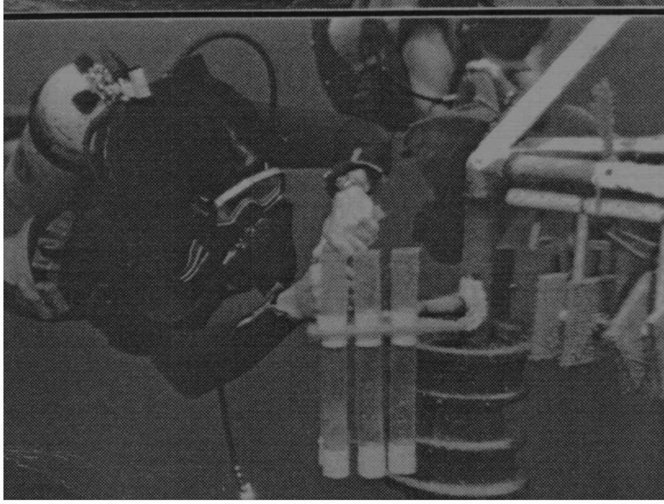


SOUTHWEST FLORIDA SHELF BENTHIC COMMUNITIES STUDY YEAR 4 ANNUAL REPORT

VOLUME II -- TECHNICAL DISCUSSION

Prepared for:

U.S. DEPARTMENT OF THE INTERIOR
MINERALS MANAGEMENT SERVICE
Gulf of Mexico OCS Region
Metairie, Louisiana

Prepared by:

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
Gainesville, Florida

and

LGL ECOLOGICAL RESEARCH ASSOCIATES, INC.
Bryan, Texas

Contract No. 14-12-0001-30071

July 1985

SOUTHWEST FLORIDA SHELF BENTHIC COMMUNITIES STUDY
YEAR 4 ANNUAL REPORT

VOLUME II--TECHNICAL DISCUSSION

Prepared for:

U.S. DEPARTMENT OF THE INTERIOR
MINERALS MANAGEMENT SERVICE
Gulf of Mexico OCS Region
Metairie, Louisiana

Prepared by:

Larry J. Danek
Michael S. Tomlinson
Gary H. Tourtellotte
William A. Tucker
Karyn M. Erickson
George K. Foster

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.
Gainesville, Florida

and

George S. Lewbel
Gregory S. Boland
Joshua S. Baker

LGL ECOLOGICAL RESEARCH ASSOCIATES, INC.
Bryan, Texas

Contract No. 14-12-0001-30071

July 1985

TABLE OF CONTENTS

VOLUME I--EXECUTIVE SUMMARY
VOLUME II--TECHNICAL DISCUSSION

TABLE OF CONTENTS
(Continued, Page 2 of 3)

TABLE OF CONTENTS
(Continued, Page 3 of 3)

LIST OF TABLES

LIST OF TABLES
(Continued, Page 2 of 5)

LIST OF TABLES
(Continued, Page 4 of 5)

LIST OF TABLES
(Continued, Page 5 of 5)

LIST OF FIGURES

LIST OF FIGURES
(Continued, Page 2 of 3)

LIST OF FIGURES
(Continued, Page 3 of 3)

1.0 INTRODUCTION

This annual report for the Year 4 studies of the Southwest Florida Shelf Ecosystems Program presents the methods used and the preliminary results of studies conducted on the Florida outer continental shelf (OCS) in the Gulf of Mexico between December 1983 and December 1984. The results and conclusions in this report will remain preliminary because the Year 4 study is only part of the proposed 2-year investigation to be completed in Year 5. Final interpretations and conclusions will be provided only when the 2-year data set is complete. However, extensive data on the biological and physical processes on the southwest Florida OCS were collected during the first year of this investigation. These data are presented in this interim report to ensure that the most recent information on the southwest Florida OCS is available as soon as practical.

The following sections provide a brief review of sampling completed during the first 3 years of the 5-year program before describing in detail the Year 4 studies. The field methods and laboratory procedures used are described, and results to date are presented. Interpretations and conclusions are presented to the extent possible, given that only half of the proposed data set has been collected.

1.1 PROGRAM REVIEW

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 Study were as follows:

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

To meet these objectives, the study was conducted over a 3-year period. During the first year of the program, a variety of geophysical, hydrographic, and biological parameters were studied along five east-west transects across the southwest Florida shelf. Geophysical data--bathymetric, seismic, and side scan sonar surveys--were collected along each transect from about 40-meter (m) water depth to 200-m water depth. Visual data--combining underwater television and 35-millimeter (mm) still color photography--were collected in depths between 20 and 100 m. Finally, a broad range of hydrographic measurements, water column samples, bottom sediment and benthic biological samples (using triangle dredge, otter trawl, and box cores) were collected from 30 stations located along the various cross-shelf study transects. These stations were occupied twice during the first year, once during a Fall Cruise (October-November 1980) and again during a Spring Cruise (April-May 1981).

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

During the second year, additional geophysical information was collected along a new north-south transect (Transect F), at about 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 each east-west transect from 100- to 200-m water depths.

Twenty-one of the 30 original hydrographic and benthic biological sampling stations occupied during Year 1 were twice resampled--once during a Summer Cruise (July-August 1981) and again during a Winter Cruise (January-February 1982). For this set of stations, hydrographic and biological data were now available on a seasonal (quarterly) basis. In addition, nine new hydrographic and benthic biological stations were established on Transects A through E, in water depths ranging from 100 to 200 m. Each of these stations was sampled during both the Summer and Winter Cruises.

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

The expanded program for Year 3 incorporated three cruises. Cruise I (conducted in October 1982) continued the bottom mapping activities that were begun in Year 1. The studies completed along several new transects included bathymetry, side scan sonar, subbottom profiling, underwater television, still photography, and hydrography. During the survey, transects B, C, and D were extended eastward to depths of 10 m, and north-south transects G, H, I, J, K, and L were added. Cruise II was conducted in December 1982 and consisted of biological and hydrographic sampling. Ten soft-bottom stations in the 10- to 20-m depth range were sampled for infauna, grain size, and hydrocarbon content in the sediments. Five hard-bottom stations in the same depth range 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 hard-bottom stations. During Cruise III, conducted in June 1983, the same stations and parameters sampled during Cruise II were resampled to provide seasonal data.

The first 3 years of investigations effectively addressed Objectives 2 and 3 listed previously. However, it was determined that to effectively 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 systems 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.

1.2 OBJECTIVES

The overall objectives for the Years 4 and 5 study required 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 shall be delineated through illustrations (maps, diagrams, charts, etc.), as well as descriptive text. Appropriate statistical analyses shall 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.

1.3 SCOPE OF WORK

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 interim, annual report presents only the results of the first year of the study (Year 4 of the program); consequently, the results presented are preliminary since only half of the intended data set has been collected.

The Year 4 field study included four seasonal cruises, with sampling conducted at two sets of stations (Figure 1.3-1). 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 5 hard-bottom and 5 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.

Five other live-bottom stations, each representing a separate epifaunal community type, were sampled during each of four seasons--fall 1983, winter 1983-1984, spring 1984, and summer 1984. A description of these hard-bottom stations is presented in Table 1.3-1. These stations are referred to as Group II stations and 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.

The Group II stations were sampled quarterly during Year 4 and are also scheduled to be sampled quarterly during Year 5. Sampling at these stations consisted of dredging, trawling, underwater television, benthic still photography, sediments, and hydrography. In addition, *in situ* instrument arrays were installed at these five stations. Each array contained a current meter that measured current speed and direction,

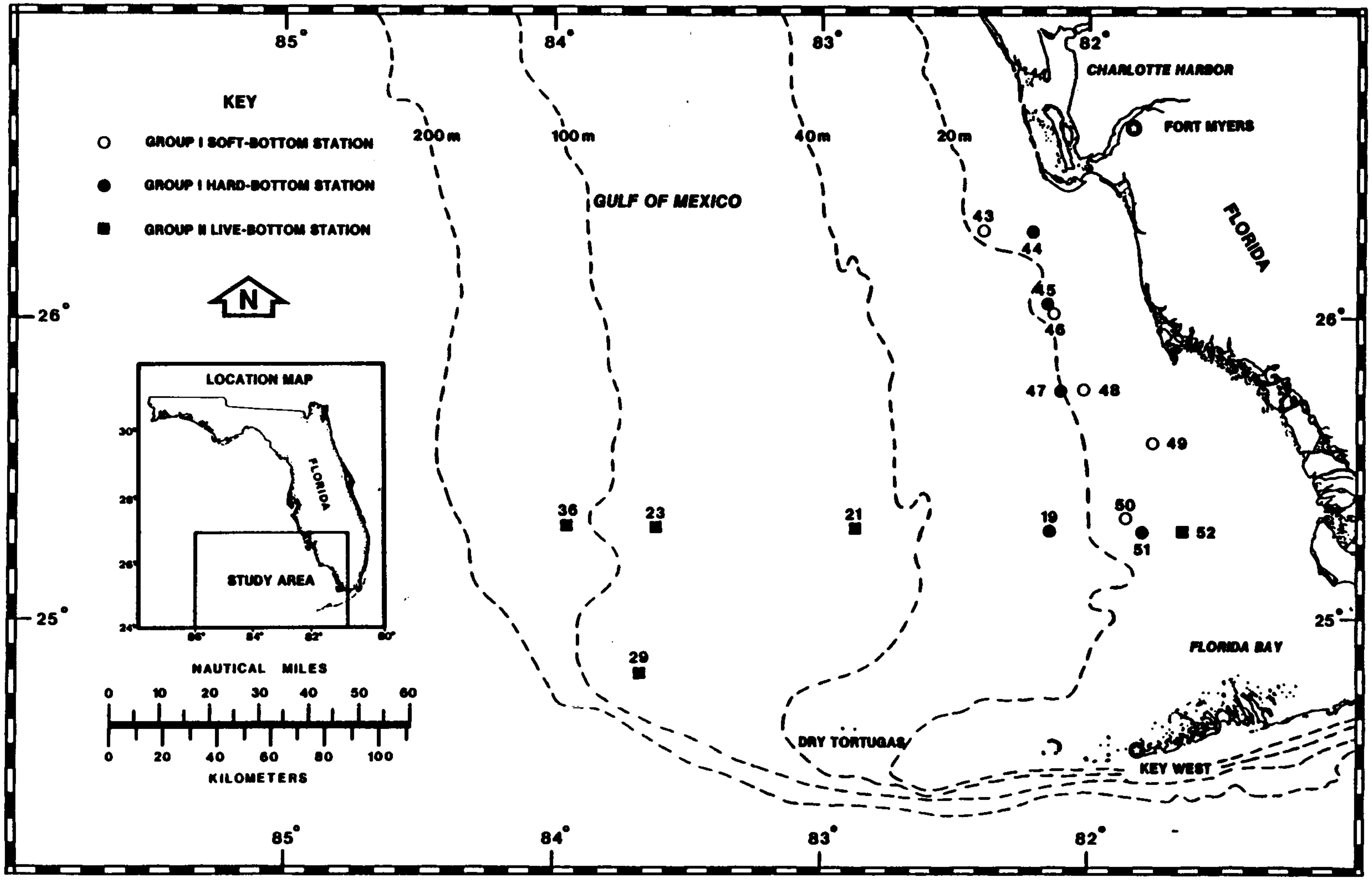


Figure 1.3-1 STATION LOCATIONS AND INSTRUMENT ARRAY LOCATIONS FOR YEAR 4

Table 1.3-1. Group II Hard-bottom Stations

Station	Depth (m)	Depth Zone	Substrate	Assemblage
52	13	Inner Shelf	Sand over hard substrate	Soft coral Assemblage I
21	47	Middle Shelf	Sand over hard substrate	Live bottom Assemblage II
23	74	Middle Shelf	Algal nodule layer/sand	Algal nodule assemblage
29	64	Middle Shelf	Algal nodule pavement	*Agaricia* coral plate
36	125	Outer Shelf	Sand over hard substrate	Crinoid assemblage

temperature, and conductivity; three sets of sediment traps at elevations of 0.5 m, 1.0 m, and 1.5 m above the bottom; and 10 sets of substrate 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 and will continue to be maintained during Year 5.

2.0 FIELD SAMPLING METHODS

The methods and instrumentation used by the Environmental Science and Engineering, Inc./LGL Ecological Research Associates (ESE/LGL) team to conduct Year 4 of the Southwest Florida Shelf Benthic Communities Study are detailed in the following sections. The sections are arranged by disciplines as follows:

2.1 PHYSICAL OCEANOGRAPHY

2.2 SEDIMENTS

2.3 INFAUNA

2.4 EPIFAUNA, NEKTON, AND MACROALGAE

These sections are further subdivided into the specific methods employed to collect data within these categories.

The vessel used by ESE was the Florida Institute of Oceanography's R/V SUNCOASTER. The specifications for this vessel are presented in Table 2.0-1. All navigation was accomplished with the vessel's Micrologic ML 3000 LORAN C navigation system with plotter. The general procedure during sampling was to record the LORAN C coordinates and the beginning and ending times of each sampling event. During any underway sampling, the vessel's LORAN C plotter was used to obtain a continuous track.

Table 2.0-1. Relevant Ship Specifications for the R/V SUNCOASTER

Length - 110 feet	Beam - 25 feet
Draft - 9 feet	Range - 7,900 nautical miles
Speed Range - 2-12 knots	Cruising Speed - 10 knots
Navigation - 2-LORAN C's 1-LORAN C Plotter	Depth Sounding - Furuno 881 EDO Western PDR
Winches - 2 electromechanical 1 trawling 1 hydro	A-Frame (Starboard Side) U-Frame (Stern) Side Boom
Work Boats - 15-foot Fiberglass 12-foot Inflatable	Wet-Dry Lab - 420 $feet^2$ Afterdeck - 588 $feet^2$
Crew - 5 (24-hour Operation)	Scientists - 12

2.1 PHYSICAL OCEANOGRAPHY

Emphasis in Year 4 of the Southwest Florida Shelf Benthic Communities Study was placed on the dynamics of the ecosystem and the natural stresses that are imposed on the system by existing physical processes. Physical processes included sediment dynamics (discussed in Section 2.2) and physical oceanography, specifically: hydrography, currents, waves, and meteorology. To study these processes, the ESE/LGL team used a variety of methods which are described in the following sections.

2.1.1 CSTD

Hydrographic data were collected at all 15 Year 4 stations and periodically during steaming. At each station a vertical survey was conducted from surface to bottom, whereas the periodic sampling conducted during steaming consisted of a surface measurement only. The hydrographic data collected consisted of conductivity, salinity, temperature, pH, dissolved oxygen (DO), and transmissivity versus depth.

These data were collected using on InterOceans® CSTD System (Figure 2.1-1). Table 2.1-1 presents the range, time constant, and accuracy of each probe of the CSTD sonde. The probe time constants coupled with the CSTD's recording system, capable of recording each parameter 7 times in 10 seconds, enabled collection of nearly continuous hydrographic data throughout the water column.

The CSTD system consisted of a Model 513D Sonde which was connected via 14 conductor wire and slip-ring winch to a Model 514D Readout, which provided both digital and analog readouts of individual parameters. The 513D Sonde also was linked to a Model 690M Magnetic Recorder, which not only recorded the CSTD data virtually continuously, but also permitted

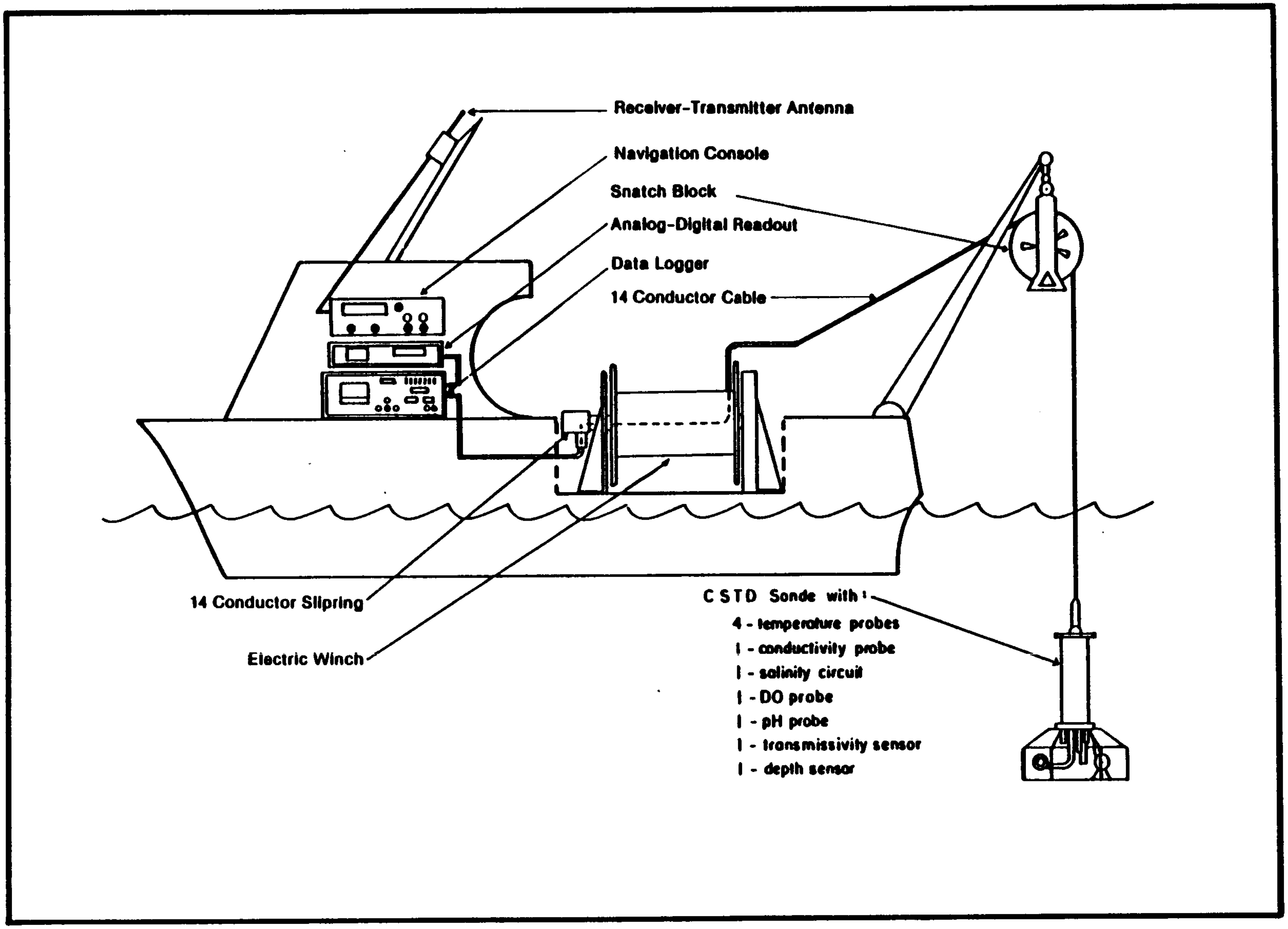


Figure 2.1-1 SCHEMATIC OF THE INTEROCEANS® CSTD SYSTEM

Table 2-1.1. Accuracy, Range, and Time Constants of Probes on InterOceans® CSTD Model 513D

Parameter	Range	Accuracy	Time Constants
Conductivity	0-65 millimhos/cm	± 0.05	10 ms
Salinity	0-45 ‰	± 0.05	1.4 s
Temperature	-5-45°C	± 0.05	60 ms
Depth	0-200 m	± 1	50 ms
DO	0-40 mg/L	± 0.2	10 s
pH	2-14 pH	± 0.1	200 ms
Transmissivity	0-100%	± 1	400 ms

the manual entry of such data as cruise number, station number, position data, or any data which could be numerically coded.

CSTD data were recorded continuously on cassette tape during descent to near-bottom at each station. Upon reaching near-bottom, the recorder was shut off, and all parameters were manually recorded on an ESE Field Data Log. The sonde was then raised to the next chosen depth and the parameters again manually recorded. The depth and number of manual recordings were decided by the Cruise Leader; however, a minimum of three depths (near-surface, mid-depth, and near-bottom) was always manually recorded. The manual records were used as a backup to the cassette tape and also made the results readily available to onboard scientists.

In addition to hydrographic casts at each station, ESE sampled the surface water every 15 kilometers (km) whenever steaming distances exceeded 37 km (20 nm). The vessel would stop, and the CSTD probe was lowered just below the surface. Conductivity, temperature, salinity, pH, DO, and transmissivity were manually recorded along with time, water depth, and LORAN C coordinates.

Calibration and calibration checks of the CSTD were made periodically. A complete calibration of the CSTD was made at least once during each cruise.

The CSTD probes were calibrated as indicated below:

1. Conductivity--Precision resistors were used to calibrate the probe during each cruise; these values were recorded on calibration sheets.
2. Temperature--The temperature probe reading was compared against an NBS traceable glass thermometer, and the readings were recorded on a calibration sheet.

3. Salinity--The salinity probe was calibrated against a laboratory salinometer and checked each cruise against the conductivity and temperature.
4. Depth--The depth probe was zero-calibrated each day with the sonde on deck.
5. DO--The probe was enclosed and the enclosure purged of all O_2 using pure N_2 gas to obtain a zero point. Periodically, samples of water were preserved for Winkler titrations as an added check on the DO probe. All of these data were recorded on calibration sheets and later used for calibration.
6. pH--The pH probe was cleaned and immersed in at least two different pH buffers (usually 7 and 10) and the pH readings and temperature recorded on calibration sheets and used to develop calibration curves.
7. Transmissivity--The probe lenses were cleaned and the probe enclosed in an opaque cover which was filled with distilled water to determine the full-scale reading. The zero point was set by covering the light sensor on the probe.

The field calibration data were returned to ESE and entered into the PRIME® computer for reduction of the CSTD data.

2.1.2 NISKIN CASTS

A hydrographic cast using a 5-L or 10-L Niskin bottle equipped with a reversing rack and a protected deep sea reversing thermometer was conducted at every station and served primarily as a calibration check of the CSTD system. At every station, the surface temperature measured with the calibrated deep sea reversing thermometer attached to a Niskin bottle was recorded on the ESE Field Data Log alongside the temperature measured with the CSTD. At three of the stations, usually those at the beginning, midpoint, and end of the cruise, two samples collected near-surface and near-bottom with a Niskin bottle and deep sea reversing thermometer were obtained for a comparison of temperature, salinity, and

DO with those same parameters measured by the CSTD. The temperature was read from the calibrated deep sea reversing thermometer. Salinity was measured with a laboratory salinometer at the Florida Institute of Oceanography. DO concentration of the sample was determined using the modified Winkler titration method outlined in Strickland and Parsons (1968). These calibration checks provided useful data on the performance of the CSTD.

A Niskin cast was also conducted at Station 36 where water depth (127 m) exceeded the length of the CSTD cable (90 m). This enabled ESE/LGL to obtain salinity, temperature, and DO values for the bottom water.

2.1.3 IN SITU ARRAY

During Year 4 of the Southwest Florida Shelf Benthic Communities Study, ESE/LGL deployed and maintained an instrumented in situ array at all five of the Group II live-bottom stations. The arrays (shown in Figure 2.1-2), their construction, and servicing procedures are discussed generally in this section. Specific components are discussed in detail in the relevant sections of this report.

All five arrays were equipped with fouling plates, three sets of sediment traps, and an ENDECO® Model 174MR Current Meter capable of measuring current speed and direction, temperature, and conductivity. In addition, two of the arrays (Stations 52 and 21) were equipped with Sea Data Model 635-11 Wave and Tide Gages and an ESE/LGL-designed time-lapse camera/strobe system.

The mooring configuration for the in situ array is illustrated in Figure 2.1-3. A permanent buoy was set to mark the site; the array was placed approximately 75 m away. The mooring line on the array was supported by a subsurface float located approximately 10 m below surface. A small surface float was attached to the subsurface float to help relocate the array. To help prevent vandalism or damage by

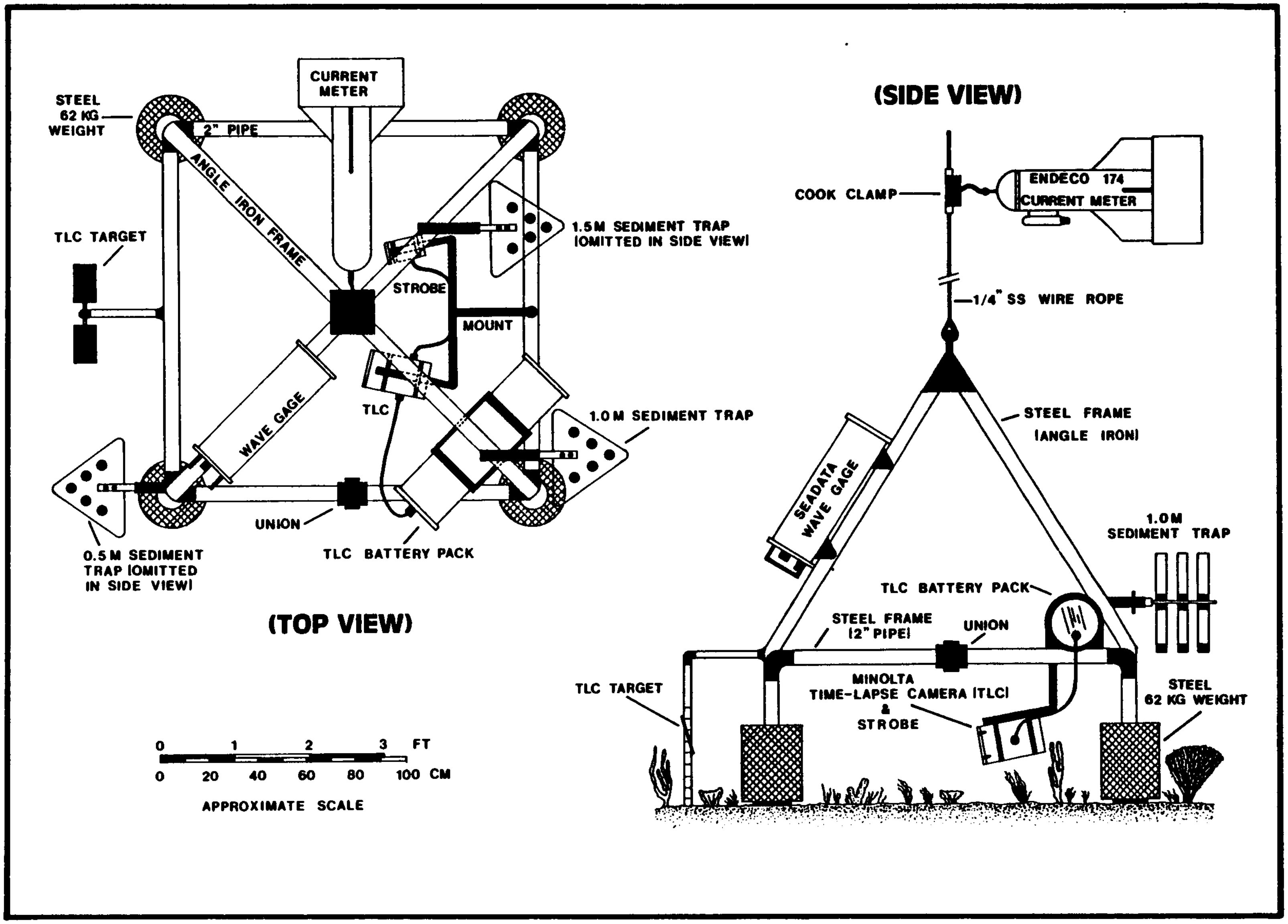


Figure 2.1-2 *IN SITU* **ARRAY (SHOWN WITHOUT FOULING PLATES FOR CLARITY)**

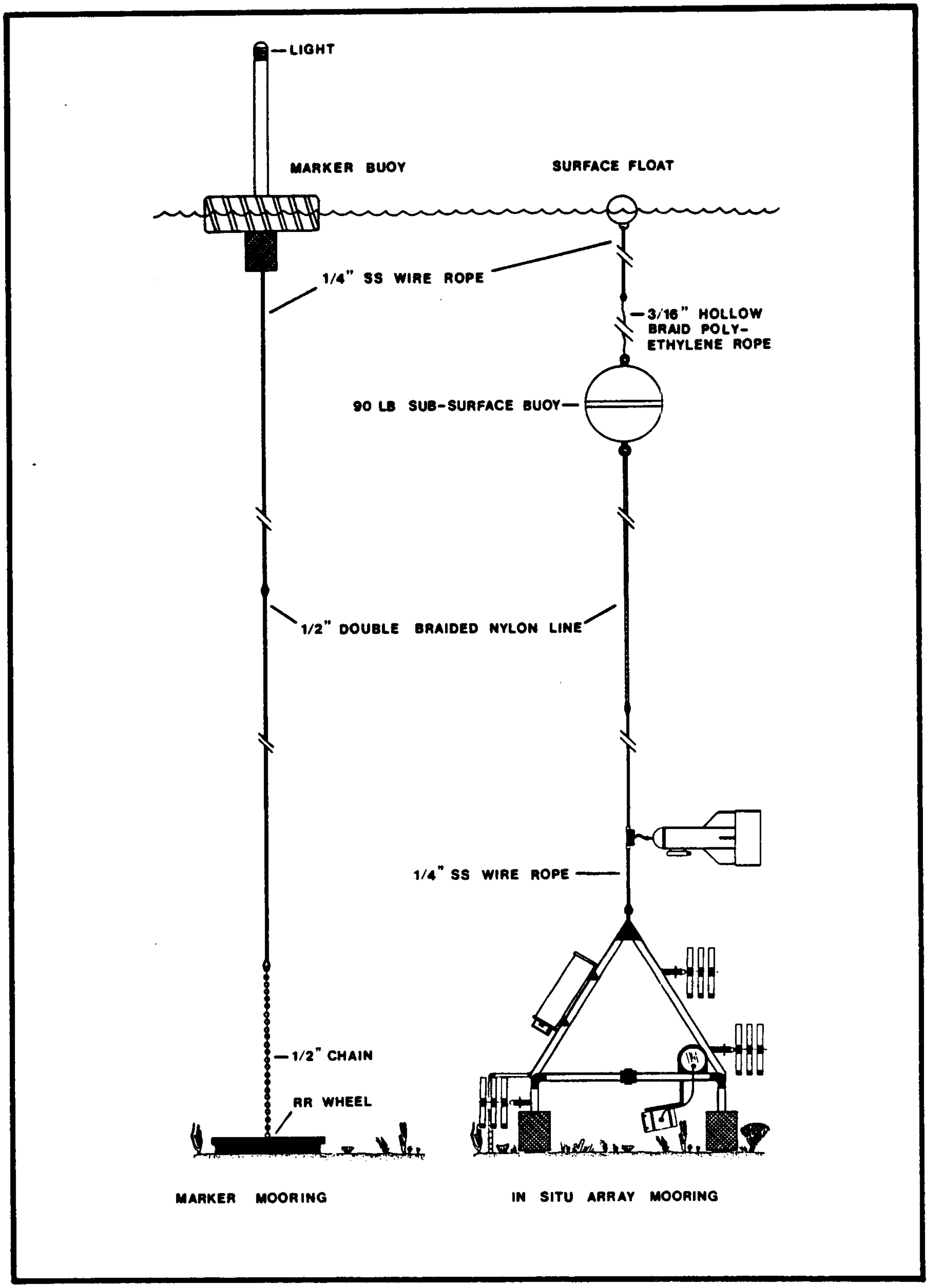


Figure 2.1-3 ***IN SITU*** **ARRAY MOORING CONFIGURATION**

vessels, the surface float was attached to a weak link that would not support the mooring.

Methods for locating the array included the marker mooring described above, accurate and redundant LORAN C fixes, and (later in the study) the addition of Helle Engineering® Model 2250 27 kilohertz (kHz) pingers attached just below the subsurface buoy of the array mooring.

To retrieve the mooring for servicing, divers attached a servicing line beneath the subsurface float. The servicing line was then attached to the vessel winch wire, and retrieval was begun. The array was raised to within 5 m of the surface. However, to avoid contamination and desiccation of the fouling plates, the array was not brought onboard. Because of boat motion, the added stress and jerking motion could have damaged the array or snapped the cable. Consequently, when the mooring was within 5 m of the surface, a temporary spar buoy was attached to the retrieving link on the mooring line. The winch cable was relaxed, and the array was suspended from the spar buoy.

There was some motion of the array induced by wave action on the buoy but not nearly as much as there would have been from the rolling vessel. To reinstall the mooring, the mooring cable was tightened on the ship's winch, the temporary spar buoy removed, and the array was lowered immediately to the bottom. A schematic of this servicing operation is presented in Figure 2.1-4.

With the array suspended from the spar buoy, the divers retrieved the instruments, sediment traps, and appropriate fouling plates. The instruments were serviced onboard and returned to the array with new sets of fouling plates. Following the servicing, the mooring was lowered to its original position, and the winch cable was detached from the subsurface float.

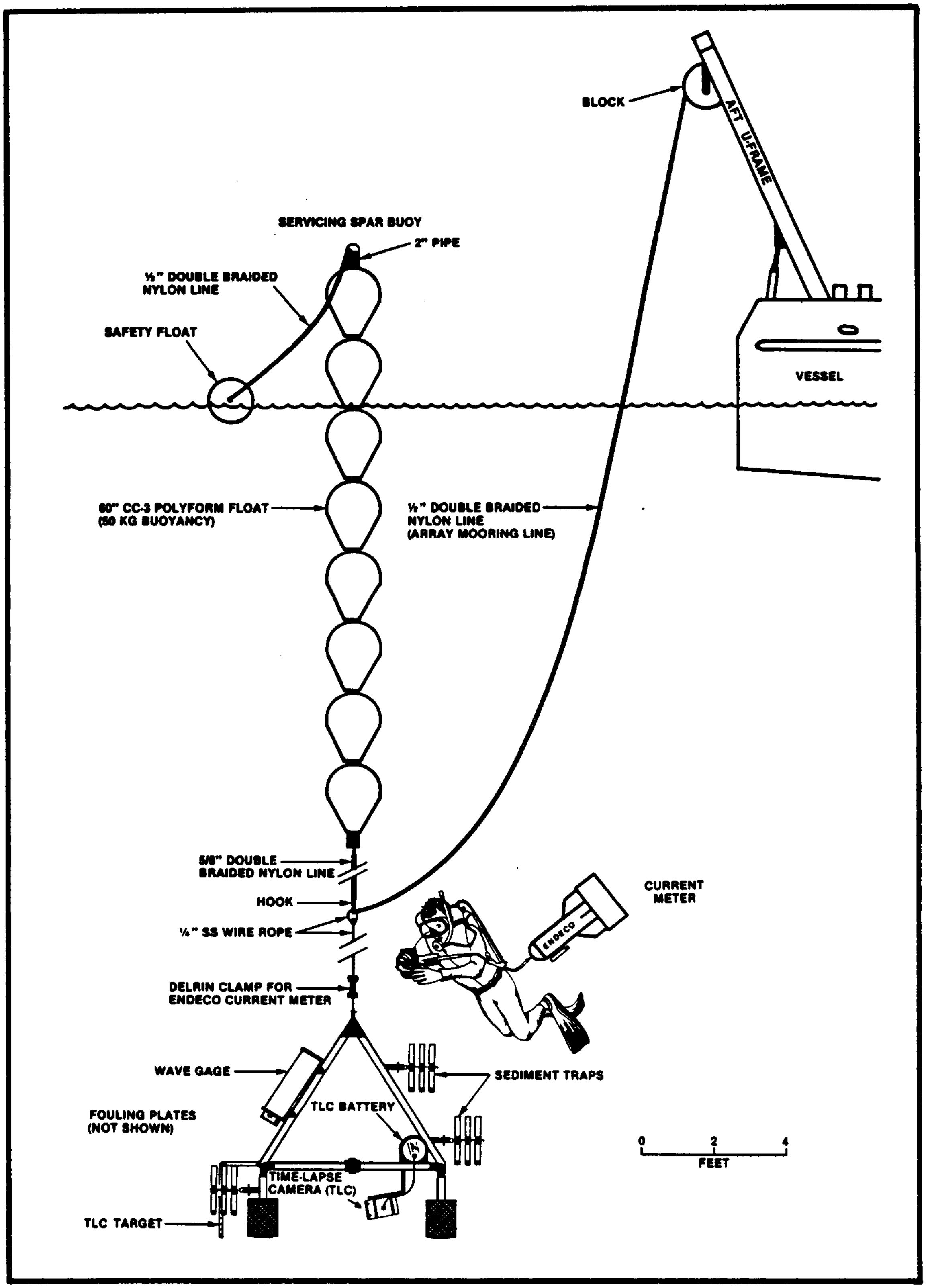


Figure 2.1-4 *IN SITU* **ARRAY SERVICING SCHEME FOR DEEP ARRAYS**

A discussion of those array components used primarily for the collection of physical oceanographic data follows. Other components are discussed in the relevant sections of the report.

