o Floating fraction damages sea birds, turtles, mammals, and intertidal coral reefs. Potential damage to seagrasses and mangroves.
		o Dissolved fraction damages corals and other reef inhabitants (through gonadal damage and reduced recruitment). Larvae and juvenile growth affected.
	o Drilling mud additives	o Toxic to corals and other marine organisms. Affect edibility. Long-term leaching.
	o Chlorinated hydrocarbons	o Toxic to most marine organisms. Affect edibility. Concentrate up the food chains.
	o Heavy metals dumped or stirred up from sediments	o Toxic to most marine organisms. Affect edibility. Concentrate up the food chains. Long-term leaching.

Table 3-1. (cont'd)

Potential Hazards	Causative Activities and Agents	Valued Ecosystem Component Effects
o Sedimentation of bottom	o Dumping of sediments from dredging or drilling	o Heavy siltation covers bottom and smothers benthic flora and fauna. Fills interstices of coarse sediment bottom. Smothers corals. Clogs sponges. Eliminates food supply of mobile animals. Interferes with larval settlement. o Reduction in substrate diversity.
	o Redistribution of bottom sediments by water currents	o (See Effects of Water Clarity Reduction)
o Mechanical damage to bottom substrates and attached communities	o Scraping by ships, wrecks, anchors, chains, cables, etc. Damage by drilling, cutting, dredging, etc.	o Direct damage to local benthic communities. Scars, infections, etc.
	o Dumping of trash, tools, and construction debris from platforms	o Direct damage to local benthic communities. Long-term leaching. Smothering.
o Modification of bottom habitat by major structures	o Above surface bottom pipelines	o Interference with bottom circulation and species migrations. Potential leakage. Potential major leakage from rupture by anchors, etc.
	o Buried pipelines	o Damage from cutting a channel for pipeline burial. Potential leakage.
	o Deep ship channel development	o Damage from initial cutting. Damage from maintenance dredging.
o Excessive noise pollution	o Increased vessel traffic	o Effects largely unknown. Potential avoidance.

previous five years has been presented, recommendations will be more meaningful. In fact--if there were not a Year 6--the strongest recommendation that ESE and LGL could make would be for a year of synthesis of the extensive data base collected during the 5-year program.

It is our general feeling that no further field or laboratory work is appropriate to meet MMS goals for this area of the shelf at this time. However, this particular project is an applied study with a specific goal, i.e., to manage the southwest Florida shelf from the standpoint of possible petroleum development. The coast and nearshore waters have been characterized (Kunneke, 1983 and Mahadevan _et_ _al_., 1984), and 5 years of descriptive work offshore in this program constitute an adequate reservoir of baseline information. There is, however, a shortage of information on ecosystem dynamics, which would be very useful for predictive purposes. This subject will be emphasized during Year 6, and data gaps addressed in the Year 6 report.

It is unlikely that any additional sample collection--other than a very extensive effort--would aid either in compiling a more complete taxonomic list, or in the quantification of abundances of most species on the shelf. It would be possible to map the area more completely in terms of habitat types, but it seems that most major communities have already been described. Consequently, site-specific surveys (which are already required where exploratory drilling is planned) are likely to be much more cost-effective than cataloging the entire shelf so as to identify all habitat localities. The possible exceptions to this are certain specific areas such as Florida Bay or areas within the Florida Keys that may harbor ecological systems that might warrant investigation.

The first question asked in pre- and post-development studies is usually, "Can we detect any biologically important change?" To answer this question for the southwest Florida shelf ecosystem will be a challenge, indeed. A great deal of previous work has demonstrated convincingly that "(in) open ocean ecosystems... we should not expect to be able to detect other than major changes in physical and biological characteristics" (Beanlands and Duinker 1984). This is particularly true of the southwest Florida shelf.

Assessing statistically significant changes in biotic abundances at most sites on the shelf by routine surveying (e.g. with underwater television transects) will be very laborious at best, and may be completely unsuccessful. The distribution of organisms at the Year 4 and 5 stations was highly patchy. To overcome this patchiness, large-scale surveys using underwater television were undertaken.

Whereas taking a larger sample did, in fact, give a more comprehensive picture of the relative abundances of various organisms within a given sample area, the underwater television data demonstrated that numerical estimates of overall abundance were generally misleading. Most species were present along transects at very high densities at a few locations, and at zero densities elsewhere. A mean density calculated in the usual fashion (divide total individuals by total area surveyed) is a marginally useful--or even deceptive--statistic for this distribution pattern, since it doesn't describe the actual density of individuals at any point along the transect.

To represent the data more accurately, it was necessary to calculate local abundances within transects. The local abundances, rather than whole-transect estimates, were then collected iteratively along transects to generate mean and variance estimates. These confidence limits calculated from these estimates were nearly always so wide as to guarantee that interseason differences for the majority of species were non-significant. In other words, patchiness at most locations and for most species made it impossible to differentiate between seasonal differences and spatial differences.

In order to examine changes in abundances of benthic organisms, such as those before and after petroleum activites, it would be most cost-effective to conduct an annual, intensive synoptic underwater television survey at each site of interest, rather than seasonal surveys. The level of effort required for this synoptic survey would be great, at least equivalent to that required for four or more cruises during Year 4 and 5. Any less effort is likely to produce wide confidence limits for abundances, and an inability to detect changes statistically.

Although this approach would lose all seasonal information, and thereby miss some ephemeral events such as the Dictyota bloom observed at several shallow stations, most of the long-lived habitat-forming species (corals, sponges) would not be expected to vary seasonally. In fact, temporal changes in long-lived fauna must be attributed to sampling variability and patchiness; 10-year-old gorgonians simply don't pop up in the spring.

If seasonal information on ephemeral events and ecosystem dynamics were desired, it would be most cost-effective to permanently mark some selected locations on the bottom at each site, and to conduct repeated surveys at those exact locations. That would differentiate convincingly between temporal changes and benthic patchiness. Alternatively, time-lapse camera data provide an excellent record of ephemeral events, albeit for limited areas. More information was collected about ecosystems dynamics (e.g. diurnal periodicity, sediment resuspension, benthic current regimes, settling community formation, fish interactions) with time-lapse cameras during Years 4 and 5 than by any other gear type. Time-lapse cameras can collect useful data on the interactions between physical processes and organisms over a long period of time at very little cost.

Finally, in situ or laboratory toxicological studies of species of particular interest--especially corals and other sessile forms--would provide invaluable information for predicting the effects of spills and other contaminants. Less direct means of predicting toxic effects are likely to result in conclusions that are either vague or trivial (e.g. "Burial by oil will kill corals"), or operationally non-testable.

The utility of conducting closely monitored field studies simulating the discharge of drill muds and cuttings into various biological assemblages found on the shelf should be evaluated. Such studies monitored intensely during simulated drilling operations and periodically over several months or years would conclusively determine the short- and long-term effects on local biota. A further effort for consideration would be the denuding of test sites within various habitat types and monitoring natural recruitment and community development. Information from such a program would far surpass the normal settling plate information. A final field effort for consideration is to simulate an oil spill under controled conditions within small enclosed test plots in shallow water and monitor the effects on the biota. ESE successfully completed such a study in the Arabian Gulf (ESE, 1983) that demonstrated the effects of oil and dispersants on corals of the Arabian Gulf.

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March 3, 1849

U.S. DEPARTMENT OF THE INTERIOR MINERALS MANAGEMENT SERVICE