Current Meter

A requirement of the *in situ* instrument arrays was to continuously monitor near-bottom current speed and direction, as well as water temperature at each live-bottom station. ESE/LGL used an ENDECO® Model 174MR current meter system mounted directly above the apex (3 m above the bottom) of the array frame at all five stations.

The Type 174 current meter is an axial flow, ducted impeller recording system capable of recording current speed and direction, water temperature, and conductivity on magnetic tape at predetermined intervals. Detailed specifications for the current meters are presented in Table 2.1-2.

To collect near-bottom data, the normal long tether-type mooring was shortened. This ensured that the current meter did not become entangled in or damage any portion of the *in situ* array. The current meter was able to rotate freely and easily 360° about a Delrin® clamp attached to the mooring wire. With the sample interval set at 5 minutes, the current meter had sufficient magnetic tape to record longer than 120 days between each quarterly servicing. Therefore, a continuous annual record of currents was available for detailed statistical analysis of the current regime.

A final feature of the current meter was a built-in pinger which provided information on the status and location of the instrument. As a status indicator, the pinger transmitted two pulses per second during normal operation; in the event of an instrument malfunction, the pinger would transmit nine pulses per second (alarm mode). This same pinger and receiver may also be used to locate the array if the surface and subsurface marker floats should become lost.

Table 2.1-2. Detailed Specifications of the ENDECO® Model 174MR Current Meter

<u>TYPE 174MR CURRENT METER</u>	
1. <u>Current Velocity</u>	
Sensor Type:	Ducted Impeller
Sensitivity:	58.0 RPM/Knot (51.4 cm/s)
Speed Range:	Dependent on sampling interval (0-4.3 knots) at 2-min interval
Impeller Threshold:	Less than 2.57 cm/s (0.05 knot)
Resolution:	0.4% of speed range
Speed Accuracy:	±3.0% of full scale
2. <u>Current Direction</u>	
Resolution:	1.4°
Accuracy:	±7.2° above 2.57 cm/s (0.05 knot) when referenced to computer calibration
3. <u>Temperature*</u>	
Sensor:	Thermolinear thermistor
Range:	-5°C to +45°C (23° to 113°F)
Accuracy:	±0.2°C referenced to computer calibration
Resolution:	0.098°C (0.216°F)
4. <u>Conductivity*</u>	
Sensor:	Electrodeless probe
Range:	5 to 55 millimhos/cm
Accuracy:	±0.55 millimhos/cm referenced to computer calibration
Resolution:	0.098 millimhos/cm
Calibration:	Internal resistors
5. <u>Recording Time and Rate</u>	
Recording Rate:	One reading of four parameters every 2, 3, 4, 5, 6, 10, 20, or 30 min (user selectable)
Maximum Recording Period:	>120 days at 5 min-interval
6. <u>Recorder</u>	
Recording Medium:	"Scotch" 90-min tape cartridge with 0.0025 cm (1 mil) x 0.64 cm (0.25 inch) x 128 m (420 ft) long magnetic tape, with an ENDECO Q.A. certification stamp
Instrument Identification:	Instrument serial number recorded on tape at time of reset
<u>TYPE 2501 DATA TRANSLATOR</u>	Required for translation of data to computer-readable format

* Using measured values of conductivity and temperature, salinity can be resolved to ±0.12‰ with an accuracy of ±0.5‰ at 35‰ at 20°C (68°F).

The quarterly servicing consisted of removing the current meter from the array for cleaning and inspection; removing and replacing of magnetic tape, batteries and desiccant; and remounting the current meter on the array.

The current meters were calibrated by the manufacturer once prior to initial deployment, and will again be calibrated after final retrieval or as deemed necessary.

Wave and Tide Gage

The arrays at Stations 21 and 52 were equipped with Sea Data® Model 635-11 Wave and Tide gages. The 635-11 was a self-contained digital recording wave and tide gage designed for subsurface deployment. The 635-11 measured waves by recording water height (pressure) with a resolution of 1:65,000 using a Paros Scientific® Quartz Sensor. The instrument simultaneously recorded wave (short-period) and tide (long-period) data. The specifications for this instrument are shown in Table 2.1-3.

2.1.4 SHIPBOARD MARINE OBSERVATIONS

Shipboard observations were made at all sampling stations either by hand-held instruments or by visual observation and were supplemented by the vessel's meteorological instruments. The parameters measured and the methods used are presented below:

Parameter	Method
Wind speed	Anemometer
Wind and wave direction	Compass and observation
Wave height	Observation
Wave period	Observation and stopwatch
Wet and dry air temperature	Psychrometer
Barometric pressure	Aneroid barometer

Table 2.1-3. Specifications for the Sea Data® Model 635-11 Wave and Tide Gage

PRESSURE - water height

Sensor: PAROS SCIENTIFIC "DIGI-QUARTZ"

	100 psia	
	feet	meters
Standard Ranges:	190	58
Maximum Depth:	235	70
Resolution - waves:	0.0035	0.1 cm
tides:	0.004	0.12 cm
Accuracy (§80 ft)	0.03	
(†80 ft)	0.05 ft	
vs temp @ 30 ft	0.004 ft/°C (max)	

Frequency Response:	DC to 1.0 Hz (Nyquist limit for 0.5 s sampling)
Stability vs time:	0.0002 %FS/month at (almost constant) ocean depths
Temperature:	zero 0.0007 %FS/°C span 0.005 %FS/°C (at 2/3 FS, 0.004 %/°C)
FM Noise:	below limit of resolution
TEMPERATURE	
Range:	-4.5°C to +34.5 °C
Resolution:	0.003°C
Accuracy:	0.07°C
Stability:	0.005°C (small temperature excursions) 0.02°C (full temperature cycling)
FM noise:	0.002°C
Time constant:	30 min
TIME BASE	4.194304 MHz special quartz crystal
Stability:	0.1 ppm/°C, 1 ppm/year unmeasurable (0.0001%) pressure data error at ocean depths
POWER	
SDB-4 Sea Data 20 AHr Alkaline battery - good for 6 months or 2 tapes	
SIZE	
Case:	7" diameter x 24" long
Mounts:	two 0.5" bolt holes on 13" centers, 1.0" clearance
WEIGHT	41 lb in air, with battery; 12.5 lb in water
PRESSURE CASE	
Material:	6061-T6 Aluminum
Hardware:	316 Stainless and Delrin® insulators
Finish:	Hard-coat anodize with electrostatic epoxy overcoat
Depth:	1,100-m operating depth

Parameter	Method
Precipitation	Observation
Cloud cover	Observation
Weather	Observation
Water transparency	Secchi disk

These observations were recorded on Field Data Logs for eventual appending to the NODC hydrographic data file.

2.1.5 OUTSIDE DATA SOURCES

In addition to the field data collected by ESE/LGL, data were obtained from various agencies and institutions concurrently collecting data. In an effort to obtain synoptic surface observations of the study area, both EROS Data Center (USGS) and Satellite Data Services Division or SDSD (NOAA) were queried for any high-quality available satellite imagery. EROS was contacted regarding the availability of LANDSAT imagery; SDSD was contacted regarding the availability of NOAA satellite and GOES imagery. The imagery of most interest was the advanced very high resolution radiometer (AVHRR) data and sea surface temperature (SST) charts available from NOAA's 7 and 8 polar-orbiting satellites. A search for imagery within the geographic location and time periods of interest was begun, and the highest quality images were obtained and examined.

Wave data were obtained from both an offshore and nearshore location (Figure 2.1-5). The offshore data were collected by NOAA Data Buoy Center's (NDBC) Buoy Number 42003 located at latitude-26°00'00"N and longitude-85°53'59"W from November 1983 to November 1984. The nearshore data were obtained from the University of Florida's Coastal Data Network (UFCDN) wave stations located offshore of Venice and Clearwater, Florida.

Continuous meteorological data, including wind velocity, air temperature, precipitation, and weather, were obtained from NDBC

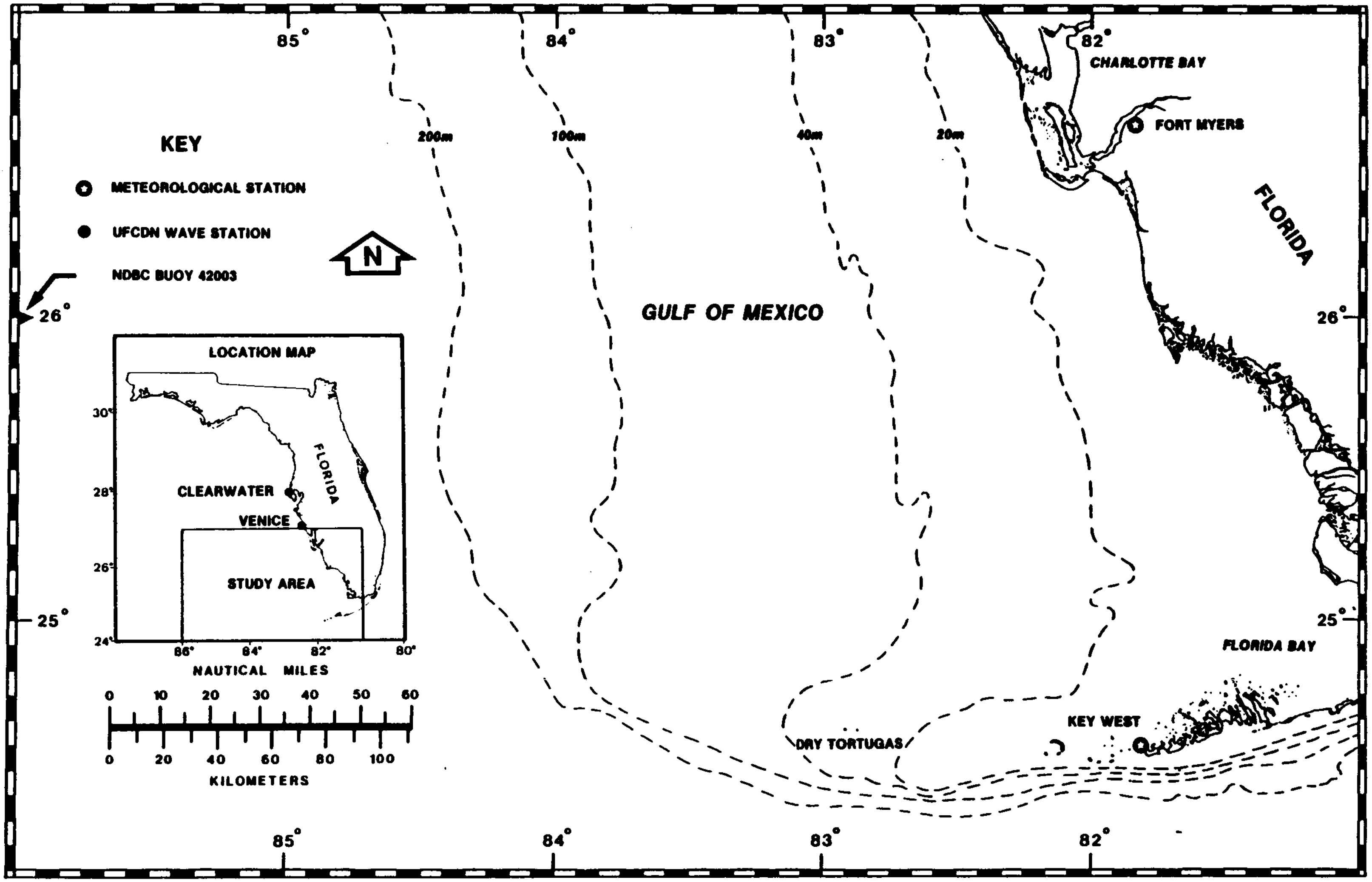


Figure 2.1-5 LOCATIONS OF NDBC BUOY 42003, UFCDN VENICE WAVE GAGE, AND NCDC METEOROLOGICAL STATIONS

Buoy Number 42003 and the Local Climatological Data Monthly Summaries (LCDs) published by the National Climatic Data Center (NCDC) for Tampa, Fort Myers, and Key West, Florida.

Although sediments are discussed in Section 2.2, it is appropriate at this point to discuss outside geological data sources. A computerized search of available geological data was conducted by the National Geophysical Data Center (NGDC). This search produced no relevant data. While NGDC is considered the repository for all geological and geophysical data (similar to the role of NODC), the search for geological data not entered into NGDC will continue during Year 5.

2.2 SEDIMENTS

Sediments and sediment dynamics were studied to provide a more complete description of the physical environment. Sediment samples were collected and characterized both physically and chemically. A variety of methods was used to measure and describe sediment dynamics in the study area; the field methods used are described below.

2.2.1 GRAB SAMPLES

Duplicate bottom sediment samples were collected from each station during the first and second cruise. Sediment samples were collected with diver-held cores where the water was sufficiently shallow. In deeper water, samples were collected with a Smith-McIntyre grab [area = 0.1 square meter (m^2)]. The upper 5 cm of sediment from the core samples was removed and stored in prelabeled jars for shipment to the laboratory. A core subsample was taken from the center or least disturbed area of the Smith-McIntyre grab sample and, as with diver-collected core samples, the upper 5 cm was removed and stored for shipment to the laboratory. In all cases, every effort was made to avoid disturbing the surficial sediments.

2.2.2 *IN SITU* ARRAY

The *in situ* arrays, previously described in Section 2.1.3, were equipped with sediment traps at all five Group II stations. The shallower Stations 52 and 21 were also equipped with time-lapse cameras. Data collected by the sediment traps and time-lapse cameras, combined with data collected by the previously described current meters and wave gages (Section 2.1.3), were used to study sediment dynamics at Group II stations. A description of the sediment traps and time-lapse cameras is presented in the subsequent sections.

Sediment Traps

Sediment traps were installed at all Group II stations to measure the time-averaged vertical sediment flux at 0.5, 1.0, and 1.5 m above the seabed. The best sediment traps are simple cylinders with diameters of 4 cm or more and height-to-diameter ratios greater than 10:1. Therefore, the traps constructed of cellulose acetate butyrate cylindrical tubing were 4 cm in diameter and 40 cm long.

Five traps were mounted at each of the 0.5-, 1.0-, and 1.5-m levels to provide replicate samples.

The sediment traps were capped, retrieved and replaced each time the instrument array was serviced by divers. The sediment samples were frozen and returned to the laboratory for analysis, as discussed in Section 3.2.2.

Time-Lapse Cameras

Time-lapse cameras were mounted on the arrays where sediment transport was most likely (the shallower and, therefore, potentially higher energy Stations 52 and 21). The use of time-lapse photography can reveal information not available by the use of standard sampling techniques. Long-term phenomena exhibit dynamics which cannot be detected under real-time conditions (Fedra and Machan, 1979). The time-lapse photographic system used a Super-8 movie camera with a standard 50-foot (ft) roll (3,600 frames) of movie film. The time interval between single-frame exposures was 1 hour. This resulted in a time compression of 1:57,600 where 1 day was represented by 24 frames of movie film and could be projected in 1 1/2 seconds (s) using a normal projection speed of 16 frames per second. A standard 50-ft movie cartridge lasted 150 days.

Major components of the system consisted of the movie camera, an electronic flash, an intervalometer for timing exposures, and an auxiliary battery pack for both the movie camera and electronic flash

(Figure 2.1-6). The camera was a Super-8 Minolta® Model XL-401 (Minolta Corporation, Ramsey, New Jersey) enclosed in an Ikelite® underwater housing. This camera had the capability for single-frame filming, synchronization with external electronic flash lighting, and an f/1.2 zoom lens. Kodak Kodachrome 40 Super-8 film (ASA 40) was used. Artificial light was provided by a Vivitar® Model 283 strobe with a guide number of 60 using ASA 50 film.

The remaining major component of the system was an electronics package designed to close the circuit at a predetermined interval. This apparatus, an intervalometer, was constructed by Electromedia Consultants of Bryan, Texas.

Underwater connectors for penetration of battery pack and system component housings were of the bulkhead type wherever possible to prevent leakage. Crouse-Hinds Electro Products® (Paramount, California) underwater electrical connectors were used.

Power requirements of the time-lapse camera system in the long-term mode of single- frame photography were considerable. The electrical capacity required for a minimum 3-month time-lapse emplacement was approximately 48 amp-hours. Sealed lead-acid batteries were chosen to meet this power requirement. This type of battery is truly sealed with no acid, acid vapor, or water loss occurring during use. Temperature characteristics of this battery are also ideally suited to the typical bottom water temperatures of the southwest Florida shelf. A package of auxiliary batteries was contained in an underwater housing measuring approximately 60 cm by 25 cm, which was attached to an instrument array support member.

Photographic product quality would be rapidly degraded by fouling of the camera ports by settling organisms if left untreated. A transparent anti-fouling preparation for optical surfaces was used. The material used was organometallic polymer described by Abbott (1979). ESE/LGL

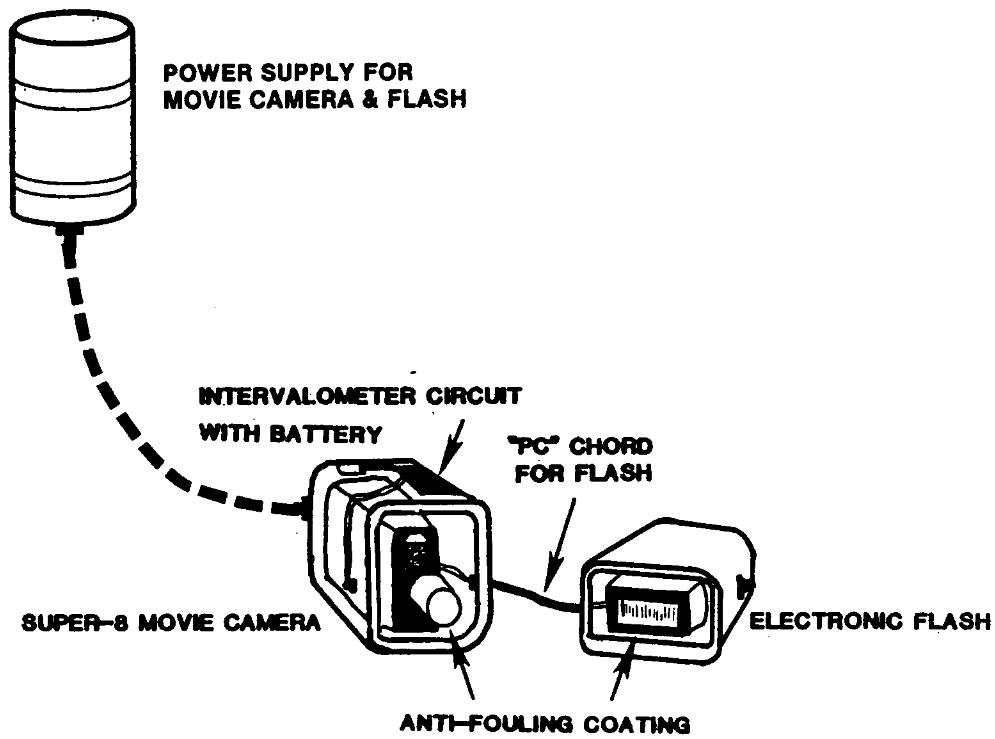


Figure 2.1-6 TIME-LAPSE CAMERA SYSTEM

obtained organometallic polymer from the Department of the Navy, Naval Ship Research and Development Center, Bethesda, Maryland. The material proved to be effective, and ESE/LGL obtained unobscured time-lapse records in excess of 3 months.

The primary function of the time-lapse camera was to provide continuous visual information on sediment transport. In the camera's field of view, a vertically oriented graduated rod extended from the instrument support frame to a point below the sediment-water interface (Figure 2.1-2). The camera was focused on the sediment rod and two steel fouling plates welded to the rod.

Several secondary functions of the time-lapse camera included documentation of biofouling community formation and fish counts. The methods are described in Section 2.4.5.

2.3 INFAUNA

Infaunal sampling at the Group I soft-bottom stations was included to complete the seasonal sampling begun in Year 3. The sampling was conducted by divers using plastic corers. Ten replicate cores, 12.5 cm on a side, were taken during December 1983 and May 1984 and corresponded with procedures used by previous contractors. Each core was vented at the top with a hole covered with 0.5-millimeter (mm) mesh screen to prevent blowout during sampling.

The sampling procedure required the diver to locate an undisturbed area and carefully insert the cores to a depth of 15 cm. The area surrounding the core was excavated, and the core was capped prior to moving. The sealed cores were returned to the ship where samples were emptied into 0.5-mm mesh sieves and gently washed with sea water. Material retained by the sieves was transferred to a 1-liter (L) bottle, and approximately 20 milliliters (ml) of 70-percent ethanol or propylene phenoxetol was added to relax the organisms. After approximately 1/2 hour, the samples were preserved with a 10-percent buffered formalin seawater mixture tinted with Rose Bengal.

The bottles were labeled on both the inside and outside and capped for shipment to the laboratory.

2.4 EPIFAUNA, NEKTON, AND MACROALGAE

Two general approaches were used to study benthic epifauna, nekton, and macroalgae: remote sensing and direct sea floor sampling. Using these techniques, ESE/LGL was able to further describe the benthic and near-bottom nektonic populations and their dynamics. The various methods used are described in the following sections.

2.4.1 UNDERWATER TELEVISION

Underwater television surveys were conducted at all Group I and Group II live-bottom stations. Weather permitting, the underwater television surveys were conducted twice (Cruises I and III) at the Group I stations, and four times (Cruises I through IV) at the Group II stations.

In conducting the underwater television surveys, a 1-km^2 block was established around each station center location. The station center and 1-km^2 block were marked on the vessel's LORAN C plotter. The ship's position was tracked relative to the station's center. Navigation fixes were taken at approximately 5-min intervals during the surveys, and at the start and finish of each habitat type traversed. The fixes were audio-dubbed on the videotapes and recorded in the underwater television/benthic still photography log. As described below, a still camera which was used to obtain qualitative photographs for detailed identifications of both epifauna and motile biota was also mounted on the frame. The location of each photograph was also logged. A detailed description of Benthic Still Photography is presented in Section 2.4.2.

Underwater television surveys were conducted using a stereo video system. The principal components of this system were twin Sub-Sea Systems Model CM-8 underwater black-and-white television cameras with Ultricon camera tubes, and the Sub-Sea Systems Model ST-1000 stereo control console with multiplexer.

Black-and-white cameras were chosen because of the enhanced contrast and superior sensitivity in low-light conditions typical of underwater habitats. More than three times the light needed by these cameras would be required for an equivalent color picture, and artificial light would be required at all times to obtain a color picture. The RCA Ultricon black-and-white camera tube was used as the best compromise between sensitivity and resolution. The Ultricon tube was approximately four times more sensitive to light than a standard 17-mm (2/3-in) Vidicon tube, and has 60,000 times the burn resistance. Camera tubes with low burn resistance would be permanently damaged and leave marks on recordings if exposed to a bright source of light, especially the sun.

For this study, observations near sunset, sunrise, and after dark were intentionally avoided to prevent significant biases of fish counts during twilight or dark periods (Starck and Davis, 1966; Collette and Talbot, 1972).

Both camera signals were transmitted through a dual coaxial cable. Video multiplexing circuitry allowed both right and left camera signals to be viewed on a single monitor and to be recorded on a portable Panasonic VHS single-channel, video tape recorder (Model NV-8410). Each 1/2-in tape cassette recorded 2 hours of observations.

Auxiliary light was provided by a Sub-Sea Systems 400-watt (W) mercury vapor lamp. Because the blue-green spectral output of a mercury vapor arc bulb is well matched to the maximum spectral transmission of sea water, the bulb is particularly efficient for black-and-white video. Both the cameras and light were attached to a Sub-Sea Systems Model A50 pan-and-tilt motor capable of a 340° pan axis and a 180° tilt axis. The pan-and-tilt motor was attached to the center of the lamp and cameras. A tripod provided a stable support structure for working, while resting on the substrate, and was easily towed. The trailing edge of the tripod frame supported a large vertical stabilization fin, which reduced twisting movements and permitted the tripod to maintain a consistent orientation during a transect drift.

The camera tripod was lowered on the trawl winch wire over the stern of the research vessel. Electronic cables were attached to the wire at appropriate intervals. Laboratory space for monitoring and recording equipment was located within the vessel at some distance from the winch operator. In order to maintain minimum response time, a public address amplifier system was used to communicate directly with the winch operator from the location of the video monitor.

An auxiliary SIMRAD® Model EY-M Echo Sounder with the transducer mounted at the surface directly over the camera frame or the ship's Furuno® Sounder was used to obtain precise depth information and to maintain a reasonably consistent height above the bottom during a transect. The returning transducer signals also warned of oncoming obstructions under turbid water situations.

A detailed discussion of the analytical methods used for underwater television surveys is presented in Section 3.4.1.

2.4.2 BENTHIC STILL PHOTOGRAPHY

Benthic still photography surveys were conducted concurrently with underwater television surveys and used a 250-frame, single-lens reflex camera (motor-driven) Olympus OM-1 and strobe system (Ikelite SS150) mounted on the same pan-and-tilt unit that held the paired underwater video system. The camera and strobe were wired to the surface and operated by the video observer, who could take photographs at will. The photographs taken were recorded in the observer's videotape log and were visible on the television screen as the strobe flashed.

The 35-mm camera system was used to photograph objects seen in the video monitors on board the vessel, geological features, and typical or unusual species. Photographs of species were taken only as necessary to aid in taxonomic identification since species density information was already recorded on videotape. A portion of the film was routinely developed in the field to verify correct camera and strobe function.

2.4.3 TRIANGULAR DREDGE

Three triangular dredge tows were made at each Group I and Group II live-bottom station each time the station was occupied. These samples provided the necessary groundtruthing for the underwater television/ benthic still photography surveys and were used to determine the various size (length)/weight relationships to estimate biomass.

A Kahl Scientific Company® triangular steel dredge was used. This dredge with a 60-cm triangular mouth was 120 cm long, had a mesh size of 1.2 cm, and was equipped with a chain three-point bridle.

After a few test tows, the ideal towing time was determined. Towing the dredge for 2 min on the bottom allowed collection of sufficient sample for analysis. Once the dredge was onboard and the total sample volume was estimated, the sample was dumped, photographed, and sorted on deck.

The procedure for sorting during Cruise I was to select unique specimens and all motile epifauna and to then take a "random" subsample with a scoop. Following discussions with COTR, it was determined that the deck-sorting method should be modified. In subsequent cruises, all motile epifauna were saved. Nonmotile species were clustered on the deck by phylum, photographed, and their volume was estimated. Representative specimens of each species, which could be visually distinguished, were saved, and duplicate specimens were then discarded. Large sponges were sectioned, a portion was saved, and the remainder was discarded. Of the organisms saved, those requiring relaxation were soaked in magnesium sulfate solution and transferred to cheesecloth bags prior to preserving with the rest of the sample in 10-percent formalin buffered with sodium tetraborate (Boraxo®). These samples were placed in 5-gallon buckets, labeled both on the inside and outside, sealed, and shipped to the laboratory for analysis.

2.4.4 ROLLER OTTER TRAWL

To provide additional groundtruthing for the underwater television/benthic still photography surveys, a single otter trawl was made at each Group I and Group II live-bottom station. At each station, the trawl was towed for 10 min, with the occasional exception of Stations 29 and 23, where the trawling time was reduced to 5 min to minimize damage to the net while trawling over the algal nodules and *Agaricia* coral pavement.

After the net was brought onboard, the sample was photographed, sorted, and all fish and motile invertebrates as well as other unique invertebrate specimens were saved. Those organisms requiring relaxation were placed in a magnesium sulfate solution, bagged in mesh, and preserved with the remainder of the sample in sodium tetraborate buffered 10-percent formalin. The 5-gallon sample buckets were then labeled both on the inside and outside, sealed, and shipped to the laboratory for analysis.

The roller-type otter trawl which was used for this study is described by the manufacturer, Marinovich Trawl Company, as follows:

> 25 ft. Semi-Balloon Trawl, 26 ft. headrope, 32 ft. footrope. Net made of nylon netting of the following size mesh and thread: 1 1/2 inch stretch No. 9 thread body, 1 1/4 inch stretch mesh No. 15 thread codend. Innerliner inserted and hogtied in codend of 1/4 inch stretch mesh mesh No. 63 knotless nylon netting to hold small samples. Head and footropes of 7/16 inch diameter Poly-Dac net rope with legs extended 3 feet and wire rope thimbles spliced in at each end. Six 3 x 3 sponge floats spaced evenly on bosom of headrope. Nine (9) 5 x 6 inch plastic mudrollers spaced evenly on 42 inch centers on footrope with 3 loops of chain 2/0 galvanized in between each set. Net treated in green net enamel on completion. Net fully rigged with lazyline and purse rope. Each net fully rigged with a pair of 36 x 18 inch sport doors with 150 feet of 3/8 inch diameter nylon rope rigged on each door for towlines.

Several modifications were made to the design. After only five trawls, the 45-m, 9.5-mm (3/8-inch) nylon trawl towlines were replaced with 18-m, 6-mm (1/4-inch) stainless steel wire rope towlines. For Cruise IV these towlines were replaced with 30-m, 6-mm (1/4-inch) plow grade steel, non-torsional wire ropes. In addition to these modifications, an 11-m, 6-mm (1/4-inch) galvanized tickler chain was attached between the otter doors for Cruise II. Chafing gear was attached to both trawls during Cruise III to minimize damage to the nets.

2.4.5 _IN SITU_ ARRAY

An overall description of the _in situ_ arrays was presented in Section 2.1.3; only the methods relevant to epifauna, nekton, and macroalgae investigations are presented here. These methods included the use of fouling plates and time-lapse cameras and are described in detail in the following sections.

Fouling Plates

A total of 48 primary fouling plates was deployed at each of the 5 Group II live-bottom stations to monitor larval recruitment, growth, and stability of epifaunal communities. The 48 fouling plates were divided into 8 groups of 6 plates each. Each group of 6 plates was attached to the array. Five of the six plates were analyzed, and the sixth was preserved intact for archiving purposes.

Two groups of settling plates were attached to each cross-member support. Two types of settling plate materials were used. A total of 42 plates consisting of 7 groups were made of 15 1/4-cm x 15 1/4-cm ceramic quarry tiles with a grooved surface on one side of each tile. These grooves were approximately 2 mm wide and 2 mm deep and were found to better simulate the irregular surface of natural substrates such as carbonate rock or algal nodules (Bright _et al._, 1983). The other plates were 15 1/4-cm x 15 1/4-cm steel plates. Only one group of six plates was made from this material, which was replaced during each cruise (at approximately 3-month intervals). The steel settling plates were intended to simulate the unpainted surface provided by an offshore oil and gas platform.

The orientation of settling plates has also been found to have significant effect on the rate and extent of in situ epifauna colonization. According to Combs (In: McGrail et al., 1982), downwardfacing settling plates were found to collect greater numbers of corals and corals of larger sizes than other surfaces of plates. Scott Baggett (personal communication, August 1983) found that vertically oriented settling plates were colonized by greater numbers of corals than both the upper and lower surfaces of horizontally oriented plates. All primary settling plates were vertically oriented on each live-bottom station instrument array.

Each group of primary plates was suspended from the underside of the array frame cross-members. This positioning close to the sediment-water interface simulated the benthic habitat at each live-bottom site. In this manner, it was possible to assess the effects of near-bottom boundary layer processes on the settling plate epifaunal communities by correlation of time-series analyses of fouling community structure, current meter data, water quality data, sediment trap information, and results of time-lapse motion picture analyses described in Section 2.4.5. The time-lapse camera system deployed on the Station 52 and 21 arrays for sediment transport observations could also film a portion of one fouling plate group to record changes in the epifaunal community characteristics over a 2- to 3-month period.

Two fouling plates were welded to the sediment rod in such a manner that when the array was on the bottom, the plates were located near the sediment-water interface. Time-lapse movies recorded information related to the resistance of developing epifaunal communities to sediment abrasion, boundary layer current forces, and burial.

A set of three horizontally mounted plates was attached to the array frame for 1 year to confirm Baggett's (1983) findings. Additionally, six vertical plates were mounted at a height of 1.5 m to determine what effect height above the bottom might have on fouling communities. These plates were collected 1 year after deployment.

The instrument platform was first deployed during Cruise I at each of the five Group II live-bottom stations. One side of the array supported one group of six tile plates and one group of six steel plates. These positions represented the 3-month period of colonization. Both of these groups were replaced each cruise, permitting the analysis of a 3-month colonization period during all seasons. During Cruise II, these 3-month groups were the only ones collected and replaced. The 6-, 9-, 12-, 15-, 18-, and 21-month positions were left undisturbed for continued colonization. During Cruise III, the 3-month positions for both tile and steel plates were again collected and replaced. Additionally, the 6-month position was collected and replaced. During Cruise IV, the last cruise of Year 4, the 3-month tile and steel positions were again collected and replaced. The 6-month position was left undisturbed as it would be colonized for only 3 months at that time. The 9-month position was the final collection during Cruise IV. The remaining positions, which represent 12-, 15-, 18-, and 21-month colonizations, were left at each site, since the project will continue through a second year. These positions will be collected on Year 5 cruises in addition to the plates replaced during Year 4 cruises and those which will be replaced during Year 5 cruises.

Each group of settling plates was constructed to permit easy removal and replacement while the instrument array remained suspended in the water after raising from the bottom to shallow diving depths below the anchored research vessel. The settling plates not collected remained in the water to prevent detrimental effects on the epifaunal organisms due to desiccation. Collected settling plates were carefully handled, photographed, placed into containers, preserved in 5- to 10-percent neutral buffered formalin, labeled, and shipped to the LGL laboratory.

Time-Lapse Camera

A complete description of the time-lapse camera is presented in Section 2.2.2. The use of the time-lapse camera to study sediment transport was discussed in that section. In addition, the time-lapse camera was used to obtain a time-series record of epifaunal community composition and growth. This was accomplished by viewing the growth on two steel plates welded to the sediment rod.

One of these plates was cleaned with a steel brush approximately every 3 months during servicing; the other plate was never cleaned. This enabled ESE/LGL to monitor seasonal differences in epifaunal recruitment as well as overall changes in the fouling community.

An additional use for the time-lapse camera was monitoring the fish that were attracted to the array. Although the field of view of the time-lapse camera was too limited to study fish population dynamics in detail, it was sufficient to determine those taxa most attracted to such an artificial structure and to observe recruitment rates and diurnal patterns of those taxa observed.

3.0 LABORATORY ANALYTICAL METHODS

3.1 PHYSICAL OCEANOGRAPHY

3.1.1 CSTD DATA

The CSTD system and the procedures for conducting a CSTD hydrographic cast were discussed in Section 2.1.1. A schematic of the data reduction and analytical procedures used to process the CSTD data is presented in Figure 3.1-1 and discussed below.

The CSTD data from the cassette were first transferred to the PRIME computer. The raw CSTD data were averaged over 1-m intervals and reformatted. Those parameters requiring calibration were corrected using the linear equation developed from the field calibration data. Sigma-t and DO saturation were calculated from the calibrated values, and the raw and calibrated data were tabulated to facilitate quality control checks. These quality control checks were done manually by (1) comparing data recorded on the cassette with values recorded manually in the field, (2) comparing manually calibrated data against computer calibrations, and (3) comparing calibrated values against acceptable standards such as deep sea reversing thermometer temperatures.

Once the CSTD data had passed all quality control checks, the calibrated data were tabulated in report-ready format, and vertical profile plots, when appropriate, were produced.

3.1.2 NISKIN DATA

Hydrographic casts using Niskin bottles equipped with protected deep sea reversing thermometer were conducted to check the operation of the temperature, salinity, and DO probes in the CSTD. Temperatures measured with the deep sea reversing thermometer were corrected using the

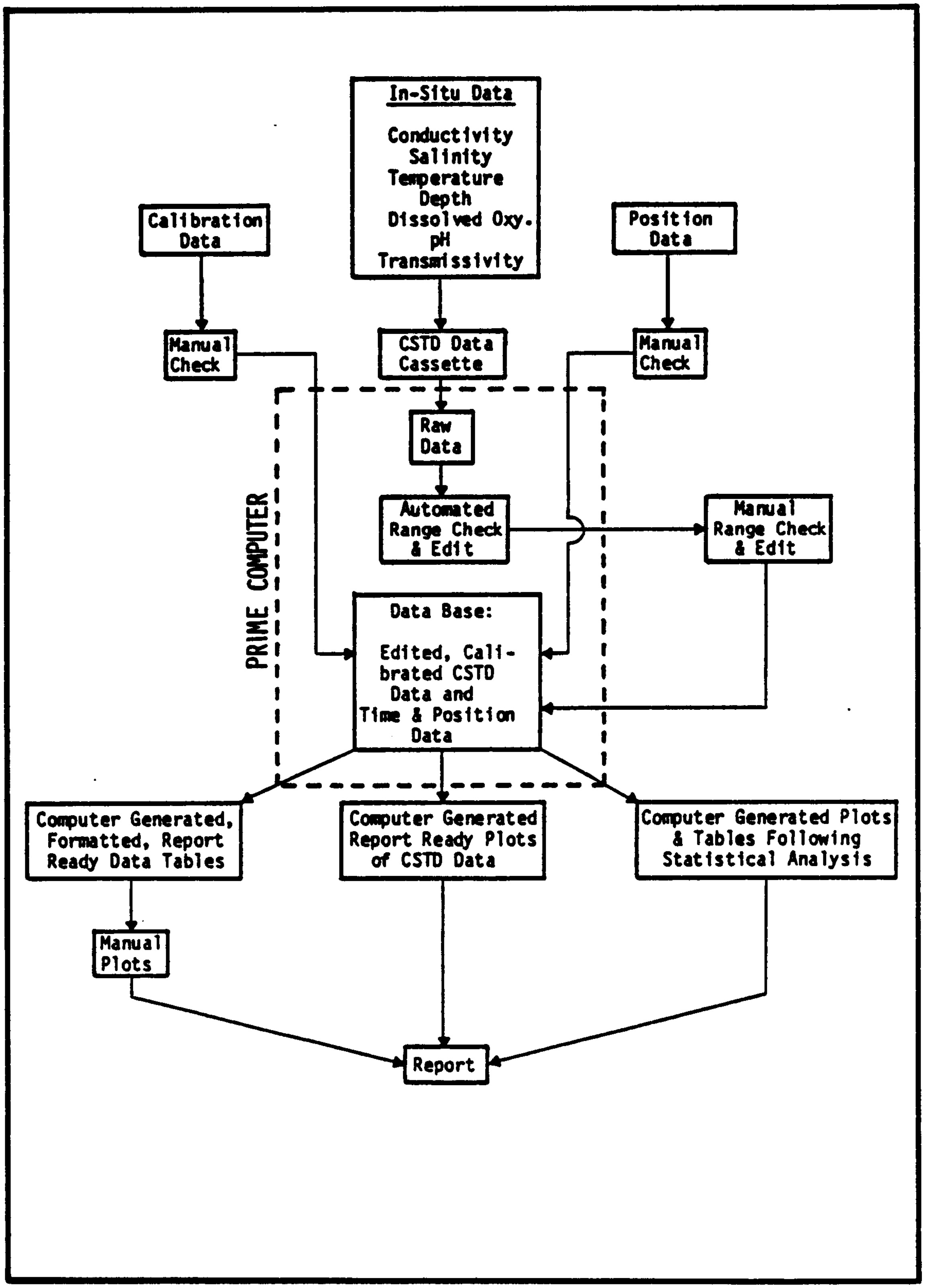


Figure 3.1-1 CSTD DATA FLOW DIAGRAM

temperature measured with the auxiliary thermometer and the standard correction equation presented in Sverdrup et al. (1946).

The salinity samples obtained from the Niskin bottle and placed in triple-rinsed sample bottles were returned to the Florida Institute of Oceanography for analysis. At the Florida Institute of Oceanography, sample salinity was measured with a Guildline Model 8400 "Autosal" salinometer. This instrument measured the conductivity ratio between the sample and a 35-‰ reference standard by continuously comparing the sample conductance with an integral reference conductance having an accuracy of ±0.003-‰ equivalent salinity. Once the conductivity ratio was determined, it was converted to practical salinity using the International Oceanographic Tables, Vol. 3, UNESCO (1981).

The DO sample, also obtained from the Niskin bottle, was collected, preserved, and analyzed using the Winkler method described in Strickland and Parsons (1968).

3.1.3 IN SITU ARRAY DATA

The five in situ instrument arrays deployed for collecting physical and biological oceanographic data near the seabed are discussed in Section 2.1.3. In addition to the ENDECO® Type 174 current meters deployed at all five stations, the arrays at Stations 21 and 52 were equipped with Sea Data® Model 635-11 wave and tide gages. Current and wave records were analyzed to supply valid estimates of the flow field near the bed for the prediction of entrainment and transport of sediment by waves and currents. The capabilities to observe the effects of flow phenomena for time scales ranging from a few seconds to many days or months are required to measure the influence from both currents and waves.

Current Meter

Current data were analyzed to provide information on the fluctuating current characteristics at each station. The current meter records included temperature, conductivity, salinity (calculated from temperature and conductivity), and current speed and current direction as a uniformly sampled time series. A sampling interval of 5 min was deemed optimal to monitor the phenomena known to affect unsteady oscillatory flow conditions for time scales as short as 10 min. A time series of near-bottom current flows affected by tides, winds, atmospheric pressure gradients, baroclinic circulations, seiching and internal waves with time scales greater than 10 min was resolved from the current meter data set.

Speed and direction were developed for monthly, seasonal, and yearly data sets, and further analyses were conducted on each current meter data set as follows:

1. Basic statistics,
2. Time series plots, and
3. Joint probability analyses.

A discussion of the methodology for each of the analyses is presented in the following paragraphs.

The basic statistics listed below were computed for each of the parameters listed for several time periods.

Statistics	Parameters
Mean	Temperature
Maximum	Salinity
Minimum	Alongshore Component of Current (approximately north-south)
Standard Deviation	Cross-Shelf Component of Current (approximately east-west)

Numerical techniques were applied to compute these statistics on a monthly, seasonal, and yearly basis for each current meter.

Time-series plots of current speed and direction, temperature, and salinity were formulated to assist in the interpretation of the physical data. Monthly plots of the time-series records are presented in Appendix B. The computational software allows for current data plots as speed and direction of alongshore and cross-shore components or major and minor flow components. In addition, the current data may be numerically filtered and presented as monthly plots of hourly time-series data.

Joint probability frequency distribution (speed and direction) of the currents was computed monthly for each meter. These results are tabulated and presented in Appendix B. Other analyses performed to describe and evaluate the current regime are as follows:

1. Principle components analysis to determine the principle direction of the *in situ* current data and the magnitudes of the major and minor flow components relative to this direction; and

2. Spectral analysis to describe current energies attributed to tides, seiching, inertial currents, or other periodic forcing functions such as excursions of the Loop Current.

Efforts concentrated on providing a detailed description of the current regime for use in prediction of sediment transport as described in Section 4.2.3.

For the initial analysis of the time series record, statistical techniques were used to determine the principle direction of the currents and the strength of the major component of flow relative to the minor component. The results of this analysis indicate whether rotating the axis of the Cartesian coordinate system relative to the computed principle direction is required prior to spectral analysis. A comparison of the strengths computed for the x and y components of flow will point to the need for further analytical tools such as cross-spectral calculations and cross-correlation analysis.

Numerical computation to compute spectra and cross-spectra directly from the current time-series data is a useful analytical tool as it represents the energy contents at different frequency components, and in the case of cross-spectra, it provides a measure of the interaction between two frequency components. Seasonal energy spectra were produced for the current speed and current direction time-series data. These spectra are discrete, and thus the energy spectrum is proportional to the total energy contained by the currents at each frequency.

Initially, a preprocessing of the data record was performed to correct all questionable data in the time series caused by instrument malfunction and voltage fluctuations. Prior to computing spectral values, the means and linear trends were removed. The records to be analyzed were then divided into equal segments or subsets. The Fourier analyses were completed on each subset, and the resulting energy at each discrete frequency was averaged to provide the final energy spectra for the seasonal current meter record.

Subsets of the time series were prepared for Fourier Analysis by using 50-percent overlap of the data and a 10-percent cosine bell tapering on each subset.

The smallest resolvable frequency can be expressed by:

$$\frac{1}{\Delta t N}$$

where: Δt = the sampling time interval, and
N = the number of data points in the subset.

The highest resolvable frequency is:

$$\frac{1}{2\Delta t} - \frac{1}{T}$$

where: $1/2\Delta t$ = the Nyquist or folding frequency, and
T = the window period.

To compute spectral values in the desired frequency range, the values of Δt, T, and the record length were specified appropriately to ensure a high degree of confidence. The stability of the spectral estimates depends on the averaging process such that the larger number of spectral subsets (equal to or greater than 15 is considered appropriate), the more stable are the resulting estimates.

Fast Fourier Transformation was performed to determine the Fourier coefficients which were then analyzed to construct the spectral and cross-spectral estimates of the time-series records. The computational technique is designed to give Fast Fourier Transformation of each subset, from which averaged spectral and cross-spectral estimates are made from all subsets.

Wave-Tide Gage

The Sea Data® digital wave-tide recorder provided a subsurface pressure record used to calculate a surface wave record and subsurface orbital velocities associated with wave motion. The contribution of surface waves to turbulence near the bottom was deemed significant only for shallow water Stations 52 and 21.

The Sea Data® gage makes both wave and tide measurements. The tide measurement interval was set to record eight averaged measurements per hour, which corresponds to 7.5-min intervals. In contrast, wave measurements consisted of a burst of pressure measurements. In the experimental design, wave measurements were recorded every 6 hours, with 1,024 wave samples in each burst at 0.5-s intervals during the burst. Wave fields characterized by low frequency and long wavelengths, with periods of 8 to 15 s, take 4 to 8 hours to change significantly. These waves contain the greatest amount of energy and are more important than shorter period waves in their effect on sediment resuspension. Consequently, a 6-hour sampling interval was deemed sufficient.

The Sea Data® instrument uses a Paro Scientific® Pressure Sensor to detect pressure fluctuations due to surface waves. The subsurface pressure record is related to the surface wave record by:

$$P(t) = K_p y(t)$$

where: $P(t)$ = the subsurface wave pressure record.

K_p = the pressure response function. This function is dependent upon both the depth of the gage and the frequency of surface wave.

$y(t)$ = the surface wave record.

The pressure response function is:

$$K_p(\omega) = \gamma \cosh(kD)/\cosh(kH)$$

where: k = the wave number,

D = distance from bottom to pressure transducer,

H = total depth of water, and

γ = specific weight of sea water.

The wave number k is related to frequency by:

$$\omega^2 = gk \tanh(kH)$$

where: g = gravitational constant, and

ω = wave frequency.

The value of k cannot be solved for in closed form from the expression above. For any frequency ω, the value of k is calculated by an iterative technique; the Newton-Raphson algorithm was used to calculate the values of k. This is a technique which uses an initial guess for k to determine a next approximation. Each succeeding approximation is used to find a new value until the values converge to within a reasonable figure.

To create a surface wave record from the bottom pressure record in the time domain would involve a convolution of the pressure response function with the pressure record. The convolution can be accomplished readily by transforming the time series record into the frequency domain and multiplying by the transformed pressure response record. This record can then be manipulated in the frequency domain to provide certain statistical information. It could also be transformed back to the time domain to recover the surface wave record.

The programs used for analysis of the Sea Data® pressure records first use the Fast Fourier Transformation to transform the data into the frequency domain. The wave number k and the pressure response function $K_p(\omega)$ are then determined for each frequency. The energy available at this frequency is calculated, and the inverse response $(1/K_p)$ is applied to create the corrected energy. From this data record, the total wave energy can be extracted. If desired, the frequency of major energy can be extracted.

$$P(\omega) = \mathfrak{F} P(t)$$

$$Y(\omega) = 1/K_p \; P(\omega)$$

$$S(\omega) = Y(\omega)^2/(2 \pi T)$$

$$S(\omega) = P(\omega)^2/(2 \pi T)/K_p{}^2$$

$$\text{Total energy} = \sum_{n=1}^{N} S(\omega)$$

$$H_s = 4 \text{ x} \sqrt{T}$$

where: $\mathfrak{F}$ = the Fourier Transform,
$Y(\omega)$ = the surface record in the frequency domain,
$S(\omega)$ = the energy as a function of frequency, and
H_s = the significant wave height.

The peak energy is at the frequency ω where $S(\omega)$ is maximum after smoothing and neglecting low frequency swells.

The pressure transducer provides a frequency output related to pressure input. The corrected pressure frequency from the sensor is used to obtain the pressure by:

$$P = A[1 - T_o/T] - B[1 - T_o/T]^2 \text{ or}$$

$$P = A[1 - T_o f] - B[1 - T_o f]^2$$

where: T = period output from Paros sensor,
f = 1/T is the frequency output from the Paros sensor, and
P = the pressure in the same units as A and B.

where: A, B, and T_o are calibration coefficients provided with each Paros unit.

In the Sea Data® unit, the pressure from the Paros sensor is a 20-bit word (1 048 756) truncated to 16 bits (65 536). In normal operation the unit will probably not under/over flow the 16-bit word length. Any under/over flows can be corrected easily, however, since the difference between the current and previous data will be greater than 32 768. This amount either needs to be added or subtracted from the data word to produce the correct value. From the corrected Sea Data® pressure word, the Paros frequency is obtained.

$$f = \text{count}/16$$

where: f = Paros sensor frequency, and
count = corrected count from Sea Data® unit.

The pressure is then determined from the pressure/frequency equation given previously. Since no data are available for barometric pressure at the test site, a standard pressure of 14.7 psia is assumed. The water height above the sensor is then produced for each pressure reading.

$$H(i) = [(P(i) - 14.7)/14.7] \times 32.0$$

These water heights are then used to calculate the spectral statistics by Fast Fourier Transformation into the frequency domain.

The calculation of subsurface orbital velocities u and v are also done from the results of the pressure transformation. Since there are no data in the pressure record indicating wave direction, only the resulting magnitude of orbital velocities can be generated. The reference angle is assumed north (0°) and can later be added. If one further assumes the wave direction is predominately from the same direction as the wind, then the phase of the orbital velocities can be obtained by referencing NOAA weather maps of the area for the times of the data runs.

$$|u| = K_u y(t)$$

where: $|u|$ = Magnitude of orbital velocity,
K_u = velocity response function, and
$y(t)$ = surface wave record.

also;

$$K_u = [\ \omega \cosh(kD)]/\sinh(kH)$$

Since

$$P = K_p y(t) \text{ and}$$

$$|u| = (K_u/K_p)P, \text{ then}$$

knowing K_u and K_p and having the pressure record (P), the subsurface orbital velocities for u can be calculated.

This general analytical method first was applied to the recorded pressure record to estimate the surface wave field that was reported as significant wave height and average wave period. The method was then used to compute the scouring velocity at the bottom that these waves produce. This method was not required for the tide data since the tidal period is very long and the energy does not attenuate with depth like wind waves. Tide readings were converted directly to water level heights for presentation.

3.2 SEDIMENTS

Three sampling methods were used at the various stations investigated for this study: sediment traps, time-lapse camera, and grab samples. Two of the sampling methods were continuous in that data collection continued uninterrupted throughout the sampling period (Group II stations only). The third sampling method involved a single collection event (both Group I and II stations).

A sampling array was positioned at each Group II station; a time-lapse camera attached to the structure photographed the proximal sea floor. A photograph was taken every hour throughout the 1-year study period. The exposed film was replaced with new film on each quarterly cruise. In addition, attached to each array were three plastic sediment traps that collected sediment as it fell to the seabed. The traps, consisting of five replicate tubes each, were positioned at elevations of 0.5, 1.0, and 1.5 m above the sea bottom. The tubes collected sediment continuously throughout the 1-year study period, and were retrieved and replaced with empty tubes each quarter.

Two replicate grab samples for bottom sediment analysis were also collected at all stations, either by a SCUBA diver or a Smith-McIntyre grab. The grab samples were collected only once during the 1-year study.

Laboratory analysis of the material collected in the sediment traps occurred in several phases and involved numerous procedures. The individual tubes were first visually inspected and photographed. The mass of sediment collected in each tube was calculated, and composite samples were prepared. The composite samples were subjected to grain-size analyses, $CaCO_3$ content determination, organic carbon content determination, and X-ray diffraction analyses.

Laboratory analysis of the grab samples was less involved than the analysis of the sediment traps. Sample evaluation included grain-size analyses, $CaCO_3$ content determinations, and organic carbon content determinations. The laboratory methods used to analyze sediment samples are discussed below; the methods used for processing the time-lapse data are provided in Section 3.4.5.

3.2.1 SEDIMENT TRAP SAMPLES

All of the sediment traps were examined visually prior to extraction of the sediment. The depth of sediment in each tube was measured and recorded, and all replicates from a given station, elevation (0.5, 1.0, and 1.5 m), and cruise were compared and checked for similarity. The tubes were cleaned of all external algae, sediment, and epifauna and returned to the freezer to await analysis. Care was exercised to prevent thawing the frozen sediment during the inspection process.

Those tubes that collected more than several centimeters of sediment exhibited slight tonal and textural variations that were visually discernible; such laminations were recorded on film. The zonations were more distinct when viewed through the clear plastic walls of the sediment tubes; therefore, longitudinal sectioning was avoided. All replicates from a given station, elevation, and cruise were placed on a white background and photographed in color in natural light. The background was labeled with all pertinent and identifying information. A vertical scale from 0 to 40 cm was included in the photograph. The sediment was not allowed to thaw, but the frost was wiped from the tubes with a damp cloth immediately prior to photographing.

The entire frozen sediment column was extruded from each tube in 2-cm increments and cut into sections with a fine-tooth saw blade. Each section was placed in a tared and labeled beaker and weighed to determine the mass of wet or frozen sediment. The sediment was dried in an oven maintained at 60°C to determine the mass of dry sediment. The percentage water in each section was calculated. Making use of the known seawater salinity at the station from which the sample was collected, the mass was corrected for the contribution made by the soluble salts precipitating in the sediment after evaporation of the water. The corrected masses of all sections from a single tube were totaled to yield the mass of dry, salt-free sediment in that tube.

Once the mass of dry, salt-free sediment was determined for all replicate tubes from a given station, elevation, and cruise, composite samples were prepared. Correlated and corresponding 2-cm sections from each of the tubes were combined, disaggregated, homogenized, and then split into eight equal and representative portions. Four of the eight parts were reserved for grain-size analyses, three for $CaCO_3$ analysis, and one for carbon analysis; all were stored in covered containers prior to examination.

Ideal sample weight for a complete grain-size analysis ranges from 10 to 25 g if the material is predominantly clay sized, 25 to 75 g if the sample is mainly silt and fine sand, and 75 to 100 g if the sample is mostly sand. Modes of investigation include pipetting, sieving, and, if deemed appropriate, settling velocity determinations (settling velocities are determined on sand and coarser material only).

Sample preparation was very important and involved the oxidation of organic matter disseminated in the sediment, the flushing of soluble salts that precipitated in the sediment during evaporation of interstitial seawater, and the dispersal of clay particles that may otherwise have exhibited a tendency to flocculate.

To remove the organic matter in the sediment, the sample was soaked in 20 ml of 30 percent H_2O_2 for several hours. To ensure that the oxidation process had reached completion, an additional small volume of

H_2O_2 was added, and the sample was examined for evidence of effervescence. The oxidation was considered complete when the addition of H_2O_2 did not initiate further effervescence. Agitation and mild heat application were used to accelerate the reaction.

To wash soluble salts and excess H_2O_2 from the sample, the treated sample was transferred to a larger centrifuge bottle which was then filled with deionized water and centrifuged at 1,000 rpm for 10 min. The water was decanted carefully so as not to disturb the sediment, and then more deionized water was added and mixed thoroughly. The filling, centrifuging, and decanting procedure was repeated several times to ensure the removal of all unwanted salts and peroxide.

The cleaned sediment was next transferred to a tared and labeled beaker and dried at 60°C to constant weight. The mass was recorded as the original bulk sample weight on the data sheet. If less than ample material remained for the grain-size analyses, a portion of that reserved for $CaCO_3$ analysis was treated and cleaned to remove organic matter and salts and added to the sample to yield sufficient quantity.

To inhibit flocculation of clay particles, the preweighed sample was soaked in 100 ml of a 4-percent sodium hexametaphosphate solution for 15 min and then transferred to a mixer cup and blended at high speed for 30 min. The sample was then transferred to a 1,000-ml glass graduated cylinder, and deionized water was added to bring the volume to just under 1,000 ml. The cylinder was allowed to stand for several hours, and the suspension was examined for evidence of flocculation. The graduated cylinder was tilted about 20 degrees from the vertical; if the deposit at the bottom flowed easily such that the sediment/water interface remained horizontal, the sample had flocculated and was not suitable for analysis. If the sample had flocculated, the material was allowed to soak longer, or a new suspension was prepared using less sample.

The pipette method of grain-size determination and distribution was sensitive to silt- and clay-sized particles only; coarser grains settled from suspension before they could be sampled. The sieve analysis was effective in determining the distribution of the coarser particles. Settling velocity determinations were valuable in predicting settling times of coarse grains that had specific gravities other than 2.65 and shapes other than spherical.

The pipette analysis involved filling the 1,000-ml cylinder to exactly the 1,000-ml graduation with deionized water, bringing all material in the cylinder into suspension by shaking or stirring, and removing 20-ml subsamples of the suspension according to a predetermined schedule of withdrawal times and depths. To account for the effects of water viscosity on settling rates of suspended grains, the withdrawal schedule was based on experiment temperature, the factor controlling water viscosity. Each 20-ml subsample was washed into a tared 50-ml beaker and dried at 60°C to constant weight. The mass of sediment collected in each beaker was corrected for the additional mass present due to the dispersing solution added to the sample. The corrected mass was then used to calculate the net mass of all material in that given size class suspended in the cylinder. Based on the data derived from the pipette analysis, the cumulative grain-size distribution of the clay- and silt-sized particles was plotted on 5-cycle semi-log graph paper.

When the pipette analysis of a given sample was completed and all data values were substantiated, the sediment was washed over a 62-um (4 phi, No. 230 U.S. Standard) sieve to separate the sands from the silt and clay. The fine material, in suspension, was collected beneath the sieve in a 1-gallon cubitainer and preserved for the duration of the project in the event that reevaluation of the sample was indicated. The coarse fraction retained on the 62-um sieve was dried at 60°C and weighed, and if its mass constituted greater than 5 percent of the original bulk sample weight and was in excess of approximately 10 g, a sieve analysis was conducted.

The dried sand was introduced through the top to a nest of graded U.S. Standard sieves (1/2 phi intervals). The sieves were placed together on an automatic Ro-Tap® and shaken for 10 min, after which they were separated and the mass of material retained on each determined. Each fraction was stored in a labeled plastic bag for the duration of the project. The cumulative grain-size distribution of the sand was plotted on the graph with the pipette results for that same sample.

The sediment size distribution was described using statistical methods outlined in Inman (1952). Following examination of the data it was concluded that, because several samples were bimodal and several were severely skewed, the method described by Inman (1952) and presented in Table 3.2-1 was inferior to the method described by Folk and Ward (1957). Therefore, the method described by Folk and Ward will be used on the Year 4 and Year 5 samples and the results presented in the Year 5 Annual Report.

The settling velocities of the sieved fractions were measured for selected samples. Because the specific gravity of biogenic sand and shell debris is in excess of 2.65 (calcite specific gravity = 2.71, aragonite specific gravity = 2.93) and because such grains tend not to be spherical, the settling velocities could not be computed using Stoke's Law and the particle diameters. The settling velocities were measured directly by timing the descent of the grains in a contained column of water through a known distance and beyond the influence of acceleration.

Samples were sorted into their various size fractions by sieving, whereupon each fraction was analyzed individually. Velocities less than about 7 cm/s were measured in a standard glass 1,000-ml graduated cylinder, but grains settling faster than this had to be evaluated in a tube of greater height to ensure accuracy. For this purpose, a specially designed clear acrylic cylinder 11 cm in diameter by 193 cm in length was used.

The 1,000-ml cylinder was filled with water well above the upper graduation, and a starting point 5 to 6 cm below the water level was marked on the cylinder wall (conveniently the 1,000-ml graduation). Near, but above the bottom of the cylinder and approximately 30 cm below the starting point, an endpoint was marked. The exact distance between the two points was noted on the data sheet. It was important that the start point be sufficiently deep so that the settling grains attained terminal velocity prior to passing it. If the grains were accelerating as they passed the mark, the calculated velocities would be less than the actual velocities.

The large acrylic cylinder was filled to nearly the top with water, and start and endpoints were located at 30- and 150-cm depth, respectively. The exact distance separating the points was noted on the data sheet, and once again, the start point had to be at sufficient depth such that falling grains had reached terminal velocity before passing it.

Fractions coarser than 62 um (4 phi) were soaked in water for 30 min to an hour immediately prior to analysis to remove trapped air in the void spaces of the grains. Single grains were removed with forceps and gently placed beneath the water surface in the appropriate cylinder and released. The time elapsed in passing between the start and endpoints, in seconds, was recorded on the data sheet. If the material appeared to be homogeneous (i.e., all grains had similar shape and color), six grains were randomly selected and measured in the manner described. If the material consisted of two or more distinctly different grain types, then three grains from each representative type were chosen randomly and measured.

Certain planar and curviplanar shell fragments settled in an "unstable" mode whereby the grains rocked and tipped back and forth (like a feather in air) and fell more slowly than expected. Certain other grains, particularly gastropod shells, tended to settle through a spiral motion and attained abnormally high velocities. The unstable settling of an occasional grain or two may have been due in part to the manner in which the grain was introduced to the water column. If either of these unstable modes (spiraling or tipping) was considered to be the norm for a given fraction or subfraction, the modes observed and the settling times as measured were recorded. If the majority of the grains in a given fraction or subfraction settled in a stable mode, then the values gathered in observing unstable grains in the same group were not included when computing average values for that group.

Sediment fractions finer than 62 um (4 phi) consisted of grains that were too small to handle individually and whose descent in the water column would have been difficult to follow. For these reasons, a "pinch" of sediment comprised of 100 to 300 grains was used for the settling velocity determinations of very fine material. The sediment was placed onto the surface of the water in the 1,000-ml cylinder where the particles coalesced and formed a patch supported by the surface tension of the water. The sediment was touched with a steel prod to cause a portion of the grains to sink. A cloud of sediment was produced whose descent was easily observed. Because of variations in grain shape and composition, and because each size fraction was actually a collection of particles within a certain range of diameters, the sediment cloud dissipated and lengthened as the faster grains outdistanced the slower ones. For each fraction, the settling time of the cloud was measured six times, three times following the head of the cloud and three times following the tail. All values were recorded on the data sheet, and average velocities for each fraction were calculated.

Depending on analyst preference, sample mass, and the nature of non-carbonate sample components, two methods were available to determine the $CaCO_3$ content of the sediment. Method 1 involved the dissolution of $CaCO_3$ in a large amount of sediment and measuring the mass of the insoluble residue. This method was limited to fairly large sample masses, and the mass required was inversely proportional to $CaCO_3$

content. Method 2 was used when the sample quantity was limited (as little as 1.5 to 2.0 g sufficed), but could not be employed if the sample contained an appreciable amount of the clay minerals. Method 2 involved burning the sample first at 550°C to remove the organic matter present, weighing the samples, and then heating to 900°C to remove the CO_2 in the $CaCO_3$. The structural water existing as hydroxyl groups (OH) in any clays present would have been lost along with the carbonate CO_2 at the high combustion temperatures, and erroneously high carbonate values would have resulted, if organic matter were not first combusted at 550°C.

$CaCO_3$ content, as determined by Method 1, involved dissolving a known mass of at least 10 to 20 g of sample contained in a tared beaker in a strong hydrochloric acid (HCl) solution. Beneath a fume hood the acid was added to the sediment slowly, gradually dissolving any carbonate present. The contents of the beaker were frequently stirred and washed from the sides to ensure complete dissolution of all $CaCO_3$.

HCl was was added until further additions failed to produce effervescence. Once the $CaCO_3$ was dissolved the beaker was filled with deionized water and the contents allowed to settle for several hours. Water, dissolved Ca^{+2} and Cl^-, and excess acid were decanted, and the beaker was refilled with deionized water and allowed to stand again for several hours. Following the final decantation, the sample was dried at 60°C to constant weight, and the amount of $CaCO_3$ in the sample based on the weight loss was determined. If only several grams of sample were available for analysis, Method 2 had to be used for $CaCO_3$ content determinations.

For $CaCO_3$ content determination, Method 2 could be completed with as little as 1.5 g of sample and could be conducted on the same samples used for carbon analysis. Several grams of sample were dried at 110°C for several hours in a small disposable aluminum dish and cooled to room temperature in a desiccator. From 1.5 to 2.0 g of dried sediment were placed in a tared combustion boat and weighed to the nearest 0.001 g. The sample was heated in a muffle furnace first at 550°C for 2 hours to remove any organic matter present. The sediment was cooled in a desiccator to room temperature and the weight loss determined. The sample was returned to the furnace at 900°C for 8 hours and then cooled in a desiccator to room temperature. The change in mass between the sample after burning at 550°C and after burning at 900°C was attributed to the loss of CO_2 by the reaction:

$$CaCO_3 + \text{heat} \longrightarrow CaO + CO_2$$

The reaction does not proceed below about 600°C. CO_2 constitutes 44 percent mass of $CaCO_3$, and the quantity of $CaCO_3$ in the sample was determined using this relationship.

The amount of organic carbon in the sample was determined by combustion as well. Several grams of sample were air dried at 110°C for 4 hours, placed in a tared combustion boat and weighed, and placed in a muffle furnace at 550°C for 2 hours. The boat was cooled to room temperature in a desiccator, weighed, and the loss in mass attributed to the combustion of the organic matter in the sediment. The percentage of organic matter in the sample was related directly to the weight loss that occurred upon burning.

Many of the sample traps received too little sediment to permit examination by the methods described in the preceding paragraphs. If visual inspection of the sediment tubes indicated that insufficient sample existed for the completion of the typical sedimentological analyses, an alternate mode of investigation was chosen. The total mass of sediment collected in each tube was measured, and the nature of the material was determined microscopically.

The frozen sediment tube was placed in a 1,000-ml beaker and thawed on a hot plate at low temperature (below the boiling point). Twenty ml of 30-percent H_2O_2 was added to the sample to rapidly oxidize the algae and other organic matter present. Several hours following treatment an additional smaller volume of H_2O_2 was added to the sample, and the reaction was observed. When doses of H_2O_2 failed to initiate further effervescence, the oxidation was considered complete, and the sample was ready for filtering.

A tared 0.45-um filter paper was placed on the base of a filter candle, and the contents of the beaker were poured inside. The residue in the beaker was washed into the candle with deionized water. Approximately 25 pounds per square inch (psi) of vacuum was applied using a conventional vacuum pump; the sides of the candle were intermittently washed with deionized water. Several sample volumes of deionized water were flushed through the filter to ensure passage of the less than 0.45-um-sized material (by definition, nonsediment material, principally dissolved salts). The filter paper was dried at 60°C to constant weight, and the mass of sediment retained on the filter was determined. The dried paper was placed in a clear plastic bag, labeled, and reserved for microscopic examination.

The various components in each sample were described and identified with the aid of a low-power binocular microscope and light. Unidentifiable components were sketched and identified following the examination. Each filtrant was qualitatively tested for $CaCO_3$ content by applying several drops of dilute HCl to the sediment and observing the sample for evidence of effervescence.

Several samples were randomly selected for X-ray diffraction analysis whereby the mineral nature of the inorganic portion of the sediment was determined. X-ray diffractograms were obtained on the bulk sample, the insoluble residue after acid treatment, and the material finer than 2 um in diameter.

The bulk sample was prepared for X-ray analysis by powdering several grams of the sample with a mortar and pestle. The sample was packed in a shallow disk designed to fit into the diffractometer and then was scanned from 2° to 60° two theta (2θ) using copper K-alpha ($CuK\alpha$) radiation. The powder mount was used primarily to determine the mineralogy of the carbonate species present.

To prepare a sample of the insoluble residue, 10 to 20 g of sediment were soaked overnight in dilute HCl or acetic acid. The material remaining after acid treatment was cleaned and dried and then powdered as described previously. The sample was scanned from 2° to 60° 2θ under similar operating conditions. Analysis of the insoluble fraction yielded the mineralogy of the noncarbonate components present, although clay minerals were difficult to distinguish by this method.

The material finer than 2 um (all clay minerals and carbonate muds) was isolated by suspending the sediment in water and removing several milliliters of the mixture after the contents had settled for many hours. The mixture was deposited on a glass microscope slide and air-dried overnight. The slide was scanned from 2° to 40° 2θ under operating conditions similar to those used previously. This method of sample preparation was particularly suited to the analysis of clays both because of the isolation of the fine-grained material and because the preferred orientation imported to the peaty clay minerals yielded enhanced basal reflections that aided in their identification.

3.2.2 BOTTOM GRAB SAMPLES

The bottom samples from the various stations collected by diver or Smith-McIntyre grab consisted of sand and coarser-sized particles. These samples were analyzed for grain-size distribution by sieving, $CaCO_3$ content, and carbon content as previously described.

3.3 INFAUNA

3.3.1 LABORATORY ANALYSIS

In the laboratory, infaunal samples were washed with water to remove the formalin. Once the formalin was removed, samples were placed in a sorting pan and organisms elutriated from the sample by gently resuspending them with running water. The overflow containing the organisms was collected on a fine-mesh screen. The sediments remaining in the sorting pan were visually inspected, and any remaining organisms were removed. Large, easily visible organisms contained in the sample elutriate were removed. The remainder of the elutriate was placed in sorting dishes, and the organisms were removed from the inorganic fraction under a dissecting microscope. Organisms were stored in 70-percent ethyl alcohol.

Taxa were identified to the lowest taxonomic level practicable, which was the species level whenever possible. The majority of taxa were identified with the aid of a stereoscopic microscope. When higher magnification was necessary, organisms were temporarily mounted in glycerin and viewed with a phase contrast compound microscope. Additionally, when necessary, organisms were permanently mounted and cleared with CMCP-10. The most recent taxonomic literature available was used for taxa identifications.

Taxa were identified and enumerated by individual sample replicates. The replicates counts were recorded on keypunch-ready taxonomic bench sheets. Taxa were recorded using the fourth edition of the NOAA Oceanographic Data Center (NODC) taxonomic code.

NODC code does not allow for the inclusion of taxa which can be distinguished at the species level but cannot be assigned a published species name, nor does it include species identifications which have been published since the fourth edition of the code. For these taxa, the individuals were lumped under the next higher code. The inclusion of these separate species under the generic level code will not measurably affect the analytical results since they constitute a small part of the data set, and the populations were generally skewed towards one of the species with the other being relatively rare. An example of this is the cumacean genus Cyclaspis. Two Cyclaspis species designated species A and species D were identified and enumerated, but were lumped under the taxon code for Cyclaspis. A second example is the inclusion of a newly published species identification. Descriptions for Heteropodarke lyonsi and H. formalis were published in August 1984 (Perkins, 1984) and, therefore, were not included in the NODC taxonomic code. These two species were lumped at the genus level (Heteropodarke) for data analysis. Records of separable species not coded as such were retained on original data bench sheets.

3.3.2 DATA ANALYSIS

Coded infaunal data were entered on computer. The data set was double keypunched to ensure accurate data entry. Report generation and data analysis proceeded once the accuracy of data entry was verified.

The coded data were used to generate a phylogenetic listing of all taxa collected from the December 1983 and May 1984 collections. A second phylogenetic listing of taxa was coupled with taxon occurrences over all stations to produce a presence-absence matrix, which depicted the occurrences of each taxon at the individual stations for both the December 1983 and May 1984 collections.

For each station, the community composition was broken down by the number of taxa of each major taxonomic group (i.e., polychaetes, amphipods, gastropods, etc.). The collections at each station were further broken down by individual taxon. At each station the taxa were ranked by numerical abundance, and the estimated mean density for each taxon, the percent contribution of each taxon, and the cumulative percent contribution were calculated. Total mean density and standard deviation of the density estimate for each station were calculated.

Indices of community structure were calculated for each infaunal collection. These indices were the Shannon-Weaver diversity index, Margalef's species richness index, and Pielou's evenness index (Pielou, 1975; Green, 1979).

The Shannon-Weaver diversity index has sometimes proven useful in the study of benthic communities and has been especially used in pollution studies. The index is attractive because it condenses a large body of data into a single number which can be evaluated by ecologists. This index considers both the numbers of taxa present, and the numbers of individuals of each taxon. A major disadvantage of any species diversity index, including the Shannon-Weaver, is that it does not retain information as to species identities, so that two completely different communities can result in identical index values; conversely, two similar communities can result in widely divergent index values. Because of this, the index must be used with caution and in conjunction with other data analyses. The Shannon-Weaver index was calculated as:

$$H' = - \sum Pi \log_2 Pi$$

where: Pi = The proportion of the community belonging to the ith species.

Two components of diversity are the number of taxa (species richness) and the distribution of individuals among taxa (evenness). The species richness component of the data was evaluated using the number of taxa present at a station and by Margalef's species richness index, which is basically a diversity index based on the number of species in a sample. It is calculated as:

$$d = (S-1)/\log N$$

where: S = the number of species, and
N = the total number of individuals in a sample.

The evenness component of diversity was calculated as Pielou's evenness index, which takes the form:

$$E = H'/\log_2 S$$

where: H' = the calculated Shannon-Weaver index, and
$\log_2$ = the theoretical maximum diversity for that sample consisting of S species which are equally abundant.

The evenness index ranges between 0.0 and 1.0. A value of 1.0 means all species are represented by equal numbers of individuals. The Shannon-Weaver and Margalef's indices have 0.0 as a lower limit and no upper limit. Values near 0.0 indicate a depauperate community.

Normal cluster analysis was performed on the data set using the CLUSTAN computer package (Wishart, 1978). Cluster analyses can be performed on both numeric data and binary (presence/absence) data. The CLUSTAN program has limits of 200 numeric variables and 400 binary variables. Since a total of 414 taxa was included in the data set, both numeric and binary classifications required the elimination of taxa.

A cluster analysis was performed on the data set with the numeric counts converted to binary data. Converting to binary data allowed the inclusion of 97 percent of the data set in the analysis.

It was necessary to reduce the list of taxa by 14 to remain within program limitations. The number of taxa were reduced to 14 by either excluding a few taxa on which identifications were indeterminate or by combining a few taxa under a single taxon code.

Communities are often defined by dominant organisms. Using binary data gives abundant taxa the same importance as rare taxa so that the classification does not separate stations by taking the abundance into account. In the case of the present data set, this was not considered problematical because of the high diversity and even distributions which resulted from the vast majority of the taxa being represented by only one to a few individuals.

Cluster analysis for binary data was performed using the Bray-Curtis dissimilarity coefficient, which was calculated as:

$$D = \frac{(B + C)}{2A + (B + C)}$$

where: A = the number of taxa in common,

B = the number of taxa in collection 1 but not in collection 2, and

C = the number of taxa in collection 2 but not in collection 1.

A hierarchical dendrogram was constructed by group-average sorting. The data sets from both the December 1983 and May 1984 sampling efforts were included in the same analysis.

Cluster analysis using numeric data was performed using the Bray-Curtis dissimilarity coefficient with group-average sorting, and log transformed [$Y = \log (x + 1)$] taxon mean densities. Only numerically dominant taxa were included in this analysis. These were defined as those taxa which accounted for 0.9 percent or greater of the mean density of total individuals at any station. Using this selection criterion, 86 taxa were included in the analysis. This accounted for 15 percent to 27 percent of the total taxa at the individual stations, and acounted for 71 percent to 88 percent of the total individuals at the respective stations. The list of taxa and the log transformed density data used in the numeric cluster analysis are included in Appendix E (Tables E-1 and E-2).

The Bray-Curtis coefficient with numeric data was calculated as:

$$Djk = \frac{\sum i \left| Xij - Xik \right|}{\sum i (Xij + Xik)}$$

where: Xij = the density of species i in the jth collection, and
Xik = the density of species i in the kth collection.

The dissimilarity coefficient ranges from 0.0 to 1.0, and a coefficient equal to 1.0 means no similarity between collections.

The Bray-Curtis coefficient based on log-transformed data and group-average sorting is one of the most widely used clustering strategies in marine ecology (Boesch, 1977). Of four common similarity indices, only the Bray-Curtis coefficient was found to reflect accurately true similarity when compared to a theoretical standard (Bloom, 1981). The Bray-Curtis coefficient does not consider joint absences, and therefore does not classify collections as similar on the basis of mutual species absence, nor is it over-influenced by chance species occurrences (Field *et al*., 1982). Densities often provide skewed data, and the Bray-Curtis coefficient can be largely determined by species with high densities, while species with low densities are relatively unimportant (Boesch, 1977; Field *et al*., 1982). To overcome this, densities need to be transformed. The log transformation scales down high densities so that they do not dominate the other data (Field *et al*., 1982). Group-average sorting appears to be the most successful clustering method because it joins groups together at the average similarity between all members of each group, and has no marked tendencies to form large groups of dissimilar collections or to split similar collections (Boesch, 1977; Field *et al*., 1982).

3.4 EPIFAUNA, NEKTON, AND MACROALGAE

3.4.1 UNDERWATER TELEVISION

Recorded videotape from field efforts was analyzed in LGL's laboratories in Bryan, Texas, using either a Model 8200 or 1750 Panasonic VHS format videotape player with a minimum of 270 lines of monochrome horizontal resolution. The tapes were viewed on a 19-inch Sony television with an attached video image enhancer for increased image resolution and contrast.

Visual identifications were made to the lowest possible taxon and confirmed by specialists as needed. Each identification was assigned a quality index number ranging from 1 to 5, depending on the confidence that could be placed in identification. A score of 5 indicated that there was virtually no doubt about the identification; a score of 1 implied that even though a name had been assigned, there was a high degree of uncertainty concerning the identification. A description of each index score used in this study appears in Table 3.4-1. The quality index of doubtful identifications was raised whenever possible by using information from benthic still photography (see Section 3.4.2). Quantitative analyses were performed only on data having a quality index value of at least 3.

Data from each videotape were first transcribed onto intermediate preprinted work forms having columns for types and numbers of organisms observed, depth of each observation, video recorder counter number, and time of day. The initial stage of analysis was to preview the first segment of bottom habitat at each station to establish types of organisms and habitat present. For many groups of organisms, individual counts were not possible due to extremely high numbers or morphological characteristics which prevented the enumeration of single individuals. In the case of high numerical abundance, a range of densities was established which could be utilized with a relatively high degree of confidence (e.g., 11-50 or 51-100/10 m^2).

Table 3.4-1. Index of Scores for Quality of Videotape Identifications

Quality Index Number	Description
1	Best guess--not usually used, in most cases used as a "flag" for later reevaluation
2	Probable but not much evidence
3	Reasonably likely
4	Fairly certain
5	Assured ID (implied if blank)

Organisms with densities less than 11/10 m^2 generally were counted individually for a more precise overall density estimate. When distinct individuals could not be identified, percentage cover estimates were employed and were also established as ranges between two values. A list of these value ranges appears in Table 3.4-2. Percentage cover estimates were used for groups such as algae, plate corals, and coralline algal nodules.

Estimates of percentage cover were made by observing the substrate beneath the camera frame as vertically as possible to minimize the effects of angular distortion. Value ranges of percentage cover were established which would be reliably selected, with narrower ranges near the extremes of 0 and 100 percent.

Determinations of accurate densities (expressed as number of organisms/ 10 m^2) required several preliminary steps at the beginning of each video transect. The transect census width was first evaluated with data taken when the paired parallel-mounted video cameras were operating simultaneously. On playback, this produced a split double image on a single televison monitor screen. LORAN C plotter diagrams of video transect position were then measured to determine transect length. This length was then compared to elapsed transect time to obtain an overall drift speed. The entire length of a particular video transect was used for these measurements. The drift rate was considered constant throughout each individual transect, except when exceptional wind velocity changes had to be taken into account.

Once transect census width and drift speed were estimated, an appropriate segment of data tape was then viewed to evaluate taxa densities in numbers/10 m^2 for those groups which required this type of measurement due to their high numerical abundances. The typical habitat segment evaluated for density was 10 m long. It was converted into seconds of viewing time using the previously calculated drift speed. Once initial densities and percentage cover information were

Table 3.4-2. Videotape Scoring Categories

Density or Percentage Cover

Taxon	Density	Taxon	Percent Cover
Gorgonians	1 - ≤1 per 10 m^2	Sponges	1 - 0
Crinoids	2 - 2-10	Algae	2 - ≤1
	3 - 11-50	Algal nodules (rubble)	3 - 2-10
	4 - 51-100	Plate corals - live	4 - 11-25
	5 - 101-200	Reef rock/bare patches*	5 - 26-50
Fish and			6 - 51-75
Other Taxa	Actual Numbers		7 - 76-90
			8 - 91-99
			9 - 100

Composition

Taxon	
Sponges	1 - All massive type
	2 - All branching
	3 - Combination of both--similar
	4 - Predominantly massive, some branching
	5 - Predominantly branching, some massive

Size

Species	1 - Very small
Specific	2 - Small
	3 - Medium
	4 - Large
	5 - Very large

Other Characterizations

1 - Apparently dead; e.g., white sand dollar, dead fish
2 - Dead Gorgonian stalk covered with algae
3 - Recorded to indicate presence; not for numerical procedures

*Hard substrate considered as an underlying pavement; other groups can be overlying substrate as a separate category of percent cover.

obtained, each transect was then viewed in its entirety and the following information entered on transcript work forms for each segment and for the entire tape:

1. Individual organisms identified to lowest possible taxon,
2. Depth and depth changes,
3. Video recorder tape counter number corresponding to specific events and observations,
4. Habitat type,
5. Changes in densities or percentage coverage of biota, and
6. Time fixes.

Many sections of tape had to be replayed numerous times or viewed at different speeds to identify organisms not distinctly visible, or in instances where large numbers of fish could be counted individually. Organisms were considered outside the transect (and therefore not counted) if they were observed more than 5 m above the bottom, or behind an imaginary line through the camera which crossed the direction of travel.

All videotapes were analyzed in their entirety without subsampling. At the end of each transect, information from completed transcript work forms was transferred to computer coding forms. Each coding form included the following header information:

1. Cruise number and date;
2. Station, transect, and videotape number;
3. Transect length and width;
4. Habitat type; and
5. Transect start-stop time designation with corresponding LORAN C navigational fixes.

Encoded data records consisted of:

1. Individual counts,
2. Densities or percentage cover of observed organisms as appropriate,

3. Depth of each event or observation,
4. Video recorder counter number (used for relocating specific observations),
5. Identification quality index, and
6. Additional index codes for a variety of other parameters.

The additional index codes allowed for the coding of supplementary information such as species-specific relative sizes, morphological features such as ratios of massive to branching sponges, and other qualitative indices, e.g., whether or not observed shells of gastropods contained living molluscs. All taxonomic codes were recorded using current NODC formats. Coded data on forms were entered and verified.

3.4.2 BENTHIC STILL PHOTOGRAPHY

Benthic still photographs taken with Ektachrome ISO/ASA 200-speed color film and electronic strobe lighting during each underwater television transect (see Section 3.4.1) were custom developed by Kodak and returned to the laboratory. Each roll of film was individually labeled and retained uncut. Film was viewed with a filmstrip projector, using field notes and voice recordings on videotape to relate still photographs to scenes viewed on the tapes.

No discrete data set was formed for benthic still photographs, which were intended to be used only as supplemental aids in identification of biota seen in videotape analysis. Their higher resolution (relative to videotapes) and color information permitted organisms seen in the videotapes to be identified to the species level in many cases when it would not have otherwise been possible.

No attempt was made to analyze benthic still photographs as independent samples, since they could not meet any reasonable criterion for random or unbiased sampling. The collection of benthic still photographs selectively portrayed both particularly notable species and species which are difficult to identify in black-and-white videotapes.

3.4.3 TRIANGULAR DREDGE

Triangular dredge samples were returned to the laboratory for analysis. Samples were first sorted into major taxonomic groups and relabeled for sample tracking purposes. All of the specimens in each group to be identified were referred to various taxonomic specialists within and outside LGL. Each specialist was responsible for identifying all specimens from all cruises within his/her particular group(s), in order to insure consistency in identifications between samples.

Several major taxa have been stored but not yet identified due to limitations on time and resources, and as a result of the plethora of species collected. Sponges are the most important organisms in this category. Additionally, polychaetes and smaller crustaceans (e.g., amphipods) that were too small to have been sampled reliably by the triangular dredge, with its relatively large mesh size, were stored but have not yet been identified.

Sorted specimens to be identified were rinsed in fresh water and then assigned to the lowest practicable taxon. Specimen identifications were recorded on computer coding forms using standard NODC guidelines and taxonomic codes, entered, and verified.

All sorted, labeled, and identified samples were returned to fixative for archival storage and for use in resolving coding errors detected during the verification process. All samples from the triangular dredge are being retained pending the completion of the Year 5 contract.

3.4.4 ROLLER OTTER TRAWL

Fish collected with the roller otter trawl were returned to the laboratory. Specimens were labeled individually by trawl, station, and cruise, rinsed in fresh water and then identified to the lowest possible taxon. All specimens were measured (fork length), drained, and weighed. Stomachs were removed from each specimen by dissection (gut from esophagus to duodenum) for contents analysis. Sex and state of maturity were then determined by dissection of each specimen. Sex and state of maturity were assessed according to the followng catgories per NODC protocols:

<u>Sex</u>:

1. Male
2. Female
3. Indeterminate
4. Hermaphroditic

<u>Gonad maturation</u>:

1. Gonad absent
2. Gonad immature
3. Gonad mature or maturing
4. Gametes ripening
5. Gametes ripe but not spawning
6. Spawning
7. Spent

Specimen identifications, length, weight, sex, and state of maturity were recorded on computer coding forms using standard NODC guidelines and taxonomic codes, entered, and verified. Stomach content analyses were not available for coding at the time of this writing.

All sorted, labeled, and identified samples were returned to fixative for archival storage and for use in resolving coding errors detected during the verification process. All samples from the trawl are being retained pending the completion of the Year 5 contract.

3.4.5 *IN SITU* ARRAY

Time-Lapse Camera

After each cruise, Super 8 movie film cartridges were appropriately packaged and mailed to the Kodak processing laboratory in Rochester, New York. Special arrangements had been made with this facility for dealing with these cartridges. One provision made was to keep the cropping of leader on the ends of each roll to a minimum, thus preventing any data loss. Kodak also agreed to develop film which had been damaged by or even totally submerged in seawater. This special attention resulted in the salvage of one water-damaged time-lapse movie which might have otherwise been ruined. Each roll of developed movie film was then duplicated.

Once the processed Super 8 film was received in the laboratory, it was evaluated for overall content, duration, and exposure. If additional enhancement was required to improve exposure or color, the original was sent to processing laboratories with special capabilities for additional reproduction before quantitative analyses were begun.

Each time-lapse movie was analyzed in its entirety for the two stations involved (21 and 52). Analyses were performed with a Super 8 movie projector with variable projection speeds (freeze-frame, 3, 6, 18, and 54 frames/s) and a manual film editor. The editor was more useful for the majority of quantitative analyses because it could be manually operated for single-frame viewing at any speed, thus allowing the hour of day for each individual frame to be determined accurately. The movie projector with its higher quality optics was then used to identify species or make counts not clearly defined on the editor. Each movie was also viewed at normal and faster-than-normal projection speeds to discern any long-term qualitative changes. For example, a segment of time-lapse film taken hourly over a 90-day period could be viewed in 40 s when seen at 54 frames/s, compressing time by a ratio of 194 400:1. This compression revealed many processes that would have been difficult to see otherwise, such as fouling organism growth, bioturbation of the substrate, and long-term habitat composition changes.

Data from each time-lapse movie were first transcribed onto pre-printed work forms with every hour of each day designated in columns. The following information was obtained from each movie frame, which represented one sample per hour of real time:

1. Numbers of individuals of fish identified to the lowest possible taxon,
2. Numbers of individuals of other vertebrates such as sea turtles,
3. Turbidity, and
4. Occlusion by organisms.

Motile invertebrates large enough for observation were relatively rare and not included in quantitative analyses but were instead noted in qualitative descriptions.

All organism counts were made within a sample area that included the inside of the array and extended just beyond the perimeter of the array. Specific individuals could not be identified reliably from one frame to the next since there was 1 hour between exposures. Consequently, cases in which the same individual was present in more than one photograph could not be separated from those in which several photographs included different representatives of the same species.

Turbidity was arbitrarily scored from 0 to 4. A score of 0 represented unobscured visibility within the sample area. A score of 4 represented zero visibility. Each intervening score represented a change of 25 percent in estimated visibility relative to the maximum visibility (i.e., 100 percent). Generally scores of 0, 1, or 2 (relative visibility of 100 percent, 75 percent, or 50 percent) did not have any detrimental effect on taxonomic counts or identifications. In the case of 50 percent relative visibility, smaller fish at the limits of the census range may have been identified to genus as opposed to species in some instances. A visibility score of 3 (25 percent), on the other hand, significantly affected fish obsevations and identifications. A score of 4 (zero visibility, turbidity maximal) referred to a total occlusion of all objects in the camera's field of view.

It was originally intended to digitize sediment depth on the sediment rod to document periods of deposition, erosion, and bedload transport. However, there was very little fluctuation in sediment depth, so this technique was abandoned. It appeared that all sediment transport resulted from resuspension and transport by currents as documented by the periods of high turbidity.

Occlusion by biota was treated separately from water turbidity. Numbers of movie frames in which the field of view was obscured by 50 percent or more by an organism were given a score of 5. In the majority of instances, this score was used because of a fish located close to the camera lens, e.g., by the jewfish which took up long-term residence inside the Station 52 array.

Fouling Plates

Fouling plates were returned to the laboratory. Plates were individually labeled for sample tracking purposes, and gently rinsed in fresh water. The wash water from each plate was sieved with a 0.5-mm screen to retain motile invertebrates. Plates were kept immersed in fresh water throughout analysis to keep from drying out fouling organisms.

Two types of abundance estimates were made for each plate: percentage cover and numerical abundance (density). The type of estimates depended upon each taxon's growth form according to the following schedule:

Taxon	Percent Cover	Numerical Abundance	Weight
Foraminifera		X	X
Porifera	X	X	X
Hydroida			X
Ctenophora		X	X
Nemertea		X	X
Bryozoa	X	X	X
Sipunculida		X	X
Polychaeta	X	X	X

Taxon	Percent Cover	Numerical Abundance	Weight
Cirripedia	X	X	X
Tubicolous amphipods	X		X
Other crustacea		X	X
Pycnogonida		X	X
Gastropoda		X	X
Bivalvia	X	X	X
Ophiuroidea		X	X
Ascidiacea	X	X	X

Percent cover was estimated for most colonial or encrusting taxa. Estimates were based on the point-intercept method, using three acetate overlays, each marked with a different pattern of 100 randomly located dots. Each dot represented 1 percent cover; the number of times a given taxon fell beneath a dot was thus multiplied by 1 percent to give an estimate of the percentage cover occupied by that taxon. Using three overlays gave three independent estimates of percentage cover for each plate.

Numerical abundance was estimated by simply counting the number of individuals or colonies appearing on each plate and in plate washings. The number of colonies of bryozoans was counted, rather than the number of zooids.

Drained weight was determined for organisms growing on the grooved (textured) sides of the ceramic plates and for organisms growing on the outermost sides of the steel plates. Organisms were sorted by taxa and weighed to the nearest 0.1 mg on a Sartorius balance.

Specimen identifications, abundances, and drained weights were recorded on computer coding forms using standard NODC guidelines and taxonomic codes, entered, and verified.

All sorted, labeled, and identified samples were returned to fixative for archival storage and for use in resolving coding errors detected during the verification process. All samples from fouling plates are being retained pending the completion of the Year 5 contract.

4.0 RESULTS AND DISCUSSION

The collection of data to characterize at least some of the stations discussed in this report began with the first year of this program. However, the majority of the stations (those with station numbers greater than 40) were sampled during Year 3 and Year 4 of this program. Much of the data from Year 3, collected by Continental Shelf Associates, is not yet available; therefore, characterization of individual stations will, for this report, rely heavily on data collected during Years 1, 2, and 4.

The Year 4 field study included four seasonal cruises, with sampling conducted at two sets of stations (Figure 4.1-1). One set of stations (Group I) was sampled during fall 1983 and spring 1984, and consisted of the 5 hard-bottom and 5 of the 10 soft-bottom stations sampled during winter 1982-1983 and summer 1983 (Year 3 study).

Five Group II live-bottom stations, each representing a separate epifaunal community type (Table 1.3-1), were sampled during each of four seasons--fall 1983, winter 1984, spring 1984, and summer 1984. These stations were selected for intensive seasonal sampling and installation of instrumented benthic arrays that would be maintained for 2 years.

The methods used to collect and analyze the various physical and biological data for Year 4 were discussed in previous sections and will not be repeated here. The following is a brief discussion of data recovery achieved during Year 4 and an itemization of data sets used for the discussion section. The reasons for lost or partial data sets are also described in this section.

Subsequent subsections discuss the physical and biological characteristics of the individual stations.

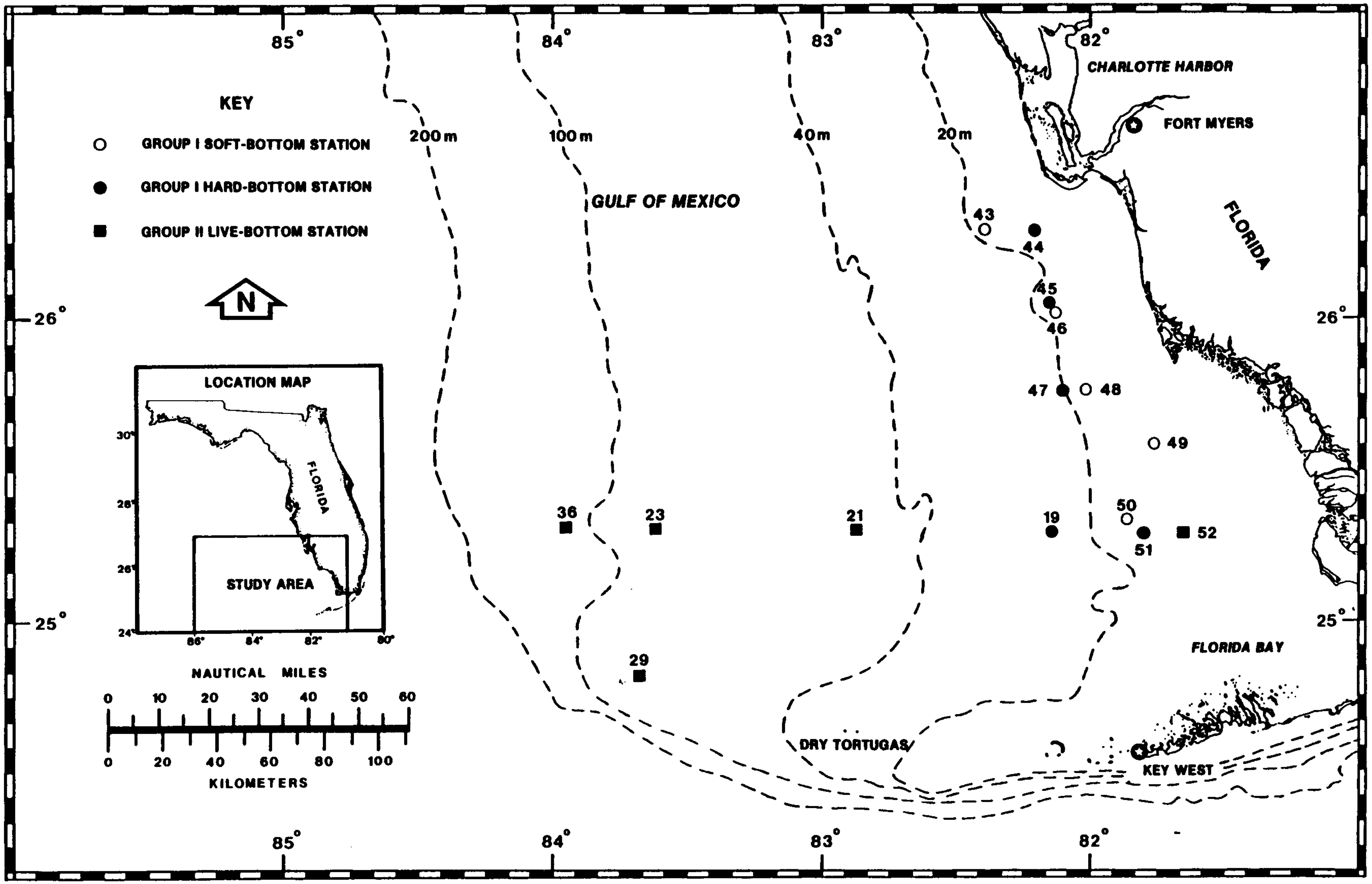


Figure 4.1-1. YEAR 4 GROUP I AND II STATION LOCATIONS

The data recovery for the various data collection techniques used by ESE/LGL during Year 4 is presented in Figure 4.1-2. There was a 100-percent data recovery for the underwater television/benthic still photography surveys. This was partly the result of additional transects appended to Cruises II, III, and IV to make up for transects not surveyed during Cruise I because of foul weather. The foul weather during Cruise I also resulted in the loss of dredge and CSTD hydrographic data at Station 21 and trawl data at Stations 21, 23, and 36.

The missing sediment data at Station 29 was the result of the continuous platelike cover of *Agaricia* coral which precluded sampling unconsolidated sediment at this station. A sample of the plate was obtained with the grab, but sediment analysis of this sample was deemed inappropriate.

A description of the problems that resulted in lost data from the instrumented *in situ* arrays is presented here. However, the actual station-by-station description of data recovery is presented in more detail in Figure 4.1-3. The greatest loss of data resulted from the loss of the arrays at Stations 21 and 29. The most probable cause was commercial fishing activity, particularly longline fishing, in the vicinity of these two stations. Extensive searches conducted with the underwater television system were fruitless; therefore, backup arrays had to be deployed at these stations. The loss of subsurface buoys at Stations 36 and 23 resulted in lost data either because of battery depletion in the current meters or, as in the case of Station 23, damage to the array during a grapnel recovery, which precluded array redeployment after servicing. Wave gage data were lost primarily because of lost equipment (Station 21) or a defective timing crystal (Station 52). Operator error caused the loss of additional data during the fourth quarter.

In addition to the problems previously mentioned, the current meters suffered the loss of some data due to battery failure, a broken data tape, and barnacle and oyster growth on the impellor or sensors.

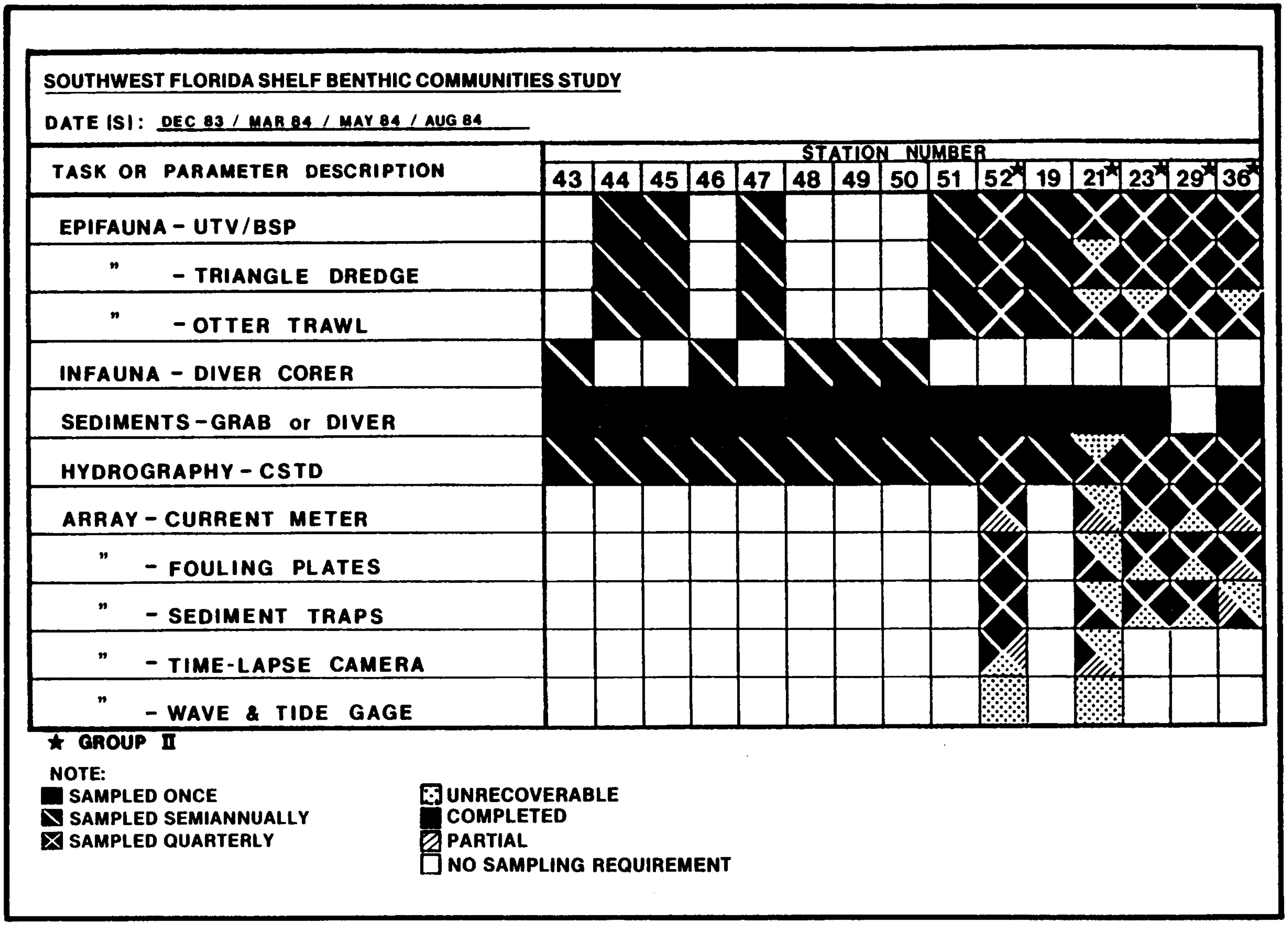


Figure 4.1-2 DATA RECOVERY STATUS FOR YEAR 4

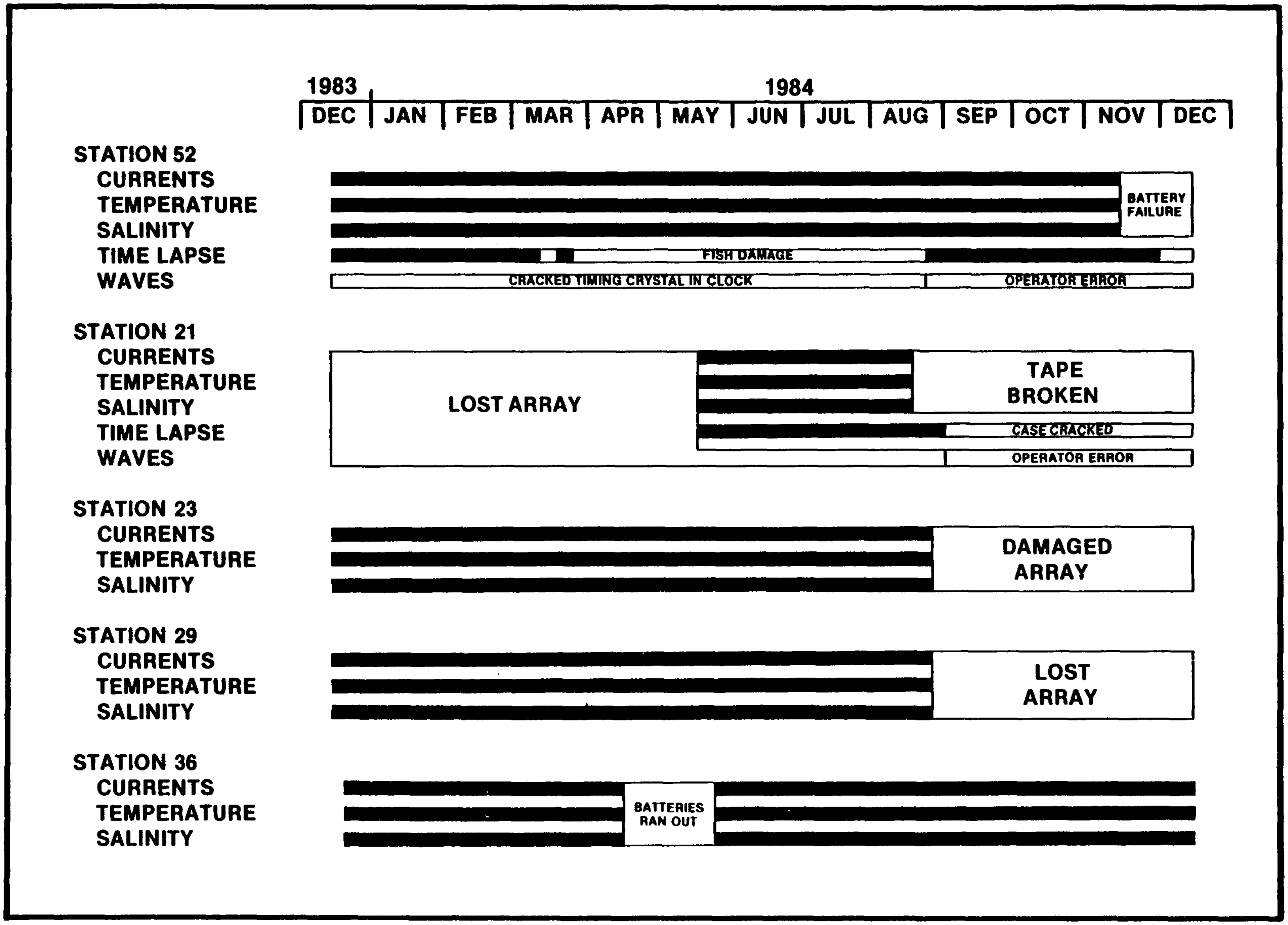


Figure 4.1-3. DATA RECOVERY FOR *IN SITU* INSTRUMENTS

The time-lapse camera data recovery suffered primarily from either the loss of the array or the flooding of the housing as a result of material failure or damage by fish. Fish damage was a particular problem at Station 52 where two large Jewfish (approximately 2 m in length) were responsible for the repeated destruction of the time-lapse cameras, sediment traps, and fouling plates. In spite of these problems, the overall data recovery (during the cruises and by the arrays) is about 85 percent.

4.1 CHARACTERIZATION OF INDIVIDUAL STATIONS

4.1.1 PHYSICAL CHARACTERIZATION

This section first presents an overview of the physical characteristics of all 15 Year 4 stations in tabular form and then describes each individual station. Detailed information of the environment is important to the understanding of biological communities' structure and dynamics at each station. Within the scope of this program, the physical characterization of a station includes the station's position and depth; relief; substrate type and composition; sedimentary characteristics and structures; and near-bottom hydrographic information such as salinity, temperature, DO concentration and saturation, pH, transmissivity, currents, and waves. It also includes temporal variability of these parameters that may induce stress to the biological community.

Table 4.1-1 provides an overview of the physical characteristics of each station, allowing inter-station comparisons. Also included in this table is information such as station position by latitude/longitude, lease block, etc., as well as a brief description of the substrate type and biological assemblage.

Table 4.1-2 presents a summary of the sediment characteristics. These characteristics are based on only two replicates collected near the center of the station either during December 1983 or March 1984. Therefore, the entire 1-km-square station can be characterized only with caution with regard to sediments and nothing can be said regarding any

Table 4.1-1. Summary for Year 4 Group I and Group II Stations

Station	Group	Depth (m)	Latitude (N)	Longitude (W)	Lease Block**	Distance*** from Shore (km)	Substrate†	Assemblage††
43	I	16	26°17.27'	82°18.93'	CH 695	30	Sand	In-Mid Sand
46	I	18	26°00.87'	82°07.92'	CH 693	34	Sand	In-Mid SAnd
48	I	18	25°45.97'	82°01.13'	PR 217	33	Sand	In-Mid Sand
49	I	11	25°35.23'	81°46.23'	MI 355	30	Sand	In-Mid Sand
50	I	16	25°20.27'	81°51.52'	MI 617	59	Sand	In-Mid Sand
44*	I	13	26°17.72'	82°12.67'	CH 697	20	TS-HS	In-Live I
45*	I	16	26°03.03'	82°08.50'	CH 692	35	TS-HS	In-Live I
47*	I	20	25°45.83'	82°06.10'	PR 215	41	TS-HS	In-Live I
51*	I	15	25°17.42'	81°48.02'	MI 602	63	TS-HS	In-Live I
19*	I	23	25°17.36'	82°09.00'	PR 698	77	TS-HS	In-Live I
52*	II	13	25°17.53'	81°39.82'	PR 655	48	TS-HS	In-Live I
21*	II	47	25°17.26'	82°52.16'	PR 683	133	TS-HS	In-Mid Live II
23*	II	74	25°16.89'	83°37.79'	PR 667	194	AN-S-D	Mid-Algal
29*	II	60	24°47.51'	83°41.19'	DT 138	229	AN-S-D	*Agaricia*
36*	II	126	25°16.50'	83°57.21'	PR 661	219	TS-HS-D	Out Crinoid

*Hard bottom.
**CH = Charlotte Harbor.
PR = Pulley Ridge.
DT = Dry Tortugas.
MI = Miami.
***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.
Sand = Sand bottom.
TS-HS-D = Thin sand over hard substrate with depressions

††In-Mid Sand = Inner and middle shelf sand-bottom assemblage.
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.
Agaricia = *Agaricia* coral plate assemblage.
Out Crinoid = Outer shelf crinoid assemblage.

Table 4.1-2. Summary of Sediment Characteristics for Year 4, Group I and II Stations

Station Number	Sediment Size Statistics (φ)†					$CaCO_3$††† Content (%)	Organic††† Carbon Content (%)
	Median	Mean	Standard Deviation	Skewness	Kurtosis		
43*	1.6	1.4	0.6	-0.2	1.4	82.4	3.0
46*	2.2	2.1	0.7	-0.1	0.9	92.4	2.9
48*	1.2	1.2	0.7	0.0	0.9	90.8	2.9
49*	2.5	2.1	0.6	-0.7	2.2	22.9	0.9
50*	2.5	2.3	0.8	-0.2	0.8	78.1	2.3
44**	0.9	0.6	1.4	-0.2	0.4	87.2	1.2
45**	1.0	0.6	1.4	-0.2	0.4	90.8	2.0
47**	2.2	1.9	1.0	-0.3	1.0	90.2	2.9
51**	2.6	2.4	0.8	-0.2	0.6	92.1	2.2
19**	1.2	1.2	0.7	0.0	0.8	93.1	2.1
52***	0.7	0.6	1.3	-0.1	0.5	92.6	1.9
21***	1.7	1.6	0.8	-0.1	0.7	91.2	2.6
23***	2.4	2.2	0.8	-0.3	0.8	95.3	2.8
29***	††	††	††	††	††	††	††
36***	0.7	0.9	1.4	0.2	0.4	94.4	2.9

*Group I Soft-Bottom Stations.
**Group I Hard-Bottom Stations.
***Group II Live-Bottom Stations.
†After Inman (1952), values given are the average of two replicates.
††*Agaricia* coral pavement precluded sampling any unconsolidated sediment.
†††Dry weight.

seasonal variation in sediment characteristics that may occur with seasonal changes in wave or current climates.

Table 4.1-3 presents a summary of hydrographic data for each station. These data were collected during Year 4 and, as stated previously, only the near-bottom data are presented in this station characterization. The Group I stations were occupied only twice during the year (December 1983 and May 1984); consequently, the ranges of the parameters are by necessity merely the two readings obtained during the two cruises. However, the Group II stations were occupied four times during Year 4. The temperature and current data are the most complete as they represent nearly continuous measurement during Year 4. Many of the oxygen saturation values are above 100 percent, which is typical of natural water with biological activity. The transmissivity value over 100 percent are an artifact of the calibration procedure, and the values are presented to illustrate relative differences in transmissivity between stations.

These tables have presented a brief overview of the physical characteristics of the 15 stations studied during Year 4. The following is a narrative description of each station.

Group I Soft-Bottom Stations

Stations 43, 46, 48, 49, and 50 were the soft-bottom stations sampled during Year 4 as a seasonal continuation of Year 3 sampling efforts. All of these stations are inner and middle shelf sand bottom assemblages with sand bottom substrates. Generally, the macrofauna are motile, and the density is usually less than one individual per square meter. There may be some sessile epifauna, but these are the exception because of the highly mobile nature of the sand bottom as indicated by the morphological features discussed below. This sand bottom designation includes unconsolidated sediments (ranging in average size from sand to silt) possibly overlying a hard substrate (e.g., limestone). The sand bottom possesses a variety of morphological and transient features such

Table 4.1-3. Summary of Near-Bottom Hydrographic Characteristics for Year 4, Group I and II Stations

Station Number	Salinity (‰)	Temperature (°C)	Sigma-t	DO (mg/L)	DO Saturation (%)	Transmissivity (%) (10 cm Light Path)	pH	Average Current Speed (cm/s)	Speed >40 cm/s (%)
43*	35.08-35.17	22.74-26.46	23.04-24.09	6.70-7.25	101-102	101-103	7.83	—	—
46*	35.34-35.86	23.51-26.05	23.29-24.46	6.70	101	81-101	7.83	—	—
48*	35.38-35.81	23.37-26.20	23.29-24.46	6.50-8.69	98-125	99-103	7.83	—	—
49*	34.56-35.43	22.93-27.26	22.33-24.30	6.90-7.16	102-106	90-96	7.85	—	—
50*	35.40-35.66	23.43-26.68	23.15-24.33	6.90-7.23	104-105	90-102	7.84	—	—
44**	35.08-35.22	23.19-26.56	22.94-24.07	6.90-8.78	104-125	98-102	7.83	—	—
45**	35.31-35.88	23.65-26.12	23.25-24.44	6.50-6.97	98-100	92-108	7.82	—	—
47**	35.59-35.92	23.61-25.94	23.52-24.48	6.70	101	88-107	7.86	—	—
51**	35.36-35.70	23.62-26.72	23.10-24.30	6.50-7.55	99-109	89-100	7.87	—	—
19**	35.92-36.46	23.94-25.17	24.00-24.79	7.00-7.02	103-104	92-97	7.88	—	—
52***	35.14-35.78	17.00-30.56	22.03-25.13	6.27-7.26	96-106	67-100	7.82-8.58	27.5	19.7
21***	36.14-36.31	20.32-25.29	24.15-25.62	6.35-9.44	95-128	89-98	7.94-8.56	13.3	0.6
23***	36.11-36.67	17.50-23.30	25.87-26.24	6.11-6.40	82-85	82-95	7.92-8.66	22.1	9.5
29***	36.11-36.64	17.85-23.90	24.94-25.92	6.40-8.59	87-114	95-100	7.94-8.64	24.5	14.1
36***	36.13-36.42	15.00-23.85	—	4.35-5.50	88-106	—	—	22.1	14.2

*Group I Soft-Bottom Stations (ranges based on a maximum of two observations).
**Group I Hard-Bottom Stations (ranges based on a maximum of two observations).
***Group II Live-Bottom Station (ranges based on maximum of four observations; temperatures at all stations, but Station 21 augmented with continuous temperature data from current meters).

as sand waves, ripples, and bioturbated areas. These sands may also be covered with small and varying amounts of algae (*Caulerpa* spp., *Halimeda* spp., *Udotea* spp., and coralline algae). It should be noted that this bottom type can vary both spatially and temporally; that sediment grain size and chemical characteristics can vary; and that virtually all of the morphological features are the result of dynamic forces and are, therefore, transient. The stations cover about 1° in latitude starting near Charlotte Harbor and extending south about 60 nm.

The following discussion is a description of the near-bottom and bottom physical characteristics of the individual Year 4 Group I soft-bottom stations based on data collected during Year 4.

Station 43

This, the northernmost station studied during Year 4, was situated in 16 m of water and was approximately 30 km offshore. The sediments at this station were medium to coarse carbonate sands consisting primarily of biogenous material and possessing a low organic carbon content. Of the Group I soft-bottom stations, 43 possessed the second coarsest sediment sampled, with a median phi size (MdØ) of 1.6. The distribution of Ø sizes was near normal but was skewed toward the coarser material. It was because of this skewing that MdØ was used to describe the most abundant grain size rather than mean Ø which would have been affected by the skewing. The sediments had a low organic carbon content of 3.0 percent and a high $CaCO_3$ content of 82.4 percent resulting primarily from the high shell fragment content.

Station 43 bottom temperatures ranged from a December 1983 low of 22.74°C to a May 1984 high of 26.46°C. Typically, the high temperature at comparable depths actually occurs around July or August and can be approximately 3°C higher. Consequently, the high temperatures at Station 43 probably reached about 29° to 30°C.

The bottom salinities remained about constant, ranging from only 35.08 to 35.17 ‰ from December 1983 to May 1984. Essentially all 15 Year 4 stations revealed only minor temporal changes in salinity (on the order of 0.5 ‰) over the course of a year. The variability between stations, however, was greater.

The water was oxygen rich with concentrations ranging from 6.70 mg/L (101-percent saturation) to 7.25 mg/L (102-percent saturation) in May 1984 and December 1983, respectively. The water was very clear, with transmissivity ranging from a low in May of 101 percent to a December high of 103 percent. The pH measured in May was 7.83 near the bottom.

Station 46

Located 40 km southeast of Station 43, Station 46 was 34 km from the nearest land with a depth of 18 m. The sediments at Station 46 characterized as fine carbonate sands were finer (MdØ = 2.2) than at Station 43 and were skewed toward the finer sizes. As with Station 43, the sediments at 46 were primarily $CaCO_3$ (92.4 percent) with a low organic carbon content (2.9 percent).

Station 46 was slightly more saline than Station 43, with near-bottom salinities ranging from a low of 35.34 ‰ in May 1984 to a high of 35.86 ‰ in December 1983; the range of values was also slightly greater. The range of temperatures at Station 46 was less than at Station 43, ranging from 23.51°C in December to 26.05°C in May.

Only bottom DO and pH values of 6.70 mg/L (101-percent saturation) and 7.83, respectively, were obtained in May 1984.

Transmissivity displayed a greater range of values from December 1983 to May 1984 of 101 to 81 percent. An examination of the shipboard wave observations reveals waves that are less than or equal to 1.0 m with comparable periods (approximately 5 s) at both stations. Therefore, this decrease was not readily explicable. An examination of the entire transmissivity profile indicated that the water was quite clear (>95 percent) except for the bottom 2 m of water, suggesting the existence of a nupheloid layer.

Station 48

Here, sediments were similar to Station 43 in that the sediments were coarse (MdØ = 1.2). The reason for the MdØ differing from Station 46 was not readily apparent. Both stations are located in 18 m of water, and Station 48 was situated only 1 km closer to land than Station 46. The $CaCO_3$ and organic carbon content of 90.8 and 2.9 percent, respectively, were comparable to Station 46.

Station 48 water characteristics were nearly identical to Station 46. The salinity values ranged from 35.38 to 35.81 ‰, temperature from 23.37 to 26.20°C, and σ_t from 23.29 to 24.46. The near-bottom DO values ranged from 6.50 (98-percent saturation) to 8.69 mg/L (125-percent saturation). The transmissivity values were comparable to those at Station 43, ranging from 99 to 103 percent. Lower transmissivity values like those at Station 46 (81 percent) were not encountered. The pH was comparable with all stations at 7.83.

Station 49

Located 30 km southeast of Station 48, Station 49 lies approximately 30 km from land in only 11 m of water (the shallowest of all 15 stations). Sediments were classified as fine sands (MdØ = 2.5). Chemically, the sediments sampled at 49 were different not only from those samples obtained from the other Group I soft-bottom stations, but from all stations sampled. The $CaCO_3$ and organic carbon contents were 22.9 and 0.9 percent, respectively. These two values were the lowest values (by nearly a factor of 3 each) encountered at any of the Year 4 stations.

Station 49 water characteristics were different from the other stations. The lowest salinity, 34.56 ‰, was observed in May 1984. This salinity reached a high in December 1983 of 35.43 ‰ , which exceeded maximum salinity values observed at Stations 43 and 44. Some of the higher near-bottom temperatures ranging from 22.93° to 27.26°C were observed. The DO values were generally higher than those observed at Stations 43, 46, and 48 (except the Station 48 maximum value of 8.69 mg/L), ranging from 6.90 mg/L (106-percent saturation) in May 1984 to 7.16 mg/L (102-percent saturation) in December 1983. Transmissivity values indicated generally clear water, with values ranging from 90 percent in May to 96 percent in December. The pH value of 7.85 was comparable with the other Group I soft-bottom stations.

Station 50

The last Group I soft-bottom station was located approximately 30 km south-southwest of Station 49 in 16 m of water. Station 50 was the Group I soft-bottom station farthest from land (excluding the Florida Keys) at 59 km. Sediments, again, were fine sands (MdØ = 2.5) and therefore, comparable with Stations 46 and 49. Chemically, the sediment (with a $CaCO_3$ content of 78.1 percent) was lower than the highest Group I soft-bottom value of 92.4 percent (Station 46), but higher than the low value of 22.9 percent (Station 49). The organic carbon content of 2.3 percent was comparable with all stations except Station 49.

Hydrographically similar to all stations but Station 49, Station 50 had salinity and temperature values ranging from 35.40 ‰ (May) to 35.66 ‰ (December) and 23.43°C (December) to 26.68°C (May), respectively. DOa values were also comparable with all stations and nearly identical to Station 49, with DO values ranging from 6.90 mg/L (105-percent saturation) in May to 7.23 mg/L (104-percent saturation) in December. Again, water was clear with transmissivity values ranging from 90 to 102 percent with the potential to become turbid during storms. The pH measured at Station 50 was 7.84.

Group I Hard-Bottom Stations

Unlike the Group I soft-bottom stations, the hard-bottom stations were surveyed and photographed twice with the underwater television/benthic still photography system which provided sufficient information for a description of bottom characteristics.

The Group I hard-bottom stations were all designated by Continental Shelf Associates, Inc. as having a thin sand over hard substrate and an inner shelf live-bottom assemblage I. According to Woodward Clyde Consultants and Continental Shelf Associates, Inc. (1983) in their Marine Habitat Atlas, this bottom type is transitional beween Rock Outcrops/Hard Bottom and Sand Bottom/Soft Bottom Substrates. This bottom type is common throughout the southwest Florida shelf and represents a thin veneer of mobile sand covering a rock substrate.

Stations designated live-bottom have, by definition, an average density of attached macrofauna greater than one individual per square meter. The macrofauna and macroalgae that make up the Inner Shelf Live-Bottom Assemblage I are discussed in detail in Section 4.1.2. A physical characterization of individual stations follows.

Station 44

The northernmost Group I hard-bottom station, Station 44, was also one of the shallowest (13 m) stations and was located the closest to land (20 km).

The sediments at Station 44 were among the coarsest encountered, with a MdØ of 0.9 (coarse sand). Generally, the size distribution was skewed toward the coarser sizes. The $CaCO_3$ and organic carbon content of 87.2 and 1.2 percent, respectively, were the lowest of all Group I hard-bottom stations.

Underwater television surveys revealed a predominantly sand bottom with occasional patches of hard bottom. During both December 1983 and May 1984, transient morphological features such as sand waves and animal tracks were observed.

The near-bottom salinity at Station 44 ranged from 35.08 ‰ in May to 35.22 ‰ in December. Station 44 was the only Group I station to have consistently fresher water (by approximately 0.25 to 0.50 ‰) at the surface. Waters at remaining Group I stations were generally well mixed.

Near-bottom temperature values ranged from 23.19° (December) to 26.56°C (May). The highest near-bottom DO values encountered at all stations were observed at Station 44. The DO concentration and saturation values ranged from 6.90 mg/L (104-percent saturation) in May 1984 to 8.78 mg/L (125-percent saturation) in December 1983.

Transmissivity, comparable with most of the stations, was relatively constant, only ranging from 98 to 102 percent. The single pH value obtained was 7.83.

Station 45

Station 45 was located approximately 28 km nearly due south of Station 44 and 35 km from land. Underwater television surveys revealed a bottom in which hard bottom predominated over sand. The sand present appeared as isolated patches, and sand waves were occasionally seen on this sand. The sand sampled was coarse with Mdϕ of 1.0 and had a bimodal distribution. The $CaCO_3$ and organic carbon content of 90.8 and 2.0 percent, respectively, were typical compared to the majority of the stations.

Station 45 salinity and temperature ranged from 35.31 to 35.88 ‰ and 23.65° to 26.12°C, respectively. DO values ranged from 6.50 mg/L (98-percent saturation) in May 1984 to 6.97 mg/L (100-percent saturation) in December 1983; transmissivity ranged from 92 to 108 percent; and pH was 7.82.

Station 47

This station was located approximately 34 km further south and 41 km from land in 20 m of water. Based on underwater television observations, Station 47 was similar to Station 44 in that the sand cover was predominant with occasional patches of hard bottom and sand waves. A prominent feature at Station 47 was sand waves which either winnowed out coarser materials and left them in the troughs or exposed the hard bottom in the trough of the sand waves.

The sediments sampled at Station 47 were considerably finer (MdØ = 2.2) than Stations 44 and 45. The distribution of sediment sizes was non-normal and skewed toward the finer sediments. The $CaCO_3$ and organic carbon contents were typical, with values of 90.2 and 2.9 percent, respectively.

The salinities ranged from a May low of 35.59 ‰ to a December high of 35.92. Temperature values ranged from 23.61° to 25.94°C. A single near-bottom DO value of 6.70 mg/L (101-percent saturation) was obtained in May 1984. The pH at Station 47 was 7.86.

Station 47 revealed some of the greatest range of transmissivity values ranging from a low of 88 percent in May to 107 percent in December. Once again, this could not be correlated with observed shipboard wave height, as the estimated wave height and period in December were 1.3 m and 5.0 s, respectively, while the May wave height and period were 1.0 m and 4.0 s. The increased turbidity was the result of storm activity prior to the day of sampling.

Station 51

Station 51, only 9 km southeast of Station 50 and 60 km southeast of Station 47, was located 63 km from land in 15 m of water. This station, like Stations 44 and 47, was predominantly sand with some sand waves. The sand sampled was the finest (MdØ = 2.6) of any of the Year 4 stations sampled. The size distribution was slightly bimodal and skewed toward the finer sediments. The $CaCO_3$ content (92.1 percent) and the organic carbon content (2.2 percent) were comparable with most of the stations.

The hydrographic measurements were not unusual compared with the other stations. Salinities ranged from 35.36 to 35.70 ‰, temperature from 23.62° to 26.72°C, DO from 6.50 mg/L (99-percent saturation) to 7.55 mg/L (109-percent saturation), and transmissivity from 89 to 100 percent. The pH was 7.87.

Station 19

The last Group I hard-bottom station, 19, was the only such station situated in water over 20-m deep. This station, located in 23 m of water, was 33 km due west of Station 51 and 77 km from the nearest land (excluding the Florida Keys). According to Woodward Clyde Consultants and Continental Shelf Associates, Inc. (1984), 64 to 66 percent of Station 19 bottom is of the Sand Bottom/Soft Bottom type. The remaining 36 to 34 percent is Thin Sand over Hard Substrate. Ripples were observed by Woodward Clyde Consultants/Continental Shelf Associates, Inc. only during their spring cruise. The ridges were oriented in a north-south direction indicating east-west wave motion. ESE/LGL observed sand waves only during the May 1984 cruise. Both ESE/LGL and Woodward Clyde Consultants and Continental Shelf Associates, Inc. observed the effects of bioturbation in the form of tracks. During May 1984, the apparent winnowing effect effect previously mentioned in the Station 47 discussion was observed.

The sediments were relatively coarse, with a MdØ size of 1.2 (coarse sand). The size distribution curve was nearly normal. Station 19 sediments had a $CaCO_3$ and organic carbon content of 93.1 and 2.1 percent.

Not surprisingly, given the slightly greater depth of the station, the salinities are the highest and the temperatures some of the lowest observed. The ranges of near-bottom salinity and temperature were 35.92 (May) to 36.46 ‰ (December)and 23.94° (December) to 25.17°C (May). The DO values were relatively high compared with many of the stations, and the range, 7.00 to 7.02 mg/L, was the smallest observed at any station.

The DO saturation ranged from 103 to 104, indicating an oxygen-rich environment. Transmissivity was also fairly unchanged, ranging from 92 to 97 percent, and pH was measured at 7.88.

Group II Live-Bottom Stations

More data exist for the Group II stations (52, 21, 23, 29, and 36) because they have been studied more intensively by Woodward Clyde Consultants/Continental Shelf Associates, Inc. and ESE/LGL. During Year 4, *in situ* arrays were installed at each Group II station and serviced quarterly. The continuous data from the arrays and the seasonal sampling provide more complete information on the Group II stations.

Unlike the Group I soft- and hard-bottom stations, each Group II live-bottom station represents a different biological assemblage and various bottom types.

Station 52

Station 52, located 48 km offshore and in 13 m of water, was the easternmost and shallowest Group II station. The bottom type designated by Continental Shelf Associates, Inc. as Thin Sand over Hard Substrate (TS-HS), was the same designation assigned to all of the Group I hard-bottom stations. Woodward Clyde Consultants/Continental Shelf Associates, Inc. (1983) described TS-HS bottom as transitional between the Rock Outcrops/Hard Bottom and the Sand Bottom/Soft Bottom Substrate. It is common throughout the southwest Florida shelf and represents a thin veneer of mobile sand covering a rock substrate. Wave-produced sand ripples were occasionally observed in the thin sand layer. The sediment sampled was coarse (Md$\emptyset$ = 0.7) sand with a high $CaCO_3$ content (92.6 percent) and, compared to most of the other stations, a slightly lower organic carbon content (1.9 percent). The size distribution was non-normal, being skewed toward the coarser materials and being bimodal.

The hydrographic characterization for Station 52 is more complete because the station was sampled during all four seasons, and these data were augmented by the *in situ* array. The near-bottom salinity ranged from a March 1984 low of 35.14 ‰ to an August 1984 high of 35.78 ‰. The near-bottom temperature ranged from 17.00° to 30.56°C. These values were considered typical for the inner shelf for Year 4. The DO values ranged from an August low of 6.27 to 7.26 mg/L; the saturation values ranged from 96 to 106 percent. The pH values observed were from 7.82 to 8.58.

The transmissivity values obtained at Station 52 were the lowest measured at any station and ranged from 67 to 100 percent near the bottom. During the March 1984 cruise, the water was turbid throughout the water column, ranging from 67 percent at the bottom to 82 percent at the surface. The time-lapse camera recorded additional, although nonquantifiable, episodes of very high turbidity. Sediment transport, at least as observed with the time-lapse camera, was most noticeable as suspended load rather than bed load. No ripple marks or scouring were observed.

The average current speed at Station 52 was 27.5 cm/s. The currents were dominated by the tide which produced an east-west flow. Station 52 current speeds exceeded 40 cm/s (the speed at which sediment transport would occur for sand) 19.7 percent of the time.

Superimposed on the tidal currents was a net current of 4.4 cm/s setting consistently to the southeast. This net current was observed during all four seasons.

Station 21

This station was located at the same latitude, but approximately 122 km west of Station 52, 133 km from land, and in 45 m of water. Woodward Clyde Consultants/Continental Shelf Associates, Inc. (1984) reported that the water depth varies from 44.5 to 45.5 m with a slight downward slope from east to west. Although the biological assemblage [Thin Sand over Hard Substrate (TS-HS)] differs from Station 52, the bottom type, TS-HS, was the same. According to Woodward Clyde Consultants/ Continental Shelf Associates, Inc. (1984), the TS-HS bottom accounts for anywhere from 57 to 83 percent; the remaining 43 to 14 percent was Sand Bottom/Soft Bottom. A few small rock outcrops were noted by Woodward Clyde Consultants/Continental Shelf Associates, Inc. (1984). There were large areas of sand with sand waves observed during March and May 1984. The sand waves were measured with the stereo underwater television and were determined to have a wave length of approximately 1 m.

The sediment was a medium sand (MdØ = 1.7), which was finer than the sediments at Station 52. The size distribution was near normal, with a slight skewing toward coarser materials. Chemically, the sediments were comparable to the majority of stations, with $CaCO_3$ and organic carbon contents of 91.2 and 2.6 percent, respectively.

The hydrographic data at Station 21 were not as complete as the other Group II stations because of the loss of an array, current meter failure, and inclement weather which precluded sampling at this station during December 1983. The near-bottom ranges of salinity and temperature were not as extreme as those exhibited by Station 52. Salinity ranged from 36.14 (May 1984) to 36.31 ‰ (August 1984) and temperature from 20.32° (March 1984) to 25.29°C (August 1984). Station 21 was, therefore, approximately 0.5 to 1.0 ‰ more saline, and the maximum temperature was approximately 5°C cooler than Station 52.

Near-bottom DO values were higher at Station 21 than at 52, with values ranging from 6.35 to 9.44 mg/L and with saturation values as high as 128 percent. This maximum DO value was the highest measured at any of the stations. The pH varied from 7.94 to 8.56.

For the brief 3-month period that the current meter was both in place and working, average currents of 13.3 cm/s were measured. The current speed exceeded 40 cm/s only 0.6 percent of the time. It is likely that, had the current meter been in place and functioning for the full year, it would have measured current speeds more similar to the other four stations (i.e., average speeds of approximately 20 cm/s).

Station 23

Station 23 is located approximately 74 km west of Station 21 and 194 km from land. Station 23 had an average depth of 70 m, but according to Woodward Clyde Consultants/Continental Shelf Associates, Inc., varied from 69.5 to 73 m, generally sloping upward from the center toward the east and west.

The bottom type was designated as Algal Nodules over Sand with Depressions (AN-S-D). This substrate represents soft (sand) bottom areas covered by varying thicknesses of coralline algal growths usually in the form of loose, uncemented nodules (usually a few centimeters in diameter); the depressions ranged from 5 to 30 m in diameter and from 2 to 3 m deep. These depressions (and some elevations) were oriented along a north-northeast to south-southwest axis.

The algal nodule layer at Station 23 accounted for 93 to 100 percent of the bottom. The Sand Bottom/Soft Bottom was sometimes present (0 to 7 percent). ESE/LGL observed that the northwest corner of the study area was nearly bare sand. No sand waves were observed. The sediment recovered from the sand areas was the finest sand sampled at any Group II station with an MdØ of 2.4. The size distribution of this sediment was severely skewed toward the finer material. This sand was the richest in $CaCO_3$ content (95.3 percent) of all of 15 stations. The organic carbon content was higher than most stations at 2.9 percent.

The highest near-bottom salinity of all stations (36.67 ‰) was measured at Station 23 during December 1983. A minimum salinity of 36.11 ‰ was measured in August 1984. Temperatures were generally cooler, ranging from 17.50° to 23.30°C.

The near-bottom DO values were the lowest (6.11 to 6.40 mg/L) encountered with the exception of deep water Station 36. DO saturation values ranged from a low of 82 percent in December 1983 and May 1984 to a high of 85 percent in March 1984. Transmissivity, while lower than many stations, with a range of 82 to 95 percent, still indicated water that was quite clear. Near-bottom pH values ranged from 7.92 to 8.66.

Fourth quarter array data were lost at Station 23 after the array was damaged during servicing. Nevertheless, three quarters of current meter data were available. From these data, the average current speed was 22.09 cm/s. The current speeds at Station 23 exceeded 40 cm/s 9.5 percent of the time. A net current of 9.7 cm/s set to the southwest for the 9 months of data.

Station 29

Located approximately 55 km south of Station 23, Station 29 was the most remote Year 4 station, being 229 km from the nearest land (excluding the Florida Keys). This station had an average water depth of 60 m, but varied from 59.5 to 64.5 m (Woodward Clyde Consultants/Continental Shelf Associates, Inc., 1984). The bottom had occasional depressions and elevations and was entirely covered with an Algal Nodule Pavement with *Agaricia* Accumulations (Woodward Clyde Consultants/Continental Shelf Associates, Inc., 1984). Only minor amounts (<1 percent) of sand were reported, and no signs of ripples or bioturbation were observed.

Salinity and temperature ranges were nearly identical to Station 23, with values of 36.11 to 36.64 ‰ and 17.85° to 23.90°C, respectively. The only major difference between Stations 23 and 29 was the high DO values (ranging from 6.40 to 8.59 mg/L) at Station 29. The maximum DO concentration was one of the highest at all stations. The Station 29 DO saturation values ranged from 87 to 114 percent. Transmissivity and pH ranges were more typical, with values of 95 to 100 percent and 7.94 to 8.64, respectively.

The average current speeds at Station 29 were the highest (24.5 cm/s) measured at any Group II station. The lack of fourth quarter data (resulting from a lost array) has an unknown effect on this average value. For the three quarters of data, the current speed exceeded 40 cm/s 14.1 percent of the time. The highest net current of all Group II stations, 14.8 cm/s setting nearly due west, was measured at Station 29.

Station 36, located 33 km due west of Station 21, 60 km north-northwest of Station 29, and 219 km from the nearest land is the last Group II station. Station 36, the deepest of the Year 4 stations, had an average depth of 126 m, with a range of 124 to 127 m. Generally, the bottom sloped downward from east to west (Woodward Clyde Consultants/Continental Shelf Associates, Inc., 1984). Also according to Woodward Clyde Consultants/Continental Shelf Associates, Inc. (1984), the predominant bottom type was Sand Bottom/Soft Bottom (59 to 76 percent), with lesser coverages (24 to 40 percent) of Thin Sand over Hard Substrate with Depressions (TS-HS-D). A few (<1 percent) rock outcrops were observed. Sand ripples and depressions during the May 1984 cruise and occasional depressions during other cruises were observed.

Within the live-bottom patches, Woodward Clyde Consultants/Continental Shelf Associates, Inc. (1984) reported sand (73 to 79 percent) and rubble (13 to 12 percent). The sediment sampled was a coarse sand ($Md\phi = 0.7$). The size distribution curves for the two replicates were dissimilar; one being unimodal, the other bimodal, and both skewed toward the coarser sediment sizes. Station 36 sediments had the second-highest $CaCO_3$ content of 94.4 percent (compared with Station 23--95.3 percent). The organic carbon content was slightly above normal, with a value of 2.9 percent.

Because the bottom at Station 36 was beyond the range of the CSTD, only salinity, temperature, and DO data were available from water samples collected near the bottom. The temperature data were augmented with continuous data from the current meter. The salinity values, while higher than most stations, were lower than those measured at Stations 23 and 29. The Station 36 salinities ranged from 36.13 ‰ in May to 36.42 ‰ in March 1984. The Station 36 near-bottom temperatures were the lowest temperatures (15.00°C) measured at any of the stations; the maximum near-bottom temperature at Station 36 was 23.85°C. The DO values were lower, ranging from 4.35 to 5.50 mg/L. These low DO values were, with the exception of occasional Loop Current intrusions, the only notable indication of different water masses observed during Year 4. According to Woodward Clyde Consultants and Continental Shelf Associates, Inc. (1984) "these values are consistent with previous research and are typical of waters found below the salinity maximum in the eastern Gulf of Mexico."

The average current speed was 22.09 cm/s and generally set to the south. The current speed exceeded 40 cm/s approximately 14.2 percent of the time. The net current was 13.5 cm/s and also set to the south.

4.1.2 BENTHIC COMMUNITY DISTRIBUTION AND STRUCTURE

The following section provides biological site descriptions of the 5 soft-bottom and 10 hard-bottom stations studied in Year 4. The soft-bottom station descriptions were developed from samples collected during two seasons where 10 replicate infaunal samples were collected at each of the 5 stations. The five shallow water Group I stations were also occupied during two seasons with biological sampling, including dredging, trawling, underwater television, and still photography. The five Group II live-bottom stations were sampled during all four seasons, and each station included an *in situ* array to provide additional time-continuous data.

Group I Soft-Bottom Stations

Taxonomic Composition-- A total of 414 taxa (Table E-3, Appendix E) was included in the infaunal benthic macroinvertebrate data set. The number of actual taxa may vary slightly from the number for several reasons. One, all groups were not identified to the species level. For example, oligochaetes were identified to the class level, and most likely were represented by more than one species. Two, taxa which could only be identified to the genus or higher level may have been the same as an animal identified to species, but could not be identified as such due to poor condition or an immature stage. Three, taxa which were separable but could not be given a published name and therefore given a letter designation, or newly described taxa could not be coded using the present version of the NODC taxonomic code and were therefore coded using the lowest level available in the code. This occasionally resulted in separate species being coded and lumped at the genus level.

From the total of 414 taxa included in the data set, 344 were identified to the genus or species level, with 212 of these identified to the species level. Polychaete taxa were the most numerous and represented 223 of the total taxa. Crustaceans were the next most numerous group with 117 taxa, 52 of which were gammarid amphipods. Fifty-four taxa were molluscs, with 23 gastropods, 25 bivalves, 5 scaphopods, and 1 polyplacophoran. Echinoderms were represented by seven taxa. The remaining 13 taxa were Phoronis architecta, Glottidia pyramidata, Branchiostoma caribaeum, oligochaetes, bryozoa, sipunculids, priapulids, pycnogonids, turbellarians, rhynchocoels, demospongiae, and hydrozoa.

The taxonomic composition of the individual stations followed the same pattern as the overall infaunal collection. Polychaetes accounted for the greatest number of taxa at each station; crustaceans ranked second, and molluscs ranked third (Tables E-4 to E-13, Appendix E). The crustacean component of the station communities was dominated by gammarid amphipods.

Infaunal Abundance, Diversity, Richness, and Evenness--The estimated mean density of individuals per square meter ($\#/m^2$) across the five stations sampled in Decmeber 1983 and again in May 1984 ranged from a low of $3245/m^2$ at Station 43 in December 1983 to a high of 15 $821/m^2$ at Station 50 in May 1984 (Figure 4.1-4). Estimated mean densities were generally higher in May than in December, with only Station 49 having a lower mean density in the second sampling effort.

The Shannon-Weaver diversity index for all stations was high. In December 1983, the index ranged from a low of 4.91 at Station 48 to a high of 5.76 at Station 43 (Table 4.1-4). In May 1984, the Shannon-Weaver diversity index ranged from 4.71 at Station 49 to 5.39 at Station 50 (Table 4.1-4). Diversity was slightly higher in December 1983 collections than in May 1984 collections, due primarily to the higher numbers of taxa recorded in the December 1983 collections. The high diversity index values resulted from both the high species richness values and the high evenness values. The evenness of the communities sampled at each station can be realized upon inspection of the rank abundance tables (Tables E-14 to E-23, Appendix E). These tables show that at each station the great majority of the taxa were present in approximately equal numbers, with most taxa represented by only a few

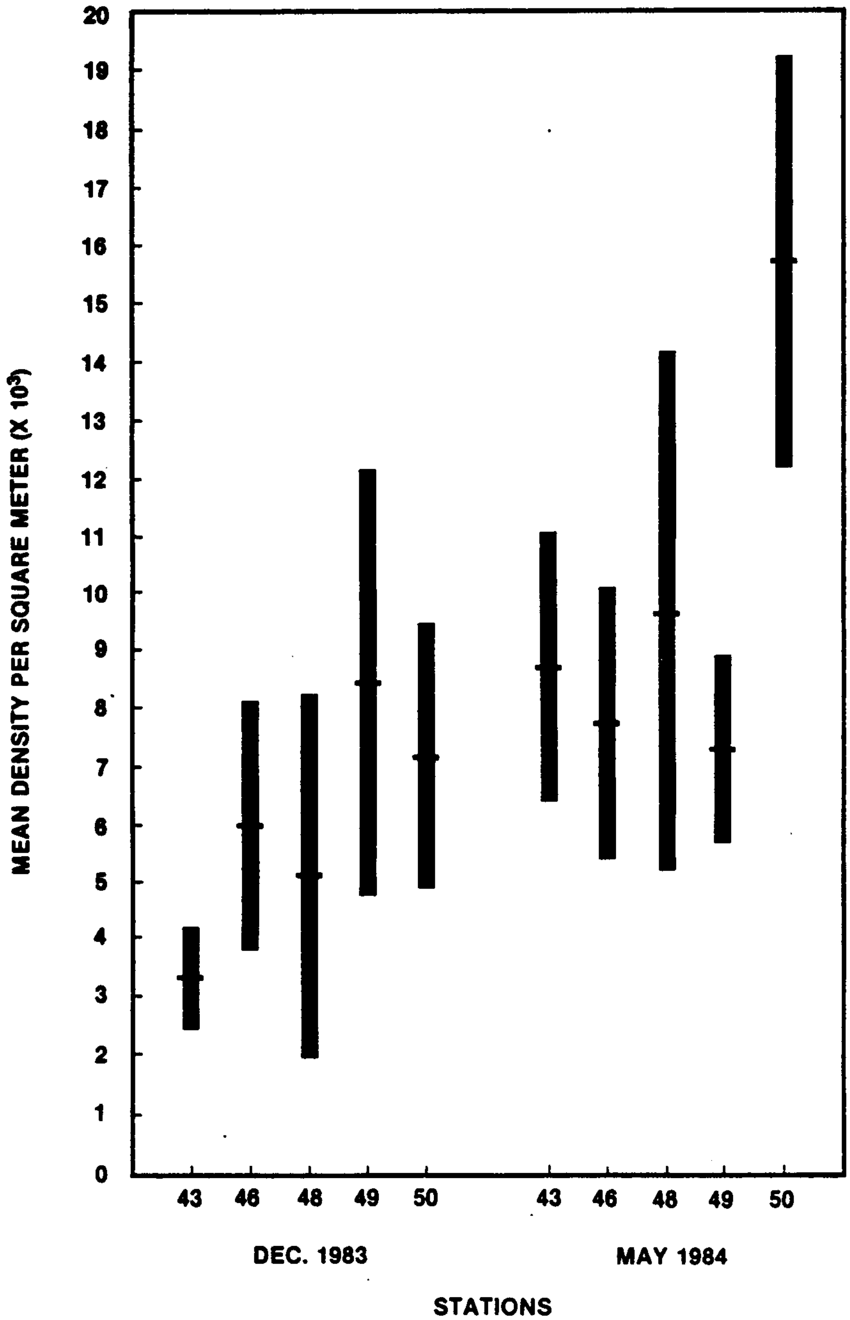


Figure 4.1-4 MEAN DENSITY OF INDIVIDUALS PER SQUARE METER ($\pm$ 1 STANDARD DEVIATION)

Table 4.1-4. Shannon-Weaver Diversity, Margalef's Species Richness, and Pielou's Evenness Values for Benthic Infauna

Station	Diversity (H')	Richness (J)	Evenness (E)
December 1983			
43	5.76	14.22	0.84
46	5.20	13.70	0.75
48	4.91	12.78	0.72
49	5.13	12.94	0.75
50	5.09	13.73	0.73
May 1984			
43	5.19	11.79	0.77
46	4.87	11.27	0.73
48	4.82	11.32	0.72
49	4.71	9.22	0.74
50	5.40	15.82	0.74

individuals equalling small percentages of the total collections. This is further pointed out in Table 4.1-5. Over all stations the number of taxa which was equal to less than 1 percent of the total individuals at a station ranged from 73.5 percent to 87.1 percent of the number of taxa at a station. The number of taxa which was equal to or greater than 10 percent of the total individuals at a station ranged from only 0.8 percent to 1.9 percent of the number of taxa at a station.

Diversity, richness, and evenness are all conservative estimates because all taxa could not be identified to the species level. Some of these taxa which were identified only to genus or a higher taxonomic level will be represented by more than one species, particularly groups such as oligochaetes, ostracods, and rhynchocoels.

<u>Live-Bottom Stations</u>

Live-bottom stations were sampled for biota with underwater television, triangle dredge, trawl, time-lapse camera, and fouling plates. Stations in Group I (Stations 44, 45, 47, 51, and 19) were sampled for biota only twice, on Cruises I and III. Group II live-bottom stations were sampled for biota on each of four cruises, weather permitting. Within each gear type, differences in numbers of species between stations may therefore reflect real biological differences, or may be a result of differences in sampling intensity. Rarer species are certainly less likely to have been collected at Group I stations. The reader is advised to avoid direct, quantitative comparisons of numbers of species or related parameters between Group I and Group II stations, even within samples collected with the same gear types. Since data are still preliminary, use of the term "seasonality" is deliberately avoided. Consequently, sampling periods are referred to cruise numbers rather than seasons.

In addition, it should be emphasized that as of this date, analysis is still underway for all of the data sets described in this draft report. At this stage most of the data have not been fully verified. Tables of

Table 4.1-5. Total Number of Taxa, Number of Infaunal Taxa by Density Percentage Categories, and Percentage Composition

	Station									
	43		46		48		49		50	
	# taxa	%	# taxa	%	# taxa	%	# taxa	%	# taxa	%
December 1983										
Total number of taxa	116	100	120	100	110	100	118	100	124	100
Number of taxa <1%	97	83.6	101	84.2	93	84.5	101	85.6	108	87.1
Number of taxa 1-5%	16	13.8	16	13.3	14	12.7	12	10.2	12	9.7
Number of taxa >5-<10%	2	1.7	2	1.7	2	1.8	4	3.4	2	1.6
Number of taxa ≥10%	1	0.9	1	0.8	1	0.9	1	0.8	2	1.6
May 1984										
Total number of taxa	108	100	102	100	106	100	83	100	154	100
Number of taxa <1%	84	77.8	83	81.4	89	83.9	61	73.5	131	85.1
Number of taxa 1-5%	19	17.6	14	13.7	11	10.4	16	19.3	20	13.0
Number of taxa >5-<10%	4	3.7	3	2.9	4	3.8	5	6.0	1	0.6
Number of taxa ≥10%	1	0.9	2	1.9	2	1.9	1	1.2	2	1.3

species presence/absence are unlikely to contain spurious entries, although spelling errors and other minor classification problems may still exist. Whenever possible, taxonomic nomenclature conforms to NODC specifications. Common names for fishes follow the recommendations of Robins et al. (1980). Common names for invertebrates are derived mainly from Kaplan (1982) and Colin (1978). Tables containing quantitative information on abundance, however, are likely to contain some factual errors. These errors will be corrected as the data set continues to be "cleaned."

Live-bottom stations are discussed individually below. Comparisons between stations are provided in Section 4.2. Stations are presented in order of increasing depth, and data sets are separated by gear types (underwater television, triangular dredge, trawl, and time-lapse camera as appropriate). Checklists showing presence/absence of organisms and fish counts at individual stations are furnished as Tables F-1 through F-10. Length and weight data for fish collected with the trawl are not discussed in this report due to time limitations, but data summaries are provided as Figure F-1. Fouling plate data are discussed in Appendix G.

The underwater television data proved to be most useful in describing each station. The total area surveyed by underwater television for all stations combined during Year 4 was 266 833 m^2. Table 4.1-6 shows the area surveyed at each station, by cruise. Analysis of videotapes included all of the area surveyed. Although surveys on Cruises I and III were intended to cover all Group I and Group II stations and approximately equal areas, considerably less total area was surveyed on Cruise I due to unusually poor weather conditions. Only Group II stations were surveyed by underwater television on Cruises II and IV.

At the time that this volume was prepared, underwater television data summaries were available only for "discrete" organisms that were individually counted such as fish and relatively low-density individual invertebrates. In many cases, organisms were present at very high

Table 4.1-6 Total Area (m^2) Surveyed by Underwater Television by Cruise and Station

	STATION										
CRUISE	52	44	51	45	47	19	21	29	23	36	TOTAL
1	5572	1025	6249	4625	9436	3750	0	5079	0	0	35736
2	0	0	0	0	0	0	4100	16794	14888	5124	40906
3	9267	12260	14940	22048	20368	16456	17908	15492	16092	4426	149257
4	7640	0	0	0	0	0	8187	7386	8316	9405	40934
TOTAL	22479	13285	21189	26673	29804	20206	30195	44751	39296	18955	266833

densities and could not be counted individually. For these, abundance estimates consisted of ranges of minimum and maximum counts or percentage cover values (e.g., 50 to 100 individuals, or 10- to 20-percent cover).

Range estimates from underwater television surveys have not yet been combined with the data from actual counts, nor can they be compared directly to them. In many instances, members of the same taxon were counted individually in one area, and their abundance assessed as a range estimate in another area, even within the same transect. The same taxon would thus appear separately in data tables showing individual counts as well as range estimates. Actual count tables are biased in favor of scarcer taxa and observations of organisms that were more widely spaced. Densities of organisms appearing on both actual count and range estimate tables are probably best assessed on the range estimate tables, which of necessity include observations of especially dense congregations of individuals. During Year 5, statistical methods for combining range estimates with actual counts will be explored.

Station 44

Underwater Television--The bottom at Station 44 was mainly carbonate sand, with scattered patches of live-bottom communities that included gorgonians, corals, sponges, and algae. The most conspicuous features of the soft bottom were tracks produced by burrowing echinoids. Asteroids and pen shells were also observed.

Individually counted organisms observed in underwater television transects on Cruises I and III at Station 44 included 18 invertebrate taxa and 16 species of fishes in the 13 285 m^2 surveyed. The most abundant individually counted invertebrates (averaged over the two cruises) were various unidentified plexaurid gorgonians (7693/km^2), followed by sand dollars (family Mellitidae) (6797/km^2); bivalves of the genus *Atrina* (580/km^2); the sponge *Ircinia campana* (572/km^2); the sea star *Chaetaster nodosus* (557/km^2); and gorgonians (unidentified *Leptogorgia* spp., 550/km^2) (Table 4.1-7a).

The most frequently counted fishes in underwater television transects (averaged over the two cruises) at Station 44 were the round scad, *Decapterus punctatus* (271/km^2); the tomtate, *Haemulon aurolineatum* (105/km^2); the jackknife-fish, *Equetus lanceolatus*; and an unidentified lutjanid snapper (both 38/km^2) (Table 4.1-7b).

There were some striking differences apparent when the underwater television data from Cruise I and III were examined separately, apparently due to the patchy nature of live-bottom habitat at this station. During Cruise I, the three invertebrates most frequently counted individually were *Ircinia campana* (7415/km^2); unidentified gorgonians of the genus *Leptogorgia* (7122/km^2); and *Ircinia strobilina* (2634/km^2). During Cruise III, the density of *Ircinia strobilina* was estimated at 8/km^2, and the other two were not observed. On the other hand, sand dollars (family Mellitidae) were seen only on Cruise III (7365/km^2). The most abundant fishes on Cruise I were *Haemulon aurolineatum* (1366/km^2); *Equetus lanceolatus* and the unidentified lutjanid snapper (both 488/km^2); and the scrawled cowfish, *Lactophrys quadricornis* (293/km^2). None of these was seen on Cruise III, nor were the only two fishes observed on Cruise III (*Decapterus punctatus*, 294/km^2; and the blue runner, *Caranyx crysos*, 65/km^2) observed on Cruise I.

Dredge--Dredge samples from Station 44 showed a typical collection of shallow-water live-bottom invertebrates usually associated with coral reefs and adjacent unconsolidated sediment patches (Table F-1a). Massive scleractinian corals included the mountainous star coral, *Montastrea cavernosa*, and the smooth starlet coral, *Siderastrea siderea*. Other smaller scleractinians included the ahermatypic coral *Phyllangia americana*; a golf ball coral, *Favia gravida*; and a bush coral, *Oculina tenella*. Five species of gorgonians were also present.

Table 4.1-7a Density (No./km^2) of Invertebrates Individually Counted in Underwater Television Transects at Station 44, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	Mean
PORIFERA			
DEMOSPONGIAE UNIDENT		65.3	60.2
IRCINIA CAMPANA	7414.6		572.1
IRCINIA STROBILINA	2634.1	8.2	210.8
CNIDARIA			
HYDROIDA			
HYDROIDA UNIDENT	1365.9	32.6	135.5
ALCYONARIA			
PLEXAURIDAE UNIDENT	1170.7	8238.2	7692.9
LEPTOGORGIA UNIDENT	7122.0		549.5
PSEUDOPTEROGORGIA UNIDENT	487.8		37.6
MOLLUSCA			
GASTROPODA			
STROMBUS UNIDENT		146.8	135.5
BIVALVIA			
ATRINA UNIDENT		628.1	579.6
CRUSTACEA			
ANOMURA			
DIOGENIDAE UNIDENT		65.3	60.2
BRACHYURA			
CALAPPA UNIDENT	97.6		7.5
PORTUNIDAE UNIDENT		8.2	7.5
ECHINODERMATA			
ASTEROIDEA			
ASTEROIDEA UNIDENT	292.7		22.6
CHAETASTER NODOSUS	975.6	522.0	557.0
ECHINOIDEA			
ECHINOIDEA UNIDENT	878.0		67.7
CLYPEASTER UNIDENT		8.2	7.5
MELLITIDAE UNIDENT		7365.4	6797.1
HOLOTHUROIDEA			
ASTICHOPUS MULTIFIDUS		16.3	15.1

Table 4.1-7b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 44, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
SCORPAENIDAE			
SCORPAENIDAE UNIDENT	97.6		7.5
SERRANIDAE			
SERRANIDAE UNIDENT	97.6		7.5
MYCTEROPERCA UNIDENT	195.1		15.1
DIPLECTRUM UNIDENT	97.6		7.5
CARANGIDAE			
CARANX CRYSOS		65.3	60.2
DECAPTERUS PUNCTATUS		293.6	271.0
LUTJANIDAE			
LUTJANIDAE UNIDENT	487.8		37.6
LUTJANUS SYNAGRIS	195.1		15.1
HAEMULIDAE			
HAEMULON UNIDENT	195.1		15.1
HAEMULON AUROLINEATUM	1365.9		105.4
HAEMULON PLUMIERI	195.1		15.1
SCIAENIDAE			
EQUETUS LANCEOLATUS	487.8		37.6
CHAETODOTIDAE			
CHAETODON SEDENTARIUS	97.6		7.5
LABRIDAE			
LACHNOLAIMUS MAXIMUS	97.6		7.5
OSTRACIONTIDAE			
LACTOPHRYS QUADRICORNIS	292.7		22.6
DIODONTIDAE			
CHILOMYCTERUS SCHOEPFI	97.6		7.5

Other typical coral reef species included various unidentified sponges; the long-spined sea urchin, Diadema antillarum; and the arrow craw, Stenorhynchus setosus. Several portunid swimming crabs were taken, including Portunus depressifrons and P. anceps, as well as a variety of other small crabs such as the box crab, Calappa sulcata, and three species of spider crabs, Mithrax hispidus, M. forceps, and M. pleuracanthus.

Soft-bottom taxa taken in triangular dredge samples at Station 44 included the fighting conch, Strombus pugilis; two sea stars, the spiny beaded sea star, Astropecten duplicatus, and the brown spiny sea star, Echinaster spinulosus; the sand dollars Encope aberrans and E. michelini; the flat sea biscuit, Clypeaster subdepressus; and the green sea urchin, Lytechinus variegatus. Several species usually found only in large areas of soft bottom were the brown and white penaeid prawns, Penaeus aztecus and P. setiferus. Soft-bottom taxa collected at Station 44 included several ophiuroids generally found on or inside sponges, e.g., the striped brittle star, Ophiothrix lineata, and the angular brittle star, O. angulata. Only four plants (all red algae) were identified from Station 44, and these were taken only during Cruise I.

Trawl--Trawl samples were extremely sparse at Station 44 (see Tables F-1b and F-14). Only three (11 individuals) were collected, and those on Cruise I: four tomtates, Haemulon aurolineatum; four scrawled cowfish, Lactophrys quadricornis; and three unidentified lizard fish, family Synodontidae.

Station 45

Underwater Television--The bottom at Station 45 consisted of carbonate sand over hard bottom, with live-bottom communities that included corals, gorgonians, sponges, and algae. Some holothuroids and asteroids were observed. The topography of Station 45 was generally flat, with a few detectable depressions or valleys 1 to 2 m deep. Sandy areas exhibited ripple marks.

Individually counted organisms observed in underwater television transects on Cruises I and III at Station 45 included 15 invertebrate taxa and 24 species of fishes in the 26 673 m^2 surveyed. The most abundant individually counted invertebrates (averaged over the two cruises) were sponges, including various unidentified demosponges (4529/km^2) and Ircinia campana (311/km^2); the scleractinian coral Solenastrea hyades (150/km^2); and the sea star Chaetaster nodosus (90/km^2) (Table 4.1-8a).

The most frequently counted fishes in underwater television transects (averaged over the two cruises) at Station 45 were an unidentified drum--probably the jackknife-fish but identified only as Equetus sp. (56/km^2); the blue runner, Caranx crysos (49/km^2); and two grunts: the tomtate, Haemulon aurolineatum, and white grunt, H. plumieri (both 45/km^2) (Table 4.1-8b).

There were major differences in individually counted invertebrates between Cruises I and III. On Cruise I, the most abundant organisms were Solenastea hyades (649/km^2); unidentified gorgonians of the genus Leptogorgia (519/km^2); Ircinia campana (410/km^2); and an unidentified sea urchin (346/km^2). Of these, on Cruise III only Ircinia and Solenastrea were abundant (290/km^2 and 46/km^2, respectively). Unidentified demosponges (5479/km^2) and Chaetaster nodosus (109/km^2) were prominent on Cruise III despite their absence from Cruise I records.

There were also major differences in the fishes between cruises. The most common fishes observed by underwater television on Cruise I were Haemulon aurolineatum (151/km^2), and the hogfish, Lachnolaimus maximus (43/km^2). Only seven species were recorded on Cruise I. On

Table 4.1-8a Density (No./km^2) of Invertebrates Individually Counted in Underwater Television Transects at Station 45, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
PORIFERA			
DEMOSPONGIAE UNIDENT		5479.0	4528.9
IRCINIA CAMPANA	410.8	290.3	311.2
IRCINIA STROBILINA	21.6	59.0	52.5
CNIDARIA			
HYDROIDA			
HYDROIDA UNIDENT	64.9		11.2
ALCYONARIA			
LEPTOGORGIA UNIDENT	518.9		90.0
PTEROGORGIA GUADALUPENSIS	21.6	9.1	11.2
ZOANTHARIA			
SCLERACTINIA UNIDENT	237.8	13.6	52.5
SOLENASTREA UNIDENT	43.2		7.5
SOLENASTREA HYADES	648.6	45.4	150.0
MUSSA ANGULOSA	108.1		18.7
ECHINODERMATA			
ASTEROIDEA			
ASTEROIDEA UNIDENT	21.6		3.7
CHAETASTER NODOSUS		108.9	90.0
ECHINOIDEA			
ECHINOIDEA UNIDENT	345.9		60.0
HOLOTHUROIDEA			
HOLOTHUROIDEA UNIDENT	21.6	22.7	22.5
ASTICHOPUS MULTIFIDUS	21.6	31.7	30.0

Table 4.1-8b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 45, by Cruise (Mean Includes all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
RHINOBATIDAE			
RHINOBATOS LENTIGINOSUS	21.6		3.7
SYNODONTIDAE			
SYNODUS INTERMEDIUS	21.6		3.7
PERCIFOMES			
PERCIFORMES UNIDENT		9.1	7.5
SERRANIDAE			
SERRANIDAE UNIDENT		4.5	3.7
EPINEPHELUS GUTTATUS		4.5	3.7
EPINEPHELUS MORIO	21.6	9.1	11.2
MYCTEROPERCA INTERSTITIAL		4.5	3.7
DIPLECTRUM FORMOSUM		9.1	7.5
CARANGIDAE			
CARANX CRYSOS		59.0	48.7
DECAPTERUS PUNCTATUS		18.1	15.0
LUTJANIDAE			
LUTJANUS APODUS		4.5	3.7
LUTJANUS SYNAGRIS		9.1	7.5
HAEMULIDAE			
HAEMULON UNIDENT		9.1	7.5
HAEMULON AUROLINEATUM	151.4	22.7	45.0
HAEMULON PLUMIERI		54.4	45.0
SPARIDAE			
CALAMUS UNIDENT		4.5	3.7
CALAMUS CALAMUS		49.9	41.2
SCIAENIDAE			
EQUETUS UNIDENT		68.0	56.2
EPHIPPIDAE			
CHAETODIPTERUS FABER		4.5	3.7
CHAETODOTIDAE			
CHAETODON UNIDENT	21.6		3.7
HOLACANTHUS CILIARIS		18.1	15.0
POMACANTHUS ARCUATUS	21.6	18.1	18.7
LABRIDAE			
LACHNOLAIMUS MAXIMUS	43.2	9.1	15.0
OSTRACIONTIDAE			
LACTOPHRYS QUADRICORNIS		13.6	11.2

Cruise III, 21 species were observed, probably because more than four times the area was surveyed at Station 45 on Cruise III than on Cruise I. The most abundant fishes on Cruise I were *Equetus* sp. (68/km^2); *Caranx crysos* (59/km^2); *Haemulon plumieri* (54/km^2); and the saucereye progy, *Calamus calamus* (50/km^2).

Dredge--The fauna of Station 45 included many species typical of shallow-water coral reefs (see Table F-2a). Many unidentified sponges were collected. Seven species of scleractinian corals were found: the mountainous star coral, *Montastrea cavernosa*; the smooth starlet coral, *Siderastrea siderea*; the small finger coral, *Porites divaricata*; the large flower coral, *Mussa angulosa*; the sinuous cactus coral, *Isophyllia sinuosa*; the blushing star coral, *Stephanocoenia michelini*; the saucer coral, *Helioseris cucullata*; and a golf ball coral, *Favia gravida*. Station 45 had a diverse gorgonian fauna; 12 species were identified.

Many bivalves and gastropods were present, including pink and milk conchs, *Strombus gigas* and *S. costatus*; the winged oyster, *Pteria colymbus*; the leafy jewel box, *Chama macerophylla*; and the spiny oysters, *Spondylus americanus*, and *S. ictericus.*

Several echinoderms were collected, including the angular brittle star, *Ophiothrix angulata*; the ruby brittle star, *Ophioderma rubicundum*; and Suenson's brittle star, *Ophiothrix suensonii*, usually found inside sponges or on gorgonians. One urchin and one sea cucumber were collected, the brown rock urchin, *Arbacea punctulata*, and the 3-rowed sea cucumber, *Isostichopus badionotus*.

Crustaceans taken at Station 45 included many brachyuran crabs, such as the lesser sponge crab, *Dromidia antillensis*, and four species of spider crabs, *Mithrax turceps*, *M. forceps*, *M. hispidus*, and *M. pleuracanthus*. Several anomuran hermit crabs were taken, including *Paguristes tortugae* and *P. sericeus*. A stomatopod, *Gonodactylus bredeni*, and three pistol shrimps, Alpheus normanni, Synalpheus minus, and S. townsendi, were also collected.

Twenty-three species of algae were identified in dredge samples (see Table F-2b). Three species were collected only on Cruise III, while 21 were taken only on Cruise I. There was little overlap between cruises; only Sargassum cf. hystrix and Botryocladia occidentalis were collected on both cruises.

Trawl--The most abundant species of the 29 individuals (representing 9 species) taken on the first cruise was the Atlantic spadefish, Chaetodipterus faber (see Tables F-2c and F-14). On the third cruise, the clear dominant among 40 individuals (representing 14 species) was the white grunt, Haemulon plumieri, followed by the slippery dick, Halichoeres bivittatus. The best represented family from the standpoint of number of species present was the porgies, Sparidae (three species).

Station 47

Underwater Television--Ripple-marked carbonate sand and coarse shell hash characterized the bottom at Station 47. There were also patches of live bottom with gorgonians, sponges, and algae observed on underwater television. The white grunt, Haemulon plumieri, was frequently present.

Individually counted organisms observed in underwater television transects on Cruises I and III at Station 47 included 19 invertebrate taxa and 16 species of fishes in the 29 804 m^2 surveyed. The most abundant individually counted invertebrates (averaged over the two cruises) were various unidentified demosponges (1731/km^2); gorgonians, Pseudopterogorgia spp. (550/km^2); the sponge Ircinia strobilina (275/km^2); unidentified plexaurid gorgonians (174/km^2); and Ircinia campana (87/km^2) (Table 4.1-9a).

The most frequently counted fishes in underwater television transects (averaged over the two cruises) at Station 47 were the white grunt,

Table 4.1-9a Density (No./km^2) of Invertebrates Individually Counted in Underwater Television Transects at Station 47, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
PORIFERA			
DEMOSPONGIAE UNIDENT	190.8	2445.0	1731.3
IRCINIA CAMPANA	159.0	54.0	87.2
IRCINIA STROBILINA	688.9	83.5	275.1
CNIDARIA			
HYDROIDA			
HYDROIDA UNIDENT		93.3	63.7
ALCYONARIA			
PLEXAURIDAE UNIDENT	275.5	127.7	174.5
PSEUDOPTEROGORGIA UNIDENT	582.9	535.2	550.3
ZOANTHARIA			
SCLERACTINIA UNIDENT	21.2		6.7
SOLENASTREA HYADES	10.6	4.9	6.7
MUSSA ANGULOSA	10.6		3.4
MOLLUSCA			
GASTROPODA			
STROMBUS UNIDENT		4.9	3.4
CHELICERATA			
LIMULUS POLYPHEMUS		4.9	3.4
CRUSTACEA			
ANOMURA			
DIOGENIDAE UNIDENT		4.9	3.4
ECHINODERMATA			
ASTEROIDEA			
ASTEROIDEA UNIDENT	21.2	44.2	36.9
ASTROPECTEN UNIDENT		4.9	3.4
OREASTER RETICULATUS	53.0	29.5	36.9
ECHINOIDEA			
ECHINOIDEA UNIDENT	95.4		30.2
MELLITIDAE UNIDENT		39.3	26.8
HOLOTHUROIDEA			
HOLOTHUROIDEA UNIDENT	10.6	9.8	10.1
ASTICHOPUS MULTIFIDUS	10.6	19.6	16.8

Haemulon plumieri (131/km^2); the jackknife-fish, Equetus lanceolatus (87/km^2); the cubbyu, Equetus umbrosus; and the red grouper, Epinephelus morio (both 27/km^2) (Table 4.1-9b).

Cruise I underwater television data for many groups of individually counted invertebrates differed somewhat from Cruise III data, although sponges and gorgonians dominated both sets of observations. On Cruise III, no sea urchins were recorded, although they were common (95/km^2) on Cruise I. Unidentified hydroids were frequently counted (93/km^2) on Cruise III but not recorded on Cruise I.

The most abundant fishes on Cruise I (Epinephelus morio, 53/km^2; Equetus lanceolatus, 95/km^2; E. umbrosus, 85/km^2; and Haemulon plumieri, 42/km^2) were, in general, present on Cruise III. The most frequently counted fish species on Cruise III were Haemulon plumieri (172/km^2), and Equetus lanceolatus (84/km^2); others were present at lower densities (less than 25/km^2).

Dredge--Triangular dredge samples at Station 47 included relatively few corals and gorgonians by comparison to other nearby stations of equivalent depth (e.g., Stations 44 and 45), although many sponges were present (see Table F-3a). In general, samples suggested a high proportion of unconsolidated sediment or low-relief live bottom. Numerous unidentified sponges were collected. Only three scleractinians were found, i.e., the mountainous star coral, Montastrea cavernosa; the smooth starlet coral, Siderastrea siderea; and a golf ball coral, Favia gravida. Just five species of gorgonians were taken by the dredge.

Several bivalves and gastropods were found at Station 47, including the spiny oyster, Spondylus ictericus; the fighting conch, Strombus gigas; the Scotch bonnet, Phalium granulatum; and the murex, Murex brevifrons.

Table 4.1-9b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 47, by Cruise (Means Based on Total Area Transected for all Cruise Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
SERRANIDAE			
EPINEPHELUS MORIO	53.0	14.7	26.8
DIPLECTRUM UNIDENT	10.6	4.9	6.7
CARANGIDAE			
CARANX CRYSOS		9.8	6.7
LUTJANIDAE			
LUTJANUS APODUS		24.5	16.8
LUTJANUS SYNAGRIS		14.7	10.1
HAEMULIDAE			
HAEMULON AUROLINEATUM	10.6	14.7	13.4
HAEMULON PLUMIERI	42.4	171.8	130.9
SPARIDAE			
CALAMUS CALAMUS	21.2		6.7
SCIAENIDAE			
EQUETUS LANCEOLATUS	95.4	83.5	87.2
EQUETUS UMBROSUS	84.8		26.8
CHAETODOTIDAE			
POMACANTHUS ARCUATUS	10.6		3.4
POMACENTRIDAE			
CHROMIS UNIDENT		4.9	3.4
EUPOMACENTRUS PARTITUS		19.6	13.4
BALISTIDAE			
MONACANTHUS UNIDENT		4.9	3.4

Many crustaceans were present. Eighteen brachyurans were identified in triangular dredge samples, including several portunid swimming crabs, Portunus anceps and P. spinimanus; the lesser sponge crab, Dromidia antillensis; the box crab, Calappa flammea; and the arrow crab, Stenorhynchus seticornis. One stomatopod, Gonodactylus bredeni, and two rock shrimp, Sicyonia laevigata and S. typica, were also collected.

The sea stars collected were species typically found only on unconsolidated sediment: the beaded sea star, Astropecten articulatus; the spiny beaded sea star, Astropecten duplicatus; the limp sea star, Luidia alternata; and Astropecten comptus. Four species of ophiuroids were also collected, including the lined brittle star, Ophiothrix lineata; the ubiquitous angular brittle star, O. angulata; Savigny's ophiactis, Ophiactis savignyi; and Astrocyclus caecilia. Several sand dollars were also taken, including Encope aberrans and the flat sea biscuit, Clypeaster depressus.

Seventeen species of algae were collected by triangular dredge at Station 47 (see Table F-3b). With one exception (Sargassum cf. hystrix), none of the species collected on Cruise I were taken on Cruise III. Only 5 species were identified in samples from Cruise III, as opposed to 14 species from Cruise I.

Trawl--Trawl samples collected at Station 47 on Cruise I included only 4 species; 12 of 14 fish collected were tomtate, Haemulon aurolineatum, and white grunts, H. plumieri (see Tables F-3c and F-14). On Cruise III, 22 fish were taken, belonging to 11 families. The most common species was the gray angel, Pomacanthus arcuatus. The best represented family was the triggerfishes, Balistidae (three species).

Station 51

Underwater Television--Station 51 was mainly a flat carbonate sand bottom with ripple marks and patchy live-bottom areas. Fish commonly observed included the white grunt, Haemulon plumieri; the red grouper, Epinephelus morio; the blue runner, Caranx crysos; and various sand perches, Diplectrum spp.

Individually counted organisms observed in underwater television transects on Cruises I and III at Station 51 included 14 invertebrate taxa and 28 species of fishes in the 21 189 m^2 surveyed. The most abundant individually counted invertebrates (averaged over the two cruises) were sponges, including unidentified demosponges (2643/km^2), Ircinia campana (1926/km^2), and I. strobilina (802/km^2). Other abundant taxa included unidentified hydroids (713/km^2) and holothuroids (47/km^2) (Table 4.1-10a).

More fish species were observed at Station 51 than at all other shallow water stations except for Station 52. The most frequently counted fishes in underwater television transects (averaged over the two cruises) at Station 51 were the white grunt, Haemulon plumieri (2898/km^2); the red grouper, Epinephelus morio (127/km^2); the cubbyu, Equetus umbrosus (123/km^2); the blue runner, Caranx crysos (113/km^2); the jackknife-fish, Equetus lanceolatus (90/km^2); and the hogfish, Lachnolaimus maximus (76/km^2) (Table 4.1-10b).

Cruise I underwater television data were very similar to Cruise III data for the most abundant group of invertebrates counted (sponges). However, on Cruise I, transects crossed some gorgonian beds, recording densities up to 128/km^2 for Pterogorgia guadalupensis, although gorgonians were not seen on Cruise III. By comparison, unidentified hydroids were extremely abundant (1011/km^2) on Cruise III but not recorded on Cruise I.

Most of the common fishes seen at Station 51 on Cruise I (Haemulon plumieri, 7873/km^2; Equetus umbrosus, 384/km^2; E. lanceolatus, 304/km^2; Epinephelus morio, 272/km^2; Lachnolaimus maximus, 160/km^2) were also abundant on Cruise III. The most abundant fish species on Cruise III were Haemulon plumieri (817/km^2); Caranx

Table 4.1-10a Density (No./km^2) of Invertebrates Individually Counted in Underwater Television Transects at Station 51, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
PORIFERA			
DEMOSPONGIAE UNIDENT	16.0	3741.6	2642.9
IRCINIA CAMPANA	1168.2	2242.3	1925.5
IRCINIA STROBILINA	1440.2	535.5	802.3
CNIDARIA			
HYDROIDA			
HYDROIDA UNIDENT		1010.7	712.6
ALCYONARIA			
PLEXAURIDAE UNIDENT	16.0		4.7
PSEUDOPTEROGORGIA UNIDENT	80.0		23.6
PTEROGORGIA GUADALUPENSIS	128.0		37.8
ZOANTHARIA			
ACTINIARIA UNIDENT		6.7	4.7
SOLENASTREA HYADES	32.0	13.4	18.9
CRUSTACEA			
BRACHYURA			
CALAPPA UNIDENT	16.0		4.7
ECHINODERMATA			
ASTEROIDEA			
ASTEROIDEA UNIDENT		13.4	9.4
ECHINASTER UNIDENT		6.7	4.7
HOLOTHUROIDEA			
HOLOTHUROIDEA UNIDENT		66.9	47.2
ASTICHOPUS MULTIFIDUS	16.0		4.7

Table 4.1-10b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 51, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
SYNODONTIDAE			
SYNODUS INTERMEDIUS	16.0		4.7
SERRANIDAE			
EPINEPHELUS MORIO	272.0	66.9	127.4
DIPLECTRUM UNIDENT	32.0	107.1	84.9
CARANGIDAE			
CARANX CRYSOS	48.0	140.6	113.3
DECAPTERUS PUNCTATUS		26.8	18.9
LUTJANIDAE			
LUTJANUS SYNAGRIS	32.0		9.4
GERRIDAE			
EUCINOSTOMUS UNIDENT		26.8	18.9
HAEMULIDAE			
HAEMULON UNIDENT		6.7	4.7
HAEMULON AUROLINEATUM	48.0	6.7	18.9
HAEMULON PLUMIERI	7873.3	816.6	2897.7
ORTHOPRISTIS CHRYSOPTERA	16.0		4.7
ANISOTREMUS VIRGINICUS		6.7	4.7
SPARIDAE			
SPARIDAE UNIDENT	48.0		14.2
CALAMUS ARCTIFRONS	16.0		4.7
CALAMUS CALAMUS	16.0	6.7	9.4
SCIAENIDAE			
EQUETUS LANCEOLATUS	304.0		89.7
EQUETUS UMBROSUS	384.1	13.4	122.7
CHAETODOTIDAE			
HOLACANTHUS UNIDENT	16.0	13.4	14.2
POMACANTHUS ARCUATUS	80.0		23.6
POMACENTRIDAE			
EUPOMACENTRUS UNIDENT		20.1	14.2
LABRIDAE			
LACHNOLAIMUS MAXIMUS	160.0	40.2	75.5
BALISTIDAE			
ALUTERUS SCHOEPFI		6.7	4.7
ALUTERUS SCRIPTUS		6.7	4.7
BALISTES CAPRISCUS		6.7	4.7
CANTHERHINES MACROCERUS		6.7	4.7
OSTRACIONTIDAE			
LACTOPHRYS UNIDENT		13.4	9.4
LACTOPHRYS QUADRICORNIS	16.0	6.7	9.4
TETRAODONTIDAE			
SPHOEROIDES UNIDENT	16.0		4.7

crysos (141/km^2); an unidentified serranid, Diplectrum sp. (107/km^2); Equetus lanceolatus (85/km^2); Epinephelus morio (67/km^2); and Lachnolaimus maximus (40/km^2).

Dredge--Numerous massive sponges were taken by triangular dredges at Station 51, but no scleractinians or gorgonians were collected (see Table F-4a). Only three bivalves (the spiny oyster, Spondylus americanus; the winged oyster, Pteria colymbus; and Pinctada imbricata) and two gastropods (the murex, Murex pomum, and the encrusting slipper shell, Crepidula aculeata) were taken by triangular dredge. Five small brachyurans, one anomuran crab, and two pistol shrimps (Synalpheus minus and S. townsendi) were collected at Station 51.

A number of invertebrates which are more typical of soft bottom than of live bottom were also taken by the dredge. These included two penaeids (the brown shrimp, Penaeus aztecus, and the prawn Metapenaeopsis goodei); several sea stars (the American sand star, Astropecten americanus; the spiny beaded sea star, Astropecten duplicatus; and the limp sea star, Luidia alternata); the flat sea biscuit, Clypeaster subdepressus; and the green sea urchin, Lytechinus variegatus.

Eight species of algae were collected by triangular dredge at Station 51 (Table F-4b). Seven of these were taken on Cruise I, while three species were taken on Cruise III. Of these, two (the green algae Udotia conglutimata and Halimeda f. simulans) were taken on both cruises, but one (an unidentified brown alga, Dictyopteris) was seen only in Cruise III samples.

Trawl--Only seven fish were taken on Cruise I: six white grunts (Haemulon plumieri) and a blackedge moray, Gymnothorax nigromarginatus (see Tables F-4c and F-14). On Cruise III, only nine individuals were taken, representing seven species. White grunts were present on both cruises, unlike all other species collected.

Station 19

Underwater Television--The bottom at Station 19 was composed of carbonate sand, marked with ripples, and patches of live-bottom communities with gorgonians, sponges, and algae. In general, epibenthic invertebrates and fishes were relatively low in density compared to shallower live-bottom communities. No fish species appeared to be the overwhelming dominant, but the species most commonly observed included several sand perches, *Diplectrum* spp., and the white grunt, *Haemulon plumieri*.

Individually counted organisms observed in underwater television transects on Cruises I and III at Station 19 included 17 invertebrate taxa and 34 species of fishes in the 20 206 m^2 surveyed. More fish species were recorded at Station 19 than at any of the five nearshore shallow water stations. Although Station 19 is only slightly deeper than they are, it is located about 50 km to the west of Station 52.

As at the other nearshore stations, the most abundant individually counted invertebrates (averaged over the two cruises) at Station 19 were sponges: *Ircinia strobilina* had a mean density of 856/km^2 (see Table 4.1-11a). Other abundant invertebrates were the reticulated sea star, *Oreaster reticulatus* (386/km^2); unidentified gorgonians, *Pseudopterogorgia* spp. (257/km^2) and various plexaurids (149/km^2); unidentified hydroids (203/km^2); and unidentified sea urchins (188/km^2).

The most frequently counted fishes in underwater television transects (averaged over the two cruises) at Station 19 were the white grunt, *Haemulon plumieri* (485/km^2); a serranid--probably the dwarf sand perch and/or the sand perch--*Diplectrum* spp. (178/km^2); the jackknife-fish, *Equetus lanceolatus* (54/km^2); and various unidentified porgies, *Calamus* spp. (50/km^2) (Table 4.1-11b). Virtually all of the fishes recorded from Station 19 were observed on Cruise I (31 of 34 species). The only abundant species seen on

Table 4.1-11a Density (No./km^2) of Invertebrates Individually Counted in Underwater Television Transects at Station 19, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
PORIFERA			
IRCINIA CAMPANA	266.7	18.2	64.3
IRCINIA STROBILINA	3733.3	200.5	856.2
CNIDARIA			
HYDROIDA			
HYDROIDA UNIDENT		249.1	202.9
ALCYONARIA			
PLEXAURIDAE UNIDENT	800.0		148.5
GORGONIIDAE UNIDENT	53.3		9.9
PSEUDOPTEROGORGIA UNIDENT	1386.7		257.3
PTEROGORGIA GUADALUPENSIS	26.7		4.9
ZOANTHARIA			
ACTINIARIA UNIDENT	26.7		4.9
MOLLUSCA			
GASTROPODA			
STROMBUS UNIDENT		6.1	4.9
CRUSTACEA			
BRACHYURA			
PORTUNIDAE UNIDENT	53.3		9.9
ECHINODERMATA			
ASTEROIDEA			
ASTEROIDEA UNIDENT	160.0	30.4	54.4
PAXILLOSIDA DIPLOZONINA	26.7		4.9
OREASTER RETICULATUS	1013.3	243.1	386.0
ECHINASTER UNIDENT	80.0		14.8
ECHINOIDEA			
ECHINOIDEA UNIDENT	1013.3		188.1
HOLOTHUROIDEA			
HOLOTHUROIDEA UNIDENT	293.3		54.4
ASTICHOPUS MULTIFIDUS		66.8	54.4

Table 4.1-11b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 19, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	MEAN
SYNODONTIDAE			
SYNODONTIDAE UNIDENT	53.3		9.9
SYNGNATHIDAE			
HIPPOCAMPUS REIDI	26.7		4.9
PERCIFOMES			
PERCIFORMES UNIDENT	320.0		59.4
SERRANIDAE			
EPINEPHELUS MORIO	160.0		29.7
MYCTEROPERCA UNIDENT	26.7		4.9
DIPLECTRUM UNIDENT	666.7	66.8	178.2
LIOPROPOMA EUKRINES	26.7		4.9
SERRANUS SUBLIGARIUS	26.7		4.9
CARANGIDAE			
CARANX CRYSOS		42.5	34.6
SERIOLA DUMERILI	26.7		4.9
LUTJANIDAE			
LUTJANUS MAHOGONI	53.3		9.9
LUTJANUS SYNAGRIS	53.3		9.9
HAEMULIDAE			
HAEMULON UNIDENT	26.7		4.9
HAEMULON AUROLINEATUM	240.0		44.5
HAEMULON PLUMIERI	2613.3		485.0
SPARIDAE			
CALAMUS UNIDENT	266.7		49.5
CALAMUS CALAMUS		24.3	19.8
SCIAENIDAE			
EQUETUS LANCEOLATUS	293.3		54.4
CHAETODOTIDAE			
CHAETODON SEDENTARIUS	133.3		24.7
HOLACANTHUS UNIDENT	160.0		29.7
HOLACANTHUS BERMUDENSIS	53.3		9.9
POMACANTHUS UNIDENT	26.7		4.9
POMACANTHUS ARCUATUS	186.7		34.6
POMACENTRIDAE			
EUPOMACENTRUS VARIABILIS	26.7		4.9
LABRIDAE			
LABRIDAE UNIDENT	26.7		4.9
HALICHOERES CAUDALIS	213.3		39.6
BALISTIDAE			
BALISTIDAE UNIDENT	26.7		4.9
BALISTES CAPRISCUS	26.7		4.9
CANTHERHINES MACROCERUS		6.1	4.9
CANTHERHINES PULLUS	26.7		4.9
MONACANTHUS UNIDENT	53.3		9.9
MONACANTHUS HISPIDUS	26.7		4.9
OSTRACIONTIDAE			
LACTOPHRYS QUADRICORNIS	80.0		14.8

Cruise III were Diplectrum spp. ($67/km^2$); the blue runner, Caranx crysos ($43/km^2$); and the saucereye porgy, Calamus calamus ($24/km^2$).

Dredge--The triangular dredge collected no sponges, no scleractinian corals, and only three species of gorgonians at Station 19 (see Table F-5a). Nine bivalve species were collected, including cockles (Laevicardium laevigatum), scallops (Argopecten gibbus and Aequipecten acanthodes), and tellins (Tellina aequistriata). Six gastropods were taken by the dredge, including the fighting conch, Strombus pugilis, and the murex, Murex brevifrons.

Nine small brachyuran crabs were present, including the arrow crab, Stenorhynchus seticornis, which is often associated with sponges; and the box crab, Calappa sulcata. There were four anomurans, including two hermit crabs, Paguristes sericeus and P. moorei. Two stomatopods were also found, Gonodactylus bredeni and an unidentified member of the same genus, and a rock shrimp, Sicyonia laevigata, was also collected, along with one pistol shrimp, Synalpheus fritzmuelleri.

Echinoderms collected by the triangular dredge at Station 19 were typical of soft bottom, and included the sand dollar, Encope michelini; the spiny beaded sea star, Astropecten duplicatus; the brown spiny sea star, Echinaster spinulosus; and Astropecten comptus. Two ophiuroids were taken, the angular brittle star, Ophiothrix angulata, and Astrocyclus caecilia; and two holothuroids, the 3-rowed sea cucumber, Isostichopus badionotus, and Thyonella pervicax.

Plants were collected by the triangular dredge at Station 19 only during Cruise I (see Table F-5b). Seven species were present, including three green algae (Udotea cyatriformis, U. conglutinatta, and Caulerpa sertularoides); one brown alga (Dictyota bartayresii), two reds (Lithothamnium occidentale and Champia parvula), and the seagrass Halophila baillonis.

Trawl--Ten fishes were taken by trawling at Station 19 (Tables F-5c and F-14). Overall, the most abundant species were the fringed filefish (*Monacanthus ciliatus*) and the gray snapper (*Lutjanus syngris*). Both of these species were taken on Cruises I and III, along with the leopard toadfish (*Opsanus pardus*), the sand perch (*Diplectrum formosum*), and the white grunt (*Haemulon plumieri*).

Eighteen fishes representing seven species were captured during Cruise I in the trawl. The most common species were the fringed filefish and the gray snapper. On Cruise III, only 10 fishes (8 species) were taken by the trawl. Again, the most common species was the fringed filefish.

Station 52

Underwater Television--Station 52 was a low-relief, flat area dominated by patches of live-bottom communities, including sponges, algae, and gorgonians projecting through a carbonate sand veneer. Fishes commonly observed included the red grouper, *Epinephelus morio*; the white grunt, *Haemulon plumieri*; the blue runner, *Caranx crysos*; and the hogfish, *Lachnolaimus maximus*. On Cruise IV, algal abundance was extremely high, reaching 75 to 90 percent cover.

Individually counted organisms observed in underwater television transects on Cruises I, III, and IV at Station 52 included 15 invertebrate taxa and 13 species of fishes in the 22 479 m^2 surveyed. Although underwater television surveys were attempted on Cruise II, it was impossible to conduct them due to zero visibility.

Station 52 was the most diverse of the five shallow-water stations in terms of numbers of invertebrate taxa recognized (Table 4.1-12a). The most abundant individually counted invertebrates (averaged over the three cruises) were sponges and gorgonians. The sponge *Ircinia campana* was most common (4253/m^2), followed by the gorgonian *Pterogorgia guadalupensis* (1090/m^2); *Ircinia strobilina* (650/m^2); and

Table 4.1-12a Density (No./km^2) of Algae and Invertebrates Individually Counted in Underwater Television Transects at Station 52, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	CRUISE 4	MEAN
PHAEOPHYTA				
SARGASSUM UNIDENT	17.9			4.4
PORIFERA				
DEMOSPONGIAE UNIDENT		1413.6		582.8
IRCINIA CAMPANA	4576.5	3895.5	4450.3	4252.9
IRCINIA STROBILINA	1220.4	604.3	288.0	649.5
CNIDARIA				
HYDROIDA				
HYDROIDA UNIDENT		669.0		275.8
ALCYONARIA				
GORGONACEA UNIDENT		10.8		4.4
PLEXAURIDAE UNIDENT		10.8		4.4
LEPTOGORGIA UNIDENT	35.9			8.9
PSEUDOPTEROGORGIA UNIDENT	71.8	10.8	104.7	57.8
PTEROGORGIA GUADALUPENSIS	664.0		2722.5	1089.9
ZOANTHARIA				
ACTINIARIA UNIDENT	17.9	10.8		8.9
SOLENASTREA HYADES	17.9			4.4
ECHINODERMATA				
ASTEROIDEA				
ASTEROIDEA UNIDENT	35.9	161.9	26.2	84.5
ECHINOIDEA				
ECHINOIDEA UNIDENT		10.8		4.4
HOLOTHUROIDEA				
HOLOTHUROIDEA UNIDENT		54.0		22.2

unidentified demosponges ($583/m^2$). Other frequently recorded invertebrates included unidentified hydroids ($276/m^2$) and sea stars ($85/m^2$).

Sponges dominated the underwater television samples on all cruises at Station 52, and their densities were relatively constant. For example, densities of Ircinia campana were $3896/m^2$ (Cruise I); $3896/m^2$ (Cruise III); and $4577/m^2$ (Cruise IV). Nonetheless, there were many differences at Station 52 between cruises with respect to some of the less abundant counted sessile organisms. Brown algae, Sargassum spp., were seen only on Cruise I, and were sparse at that time ($18/km^2$). Unidentified hydroids ($669/m^2$) and holothuroids ($54/m^2$) were noted only on Cruise III. Unidentified asteroids were also most common ($162/m^2$) on Cruise III, though present at lower densities on Cruises I and IV. Gorgonians varied considerably in density, ranging from 0 to $11/m^2$ on Cruise III to $2723/m^2$ on Cruise IV.

The most frequently counted fishes (averaged over the three cruises) at Station 52 were the white grunt, Haemulon plumieri ($3764/m^2$); the hogfish, Lachnolaimus maximus ($280/m^2$); the blue runner, Caranx crysos ($258/m^2$); the pigfish, Orthopristis chrysoptera ($231/m^2$); and the red grouper, Epinephelus morio ($160/m^2$) (Table 4.1-12b). The white grunt, the red grouper, and the hogfish were seen on all three cruises, as were the scrawled cowfish (Lactophrys quadricornis), the jackknife-fish (Equetus lanceolatus), unidentified porgies (Calamus), and the porkfish (Anisotremus virginicus).

Dredge--Triangular dredge samples for Station 52 included many unidentified sponges (see Table F-6a). Few scleractinians were present, but many gorgonians were sampled. Thirteen species of gorgonians and three scleractinian corals (a golf ball coral, Favia gravida; the ahermatypic coral, Phyllangia americana; and the smooth starlet coral, Siderastrea siderea) were present.

Table 4.1-12b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 52, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	CRUISE 3	CRUISE 4	MEAN
FISHES				
CLUPEIDAE				
CLUPEIDAE UNIDENT			104.7	35.6
SYNODONTIDAE				
SYNODONTIDAE UNIDENT	17.9			4.4
SYNODUS UNIDENT	17.9	10.8		8.9
PERCIFOMES				
PERCIFORMES UNIDENT			13.1	4.4
SERRANIDAE				
SERRANIDAE UNIDENT			13.1	4.4
EPINEPHELUS MORIO	251.3	64.7	235.6	169.0
DIPLECTRUM UNIDENT	53.8			13.3
ECHENEIDAE				
ECHENEIS NAUCRATES	17.9			4.4
CARANGIDAE				
CARANX BARTHOLOMAEI			13.1	4.4
CARANX HIPPOS			52.4	17.8
CARANX CRYSOS	17.9		746.1	258.0
CARANX RUBER			222.5	75.6
LUTJANIDAE				
LUTJANIDAE UNIDENT			26.2	8.9
LUTJANUS SYNAGRIS			13.1	4.4
HAEMULIDAE				
HAEMULON AUROLINEATUM			13.1	4.4
HAEMULON PLUMIERI	5850.7	518.0	6178.0	3763.5
ORTHOPRISTIS CHRYSOPTERA		75.5	589.0	231.3
ANISOTREMUS VIRGINICUS	35.9	10.8	52.4	31.1
SPARIDAE				
ARCHOSARGUS PROBATOCEPHALUS		54.0	91.6	53.4
CALAMUS UNIDENT	35.9	64.7	104.7	71.2
SCIAENIDAE				
EQUETUS LANCEOLATUS	89.7	32.4	130.9	80.1
CHAETODOTIDAE				
POMACANTHUS UNIDENT			26.2	8.9
LABRIDAE				
LABRIDAE UNIDENT			26.2	8.9
HALICHOERES UNIDENT			13.1	4.4
LACHNOLAIMUS MAXIMUS	484.6	21.6	445.0	280.3
BALISTIDAE				
ALUTERUS SCHOEPFI			78.5	26.7
BALISTES CAPRISCUS			13.1	4.4
MONACANTHUS UNIDENT			13.1	4.4
OSTRACIONTIDAE				
LACTOPHRYS QUADRICORNIS	71.8	10.8	26.2	31.1
TETRAODONTIDAE				
TETRAODONTIDAE UNIDENT	17.9			4.4
SPHOEROIDES SPENGLERI			13.1	4.4

Nineteen species of bivalves were collected, including forms typically attached to hard substrate, such as the spiny oyster, *Spondylus americanus*; four species of jewel boxes, *Chama macerophylla*, *C. congregata*, *C. florida*, and *Chama* sp. 1; and two winged oysters, *Pteria colymbus* and an unidentified species of the same genus. Many gastropods were collected, including the queen conch, *Strombus gigas*; the Florida fighting conch, *Strombus alatus*; the banded tulip shell, *Fasciolaria lilium*; the horse conch, *Pleuroploca gigantea*; and two murexes, *Murex brevifrons* and *M. florifer*.

A large number of brachyuran and anomuran crabs were collected with the triangular dredge at Station 52, including the arrow crab, *Stenorhynchus seticornis*; two portunid swimming crabs, *Portunus gibbesi* and *P. floridanus*; several spider crabs, *Mithrax hispidus*, *M. pleuracanthus*, and *M. turceps*; and the lesser sponge crab, *Dromidia antillensis*. Two stomatopods of the genus *Gonodactylus* were also taken at Station 52. Several typically soft-bottom crustaceans were collected, including a penaeid prawn, the pink shrimp, *Penaeus duorarum*; and a rock shrimp, *Sicyonia laevigata*. Seven caridean shrimps were collected, including some species that are typically associated with sponges or anemones, e.g., *Periclimenaeus caraibicus* and *P. americanus*, as well as several pistol shrimps, *Synalpheus minus*, *S. townsendi*, and *S. longicarpus*.

Only three asteroids were collected at Station 52 in triangular dredges: the brown spiny sea star, *Echinaster spinulosus*; the spiny beaded sea star, *Astropecten duplicatus*; and *Echninaster modestus*, all typically soft-bottom animals. There were also three ophiuroids taken: *Ophiostigma isacanthum*; the angular brittle star, *Ophiothrix angulata*; and Savigny's ophiactis, *Ophiactis savignyi*. Echinoids were also typical of soft bottom, and included the flat sea biscuit, *Clypeaster subdepressus* and the inflated sea biscuit, *Clypeaster rosaceus*; the green sea urchin, *Lytechinus variegatus*; and the brown rock urchin, *Arbacia punctulata*.

Algae collected at Station 52 with the triangular dredge included 22 species taken on Cruises I and IV (see Table F-6b). Two species of green algae, Udotia flabellum and Caulerpa sertularoides; 3 brown algae, all species of Dictyopteris; and 17 species of red algae belonging to at least 6 genera were collected. Of these, all but four (Dictyopteris cf. membranacea, Spyridia filamentosa, Lawrencia sp., and an unidentified red algae) were seen only on Cruise IV. The latter two of the four species collected on Cruise I were not collected on Cruise IV.

Trawl--The most common species overall (in descending order of abundance) were the white grunt, Haemulon plumieri (67 individuals); the grass porgy, Calamus arctifrons (30 individuals, all taken on Cruise I); and the hogfish, Lachnolaimus maximus (17 individuals) (see Tables F-6c and F-14). Seventeen species were collected, belonging to 14 families. The hauls from Cruises II and III produced far more specimens than the haul from Cruise IV, which captured only five fish.

Time-Lapse Camera--In addition to the dredge, trawl, and underwater television data, Station 52 was equipped with a time-lapse camera that took a picture every hour. The time-lapse camera was originally installed for monitoring sediment transport, but it also proved useful in monitoring fish movements around the structures. The results of the time-lapse camera installation at Station 52 are presented in the following paragraphs.

Cruise I to Cruise II--Station 52, at a depth of 13 m, was the only array station during Year 4 that was not moved during servicing. For this reason, the artificial reef "effect" was a consistent progression beginning from installation during Cruise I in December 1983. The array was first installed during Cruise I on December 9, 1983, and was retrieved during Cruise II on March 2, 1984. The system functioned successfully for 48 days, 3 hours (1155 hourly samples) before malfunctioning on January 19, 1984. A summary of the periods of operation, data points collected, and relative visibility (or clarity) of the water for the time-lapse camera data are presented in Table 4.1-13.

The water during this period was generally quite turbid. Only 24.7 percent of the frames were scored 0 for turbidity (see Section 3.4.5 for scoring system). A total of 12.8 percent of the frames was taken in 75 percent relative visibility and 18.7 percent with 50 percent relative visibility, neither of which significantly affected results. The proportion of frames recorded under conditions of 25 percent relative visibility and zero relative visibility were substantial, 23.9 percent and 19.9 percent of the total number of frames, respectively. Three major turbidity "storms" resulted in decreased visibility (25 percent or less relative visibility) during the 48-day period. The first of these was on day 15, December 23, lasting 3 days until December 26. Another turbid period began on December 29 and lasted 4 days. During this period, the metal fouling plate target was detached from the array by some unknown means. It was later located on the bottom near the array by divers during servicing on Cruise II. A third major decrease in water visibility occurred on January 10, 1984, and lasted 3 days.

The biological community viewed by time-lapse camera was similar to that derived from information about the station obtained from underwater television transects, triangular dredges, and roller otter trawls. The major groups of attached epifauna included gorgonians, sponges, and algae. The gorgonians visible in the field of view at the beginning of the sampling period were present throughout the time-lapse film. Clumps of algae on the substrate were relatively dense, and their estimated abundance remained relatively constant throughout the 48-day sampling period.

The development of the fouling community was of particular interest during this period since the array had just been installed and all fouling organisms settling during this initial period would be original

Table 4.1-13. Station 52 Summary of Operation

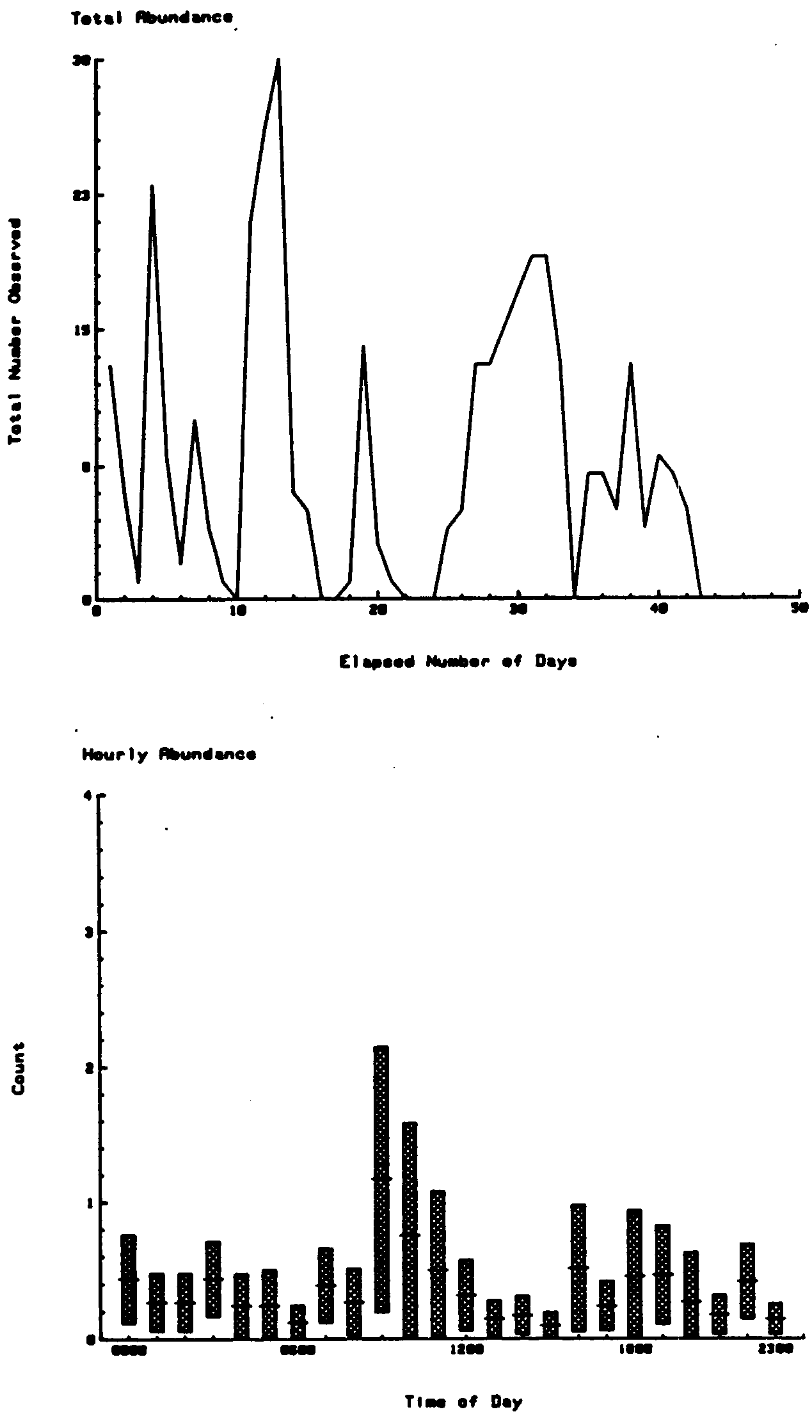
	Cruise			
	I-II	II-III	IV-V	
Start Time	0900 Dec. 9/83	1500 Mar. 2/84	1900 Aug. 16/84	
End Time	2000 Jan. 19/84	2100 Mar. 10/84	0900 Sept. 20/84	
Total Number of Frames	1155	198	831	
Total Number of Days/Hours	48 days, 3 hours	8 days, 6 hours	34 days, 15 hours	
Relative Visibility (%):				Total
100	24.7	15.9	100.0	53.1
75	12.8	40.9	0	10.8
50	18.7	16.3	0	11.2
25	23.9	15.9	0	13.8
0	19.9	11.1	0	11.2
	100.0	100.0	100.0	100.0
Biota Occlusion ≥50% of Frame	0.2	5.3	12.4	5.5

colonizers. Ceramic plates close to the time-lapse camera had no visible epifaunal growth during the first 25 days in situ. Just after the turbidity cleared on day 25, a thin mat of hydroids and algae was visible on the ceramic plates. The amount of fouling material remained approximately the same for the remainder of the period. The metal fouling plate target showed no fouling growth.

For all fishes observed, pronounced variability from one day to the next in sightings was the rule (see Figure 4.1-5). Most fishes were seen near the array in mid-morning, as illustrated in Figure 4.1-5. The dominant fish observed was the white grunt, Haemulon plumieri (Table 4.1-14). Although a trawl sample was not taken at Station 52 during Cruise I, the trawl collection obtained at nearby Station 51 was also dominated by H. plumieri during Cruise I. Out of seven fishes collected, six were white grunts. White grunts were also most abundant in the trawl sample from Cruise II at Station 52, although the trawl sample was more diverse. Out of 82 fish of 13 species, the most abundant was the white grunt (22 individuals).

A plot of the daily occurrence (Figure 4.1-6) shows two major peaks in abundance of white grunts during the 48-day recording period. The first of these began on the same day the array was first installed and extended for approximately 8 days. The other major group of observations began on day 25 and extended for 8 days to day 33, followed by a few less substantial peaks, ending on day 42. The mean count of white grunts by hour of day (Figure 4.1-6) was relatively evenly spread throughout all 24 hours. The maximum value was recorded for 1600 hours, but the minimum value (zero observations) was at 1500 hours, only 1 hour earlier.

The second most abundant category included various unidentified species represented by small fishes which usually appeared in relatively large groups (10 to 20 individuals within a single frame). These were classified as unidentified Perciformes for analysis (Figure 4.1-7).



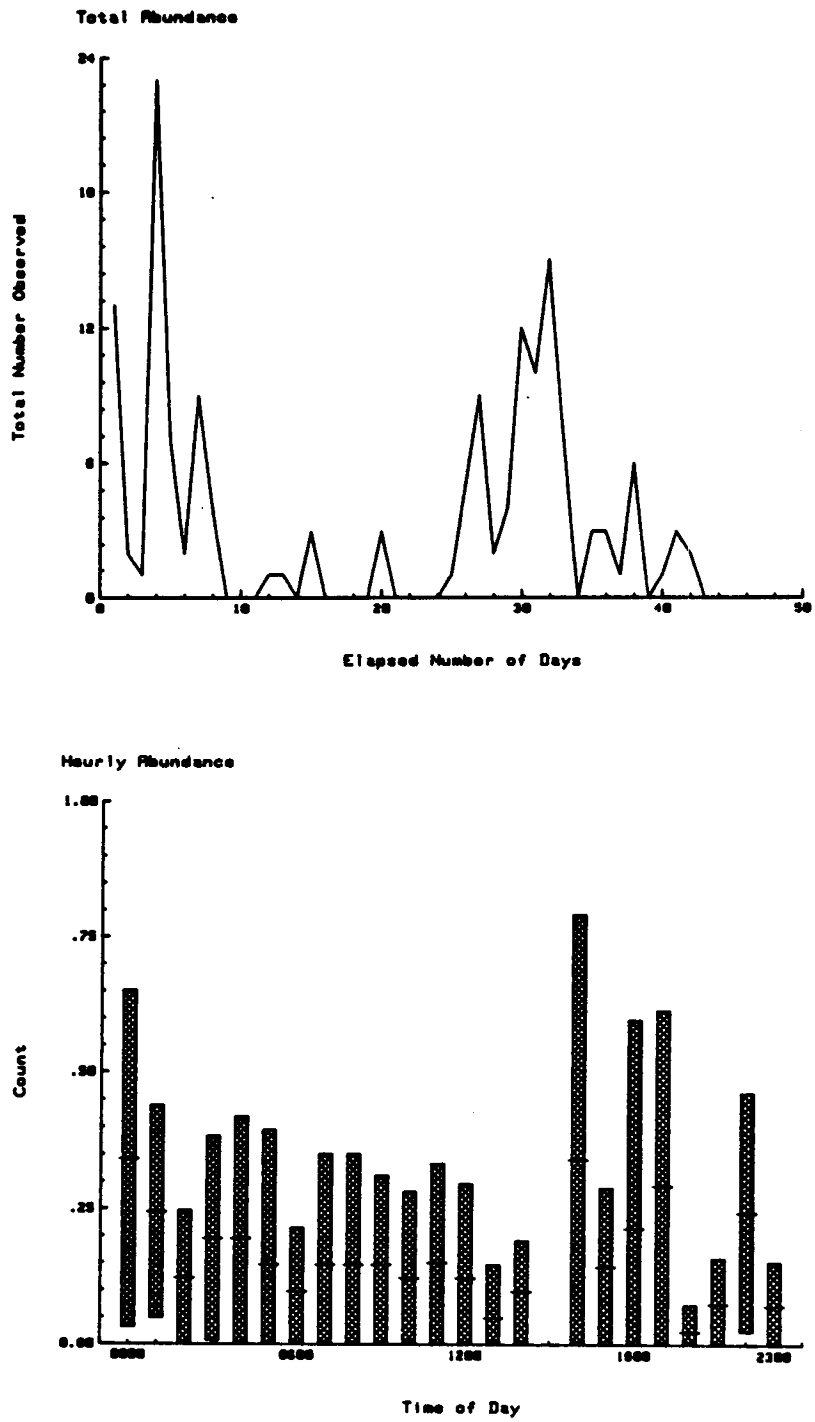
NOTE: VALUES PLOTTED AS MEAN ± TWO STANDARD ERRORS ABOUT THE MEAN.

Figure 4.1-5 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING DECEMBER 1983 — ALL FISHES

Table 4.1-14 Total Number of Fishes and Turtles (*) Observed from Time-Lapse Camera at Station 53, by Cruise

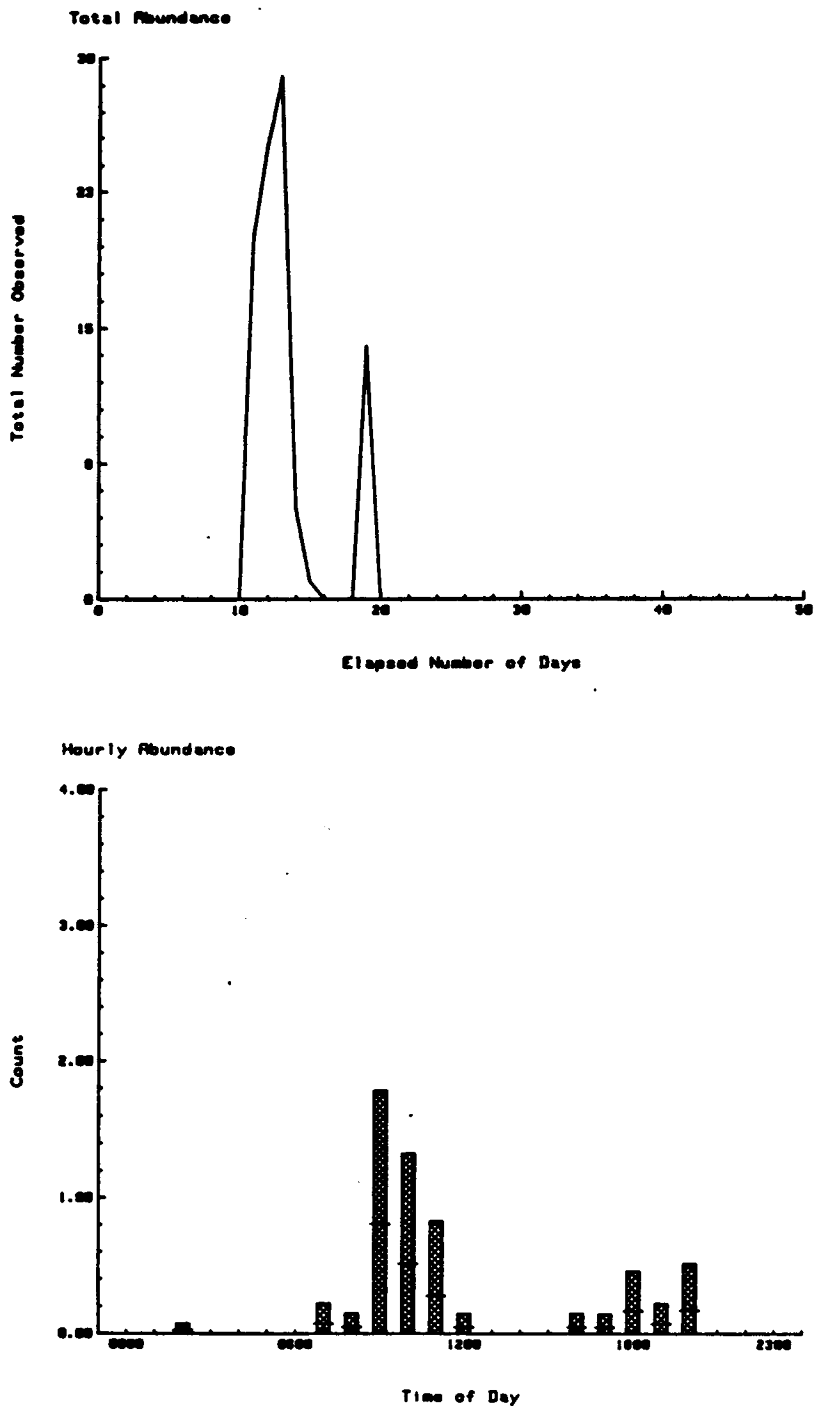
STATION 52

	CRUISE			
	1-2	2-3	4-5	TOTAL
PERCIFORMES UNIDENT	94	0	1400	1494
LUTJANUS GRISEUS	16	164	495	675
HAEMULON PLUMIERI	153	1	3	157
EPINEPHELUS ITAJARA	0	1	114	115
ANISOTREMUS VIRGINICUS	26	3	57	86
EPINEPHELUS MORIO	8	9	19	36
ARCHOSARGUS PROBATOCEPHALUS	19	1	5	25
CHAETODIPTERUS FABER	2	11	0	13
CARETTA CARETTA *	2	1	6	9
CHAETODON OCELLATUS	0	0	6	6
SPARIDAE UNIDENT	4	0	0	4
MYCTEROPERCA UNIDENT	4	0	0	4
LABRIDAE UNIDENT	4	0	0	4
EQUETUS LANCEOLATUS	2	2	0	4
SCORPAENA UNIDENT	3	0	0	3
RYPTICUS MACULATUS	2	1	0	3
HAEMULIDAE UNIDENT	2	0	0	2
LACHNOLAIMUS MAXIMUS	0	0	2	2
LUTJANUS SYNAGRIS	2	0	0	2
LUTJANUS ANALIS	0	1	0	1
LUTJANIDAE UNIDENT	1	0	0	1
APOGONIDAE UNIDENT	1	0	0	1
POMACANTHUS ARCUATUS	1	0	0	1
LAGODON RHOMBOIDES	0	1	0	1
HAEMULON AUROLINEATUM	1	0	0	1
BOTHIDAE UNIDENT	0	1	0	1
MONACANTHUS HISPIDUS	1	0	0	1
CHELONIIDAE UNIDENT	0	1	0	1
ARCHOSARGUS RHOMBOIDALIS	1	0	0	1
NUMBER OF OBSERVATIONS	349	198	2107	2654
NUMBER OF FRAMES	1155	198	831	2184



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

Figure 4.1-6 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING DECEMBER 1983 — HAEMULON PLUMIERI



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

Figure 4.1-7 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING DECEMBER 1983 — PERCIFORMES

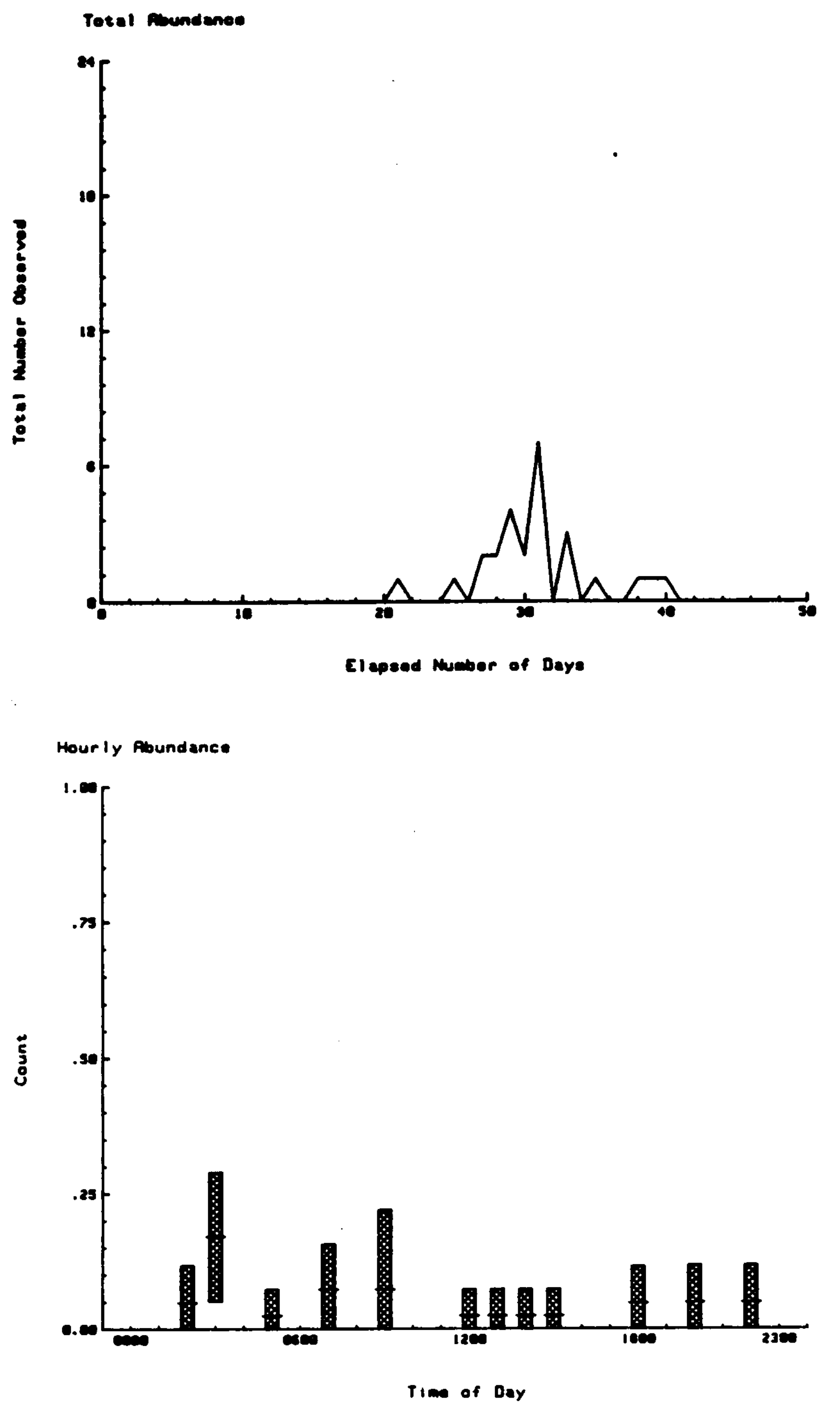
They appeared within a very narrow time window, between day 11 and day 19, and were observed mainly between 0700 and 1200 hours and 1600 and 2000 hours.

The majority of these individuals were believed to be juveniles, probably of Anisotremus virginicus, the porkfish. In fact, a number of small fish were positively identified as porkfish. This species was the third most abundant (26 observations); many had distinctive juvenile coloration patterns. Abundance of observations by day and mean counts by hour for this taxon are shown in Figure 4.1-8.

Note that the confidence interval bars shown on all figures that portray diurnal sighting patterns indicate no statistically significant differences, in most cases. However, the height of the bars and the location of the mean value for each time can be interpreted as the indication of activity patterns around the array. High variability about a high mean suggests that schooling fish are usually present and that the camera either captured images of part or all of a school, or missed most or all of it. These data are still under analysis and are expected to yield some revealing information about diurnal activity patterns.

Other species frequently observed included the sheepshead, Archosargus probatocephalus, with 19 observations; the gray snapper, Lutjanus griseus, 16 observations between days 28 and 42; and the red grouper, Epinephelus morio, with 8 observations. Sixteen other less common fish species were also recorded (see Table 4.1-14). Of special note here is that the jewfish, Epinephelus itajara, a common resident later, did not appear in any of the 1155 frames of this period.

Cruise II to Cruise III--After reinstallation of the system on March 2, 1984, during Cruise II, the system failed on March 10, the ninth day of operation. Only 198 frames were exposed before the system was retrieved on May 12 on Cruise III. The reason for the system's failure was damage



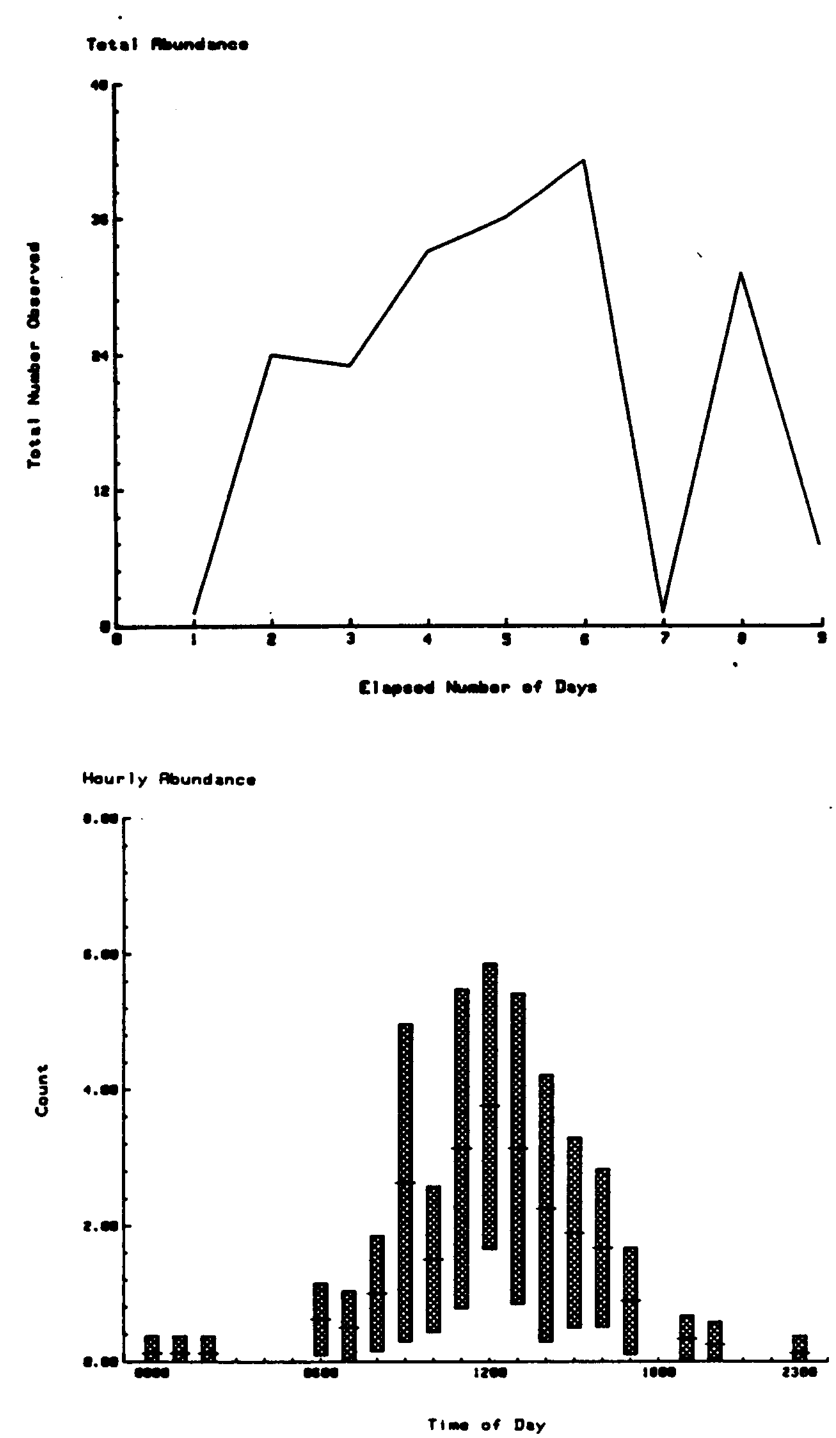
NOTE: VALUES PLOTTED AS MEAN ± TWO STANDARD ERRORS ABOUT THE MEAN.

Figure 4.1-8 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING DECEMBER 1983 - *ANISOTREMUS VIRGINICUS*

by large marine life. Sixteen hours before the system failed, a large loggerhead turtle, Caretta caretta, was photographed inside the array framework. The diameter of the turtle's neck was approximately 13 cm, and the shell length was 75 to 90 cm, estimated by comparing the turtle's dimensions to adjacent objects of known size. A turtle (possibly a second individual) was again photographed 11 hours prior to equipment failure. Five hours (five frames) prior to failure, the metal fouling plate target shifted significantly in position, probably due to impact from a turtle. After recovery of the time-lapse equipment, severe damage to an electrical cable was found on the camera housing.

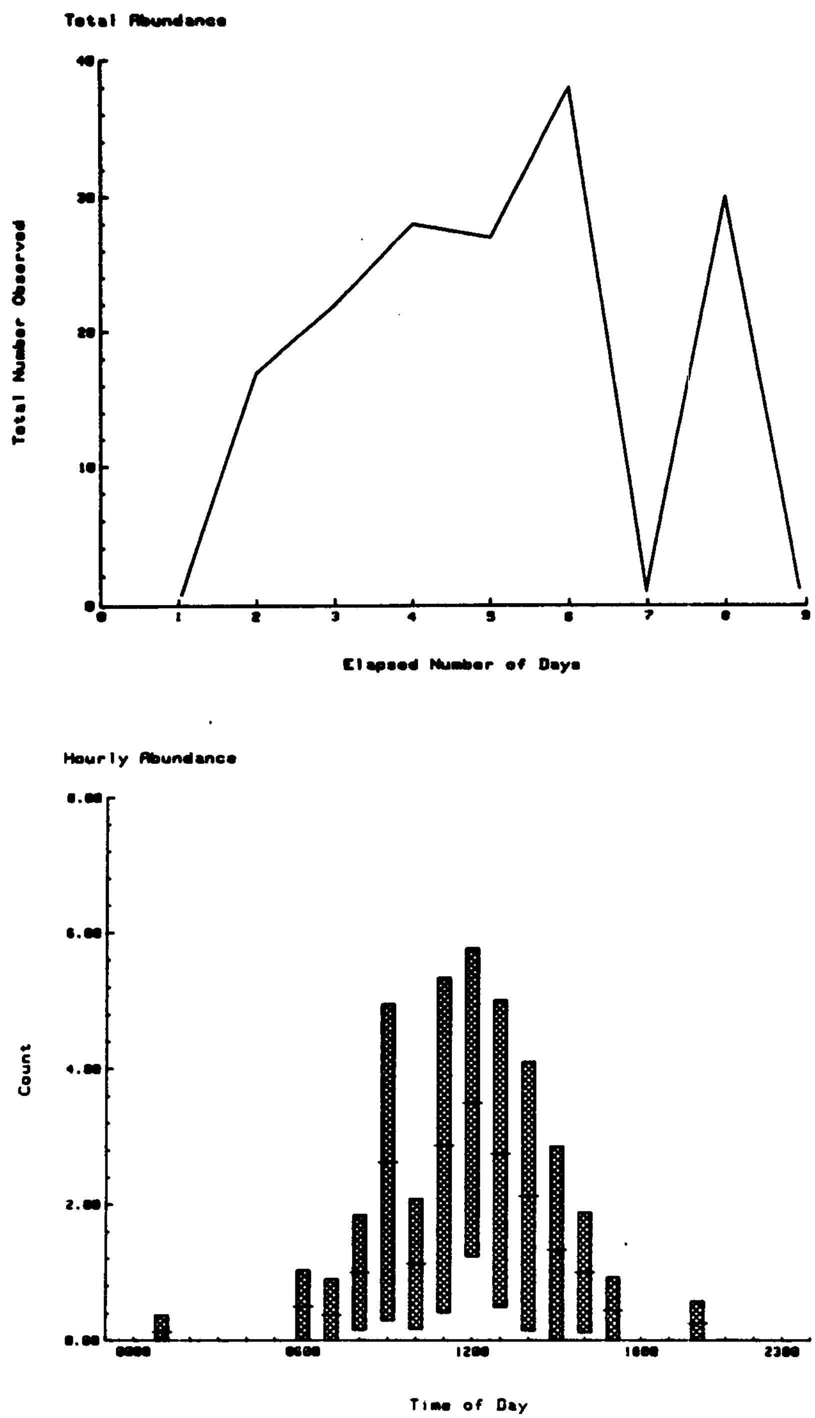
Although this data set was quite limited, some trends were evident. Overall abundance rose immediately after reinstallation (see Figure 4.1-9), and there were significantly more fish sighted during mid-day than during the night. This diurnal difference reflects activity patterns of the most abundant species recorded, the gray snapper. A dramatic shift in fish species composition from one time period to the next was thus recorded. During the period between Cruise I and Cruise II, white grunts had been most abundant, and gray snapper were much less common. During the second sampling period, 164 observations were recorded for gray snapper (see Table 4.1-14). These numbers resulted primarily from repetitive frames of groups of fish, with some individuals being counted more than once. Although this repetition of observation restricts the type of statistical analyses possible, it does not preclude describing the typical suite of species that one would encounter at the site.

Figure 4.1-10 illustrates both the observations of gray snappers by successive elapsed days and mean count by hour of day. Gray snappers were first recorded on day 1, and exhibited a pronounced peak of occurrence around noon. Most observations were made between 0600 and 1700 hours. Of particular note is that only a single observation of the white grunt, the dominant species during the previous period, was made throughout this sampling period. As more data become available, the



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

Figure 4.1-9 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING MARCH 1984 — ALL FISHES



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

Figure 4.1-10 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING MARCH 1984 — LUTJANUS GRISEUS

physical parameters collected at the station will be examined to explain these changes in fish patterns.

Only two other fishes were well represented: the red grouper, *Epinephelus morio*, and the Atlantic spadefish, *Chaetodipterus faber*. Spadefish appeared on the first day and were last observed on day 6. Observations of spadefish were restricted to the afternoon, between 1200 and 1700 hours.

Eleven other less common fish were observed. One species was *Epinephelus itajara*, the jewfish, seen in only a single frame during day 4 of this period. This was the first photographic record of this species inside the array at this station. There were no observations of small or juvenile fish (unidentified Perciformes in the previous data set).

One significant turbidity period during the 9 days diminished water clarity enough to impair counts. This turbid period began on day 6, March 7, reducing relative visibility range from 25 percent to zero during the day and continuing until the end of day 8, March 9. The remainder of the frames (73.1 percent of the total) was not significantly affected by water turbidity and had turbidity scored as 0-2 (relative visibility of 50 percent or greater). Occlusion by biota (score = 5) during the sampling period occurred in only 5.3 percent of the total 198 frames. Most of these blocking situations were due to groups of gray snappers.

Fouling organisms on ceramic plates in view of the time-lapse camera were substantially more developed than those observed between Cruises I and II. The fouling community appeared to be dominated by hydroids which were approximately 6 to 7 mm long. Although one side of the two metal fouling plate-targets was scraped clean during the initial

Cruise II array servicing, the two metal plates looked very similar to each other during the 8 days of records. There was no apparent growth on any of the fouling surfaces during the short data period.

One dramatic change in general habitat characteristics was the complete disappearance of filamentous and foliose clumps of algae, which were prevalent in the previous time-lapse movie. Similarly, no algae were collected by any of the three triangular dredge hauls during Cruise II, unlike the hauls of Cruise I.

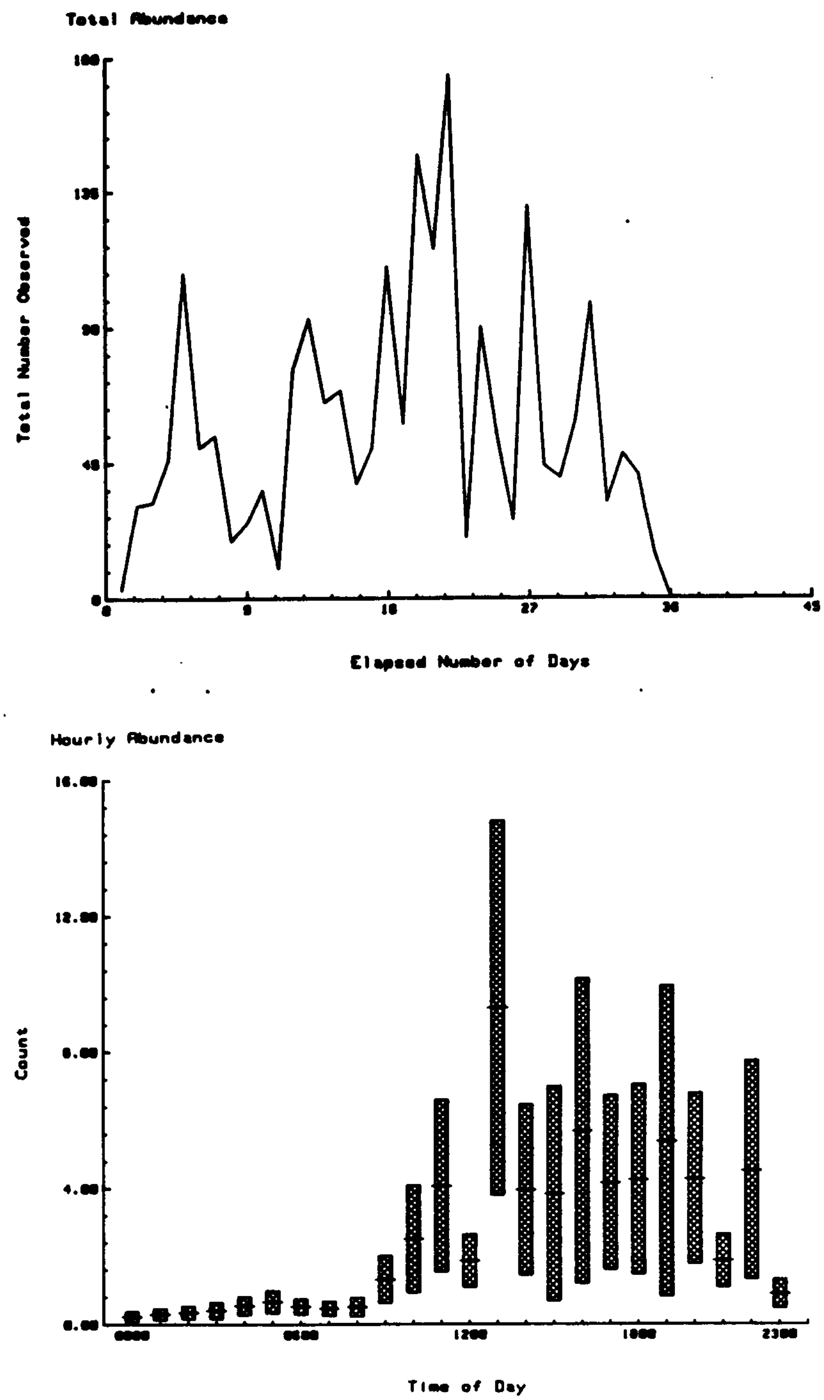
Cruise III to Cruise IV--Photographic data from this period were lost due to a processing error at Kodak.

Cruise IV to Cruise V--The system was reinstalled during Cruise IV on August 16, 1984, and collected during Cruise V on December 6, 1984. The camera recorded 831 data frames or 34 days, 15 hours, before failing due to a water leak on September 20. Although the photographic film was water-damaged, causing some color loss, it was still usable for evaluation.

Illustrations of observations by elapsed day and hour for all 10 taxa seen during this sampling period are shown in Figure 4.1-11. Total abundance for all species together was highly variable. Most observations were clustered between mid-morning and 2300 hours, with few observations between midnight and 0900 hours. The hours with highest apparent abundance also showed high variability from one night to the next, suggesting periods of schooling activity adjacent to the array.

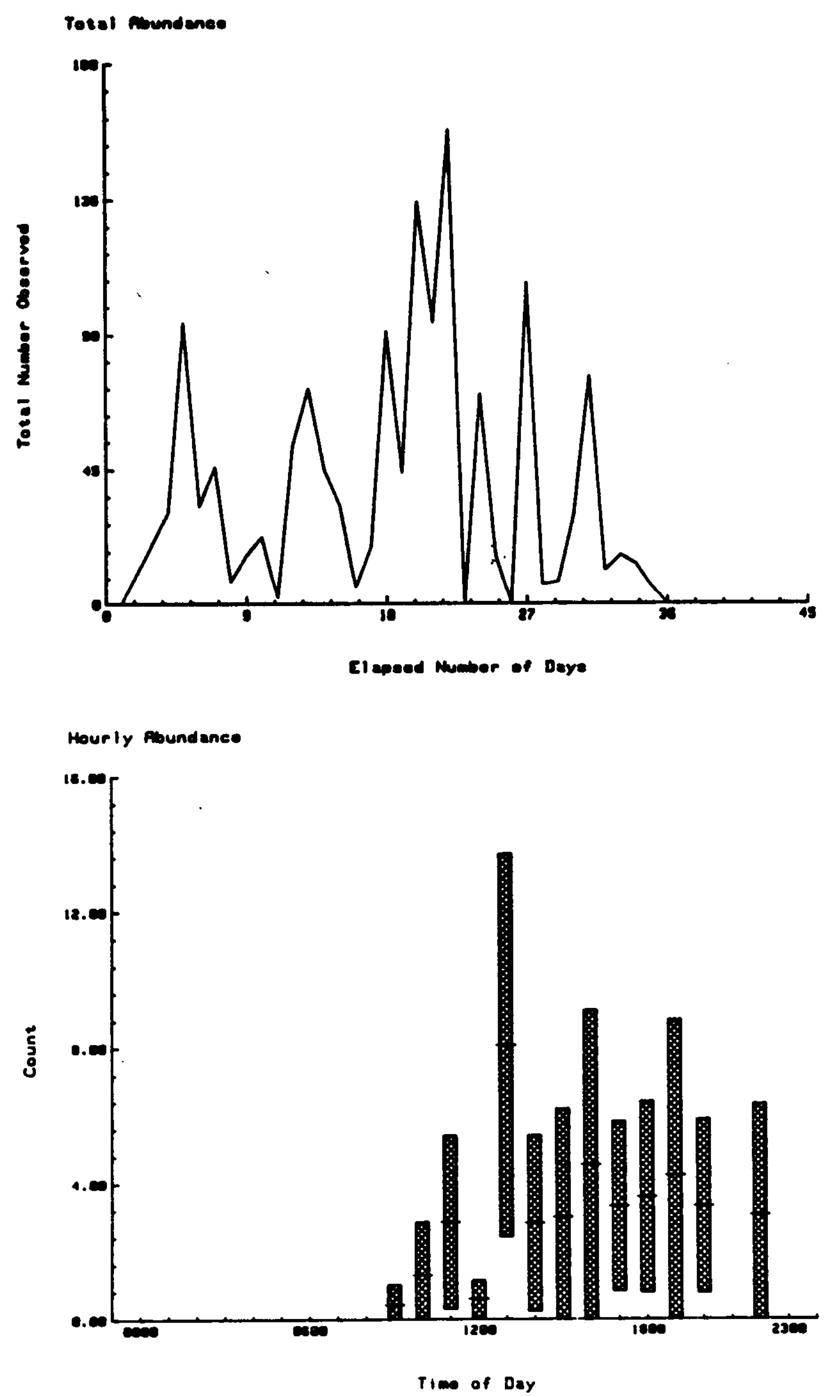
During this sampling period, small fish not identifiable to a lower taxon than order Perciformes were numerically dominant (1400 observations, Figure 4.1-12). No juveniles were noted, and it was unclear if these observations were indeed young of a commonly represented demersal fish or perhaps some small nondemersal species.

The second most abundant fish was the gray snapper, with a total of 495 observations recorded (Figure 4.1-13). Gray snappers were most



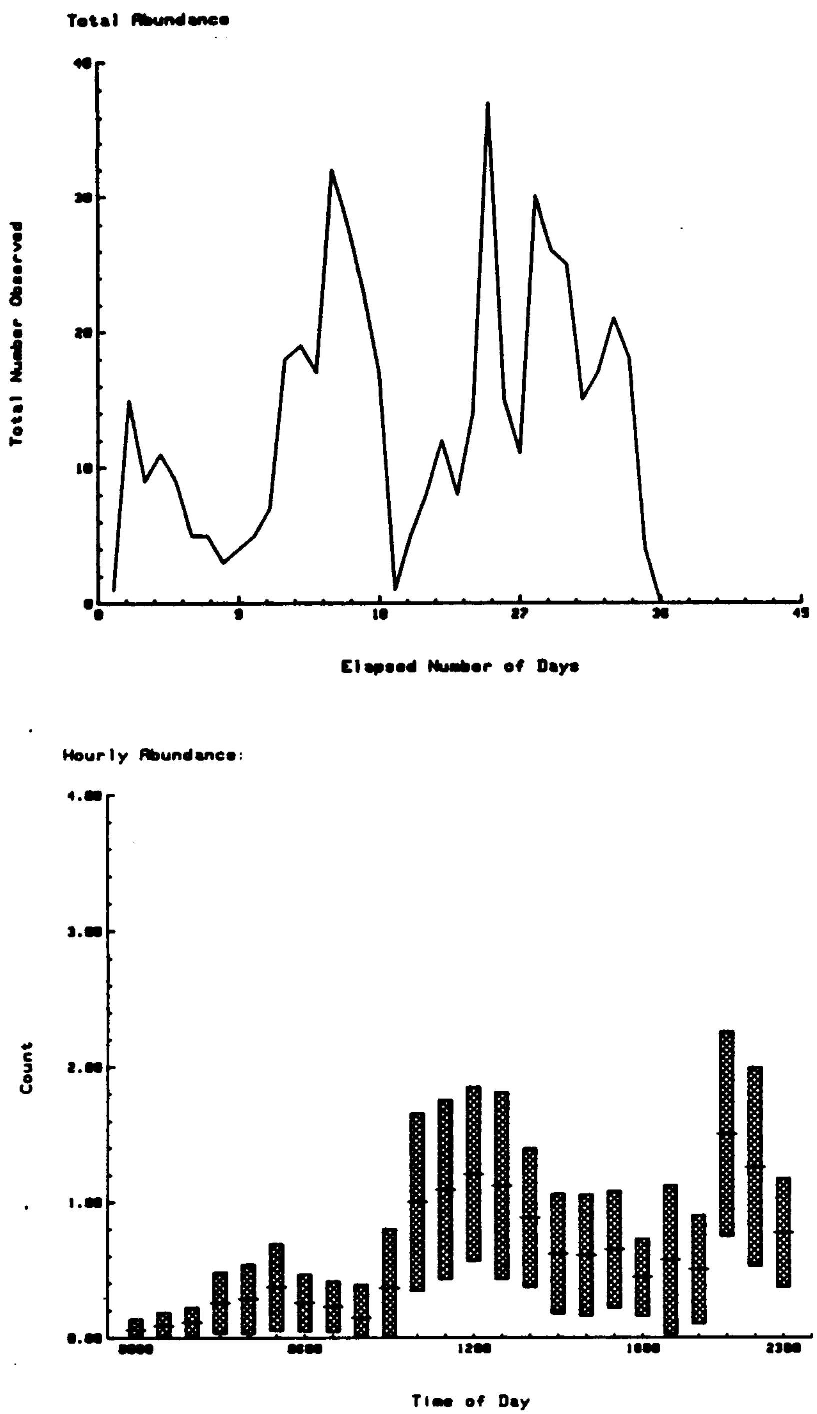
NOTE: VALUES PLOTTED AS MEAN ± TWO STANDARD ERRORS ABOUT THE MEAN.

Figure 4.1-11 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING AUGUST 1984 — ALL FISHES



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

Figure 4.1-12 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING AUGUST 1984 — PERCIFORMES



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

Figure 4.1-13 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 52, BEGINNING AUGUST 1984 — LUTJANUS GRISEUS

often seen near the array between 1000 and 2300 hours. Only three observations of white grunt were obtained.

The third ranking fish was the jewfish, with 114 recorded observations. This figure is potentially misleading because of the behavior of this species, and perhaps more than for most other species does not reflect independent samples. The number of occlusions due to biota for this period was 12.4 percent of the total 831 frames; jewfish were responsible for three-fourths of these events. In some cases, a single individual (apparently) remained directly in front of the camera continuously for up to 13 hours. At least three separate jewfish were reported by divers. As described in Section 4.5, efforts have been made to exclude these large fish from entering the array in the future.

Other numerically abundant fishes included the porkfish, with 57 observations, all between 0900 and 2200 hours, and the red grouper (19 recorded observations).

The fifth most commonly observed species was the loggerhead turtle (*Caretta caretta*) (six observations). Identifiable portions of a loggerhead turtle were recorded on widely spaced occasions on days 8, 9, 15, and 27. These interrupted observations suggest that at least one sea turtle was attracted to the array on an intermittent basis. It seems unlikely that a resident turtle would not be photographed during a period spanning 12 days (between days 15 and 27). Of course, the different observations may indeed represent different animals. Considering the relatively low overall density of loggerhead turtles believed to occupy the nearest southwest Florida shelf between August and December (approximately one per 10 to 16 km^2) (Fritts *et al*., 1983), it seems more likely that a single turtle discovered the array, left the area, and repeatedly returned to the array over an extended period of time. This type of behavior by a single identifiable loggerhead turtle was observed during a multi-year study on the Flower Garden Banks in the northern Gulf of Mexico (Boland *et al*., 1983).

Water turbidity did not interfere with observations during this period. All 831 frames were scored 0 for turbidity, i.e., 100 percent relative visibility.

The fouling community visible on ceramic plates during this period showed no major growth periods throughout the 35-day photographic record. The cleaned side of the paired metal fouling plate targets, however, did develop bushy, hydroid-type growth which became visible during day 20 when the targets were shifted to one side. The relocated targets were out of the camera's field of view and very close to the array structure where more direct settling of epifauna might have been facilitated by already well-developed growth on the array. When the targets were shifted a second time back to a nearly normal position, after several days of displacement, the previously cleaned target plate had developed considerable growth, probably hydroids or branching bryozoans.

Station 21

Underwater Television--Station 21 consisted mainly of coarse, carbonate sand. Patches of sponges and algae were relatively uncommon. The sand bottom was fairly bare until Cruise IV, during which dense, bushy algal patches were present, and the open sand bottom in other areas supported large numbers of nonfoliose algae (*Caulerpa* spp.). The topography was flat, and ripple marks and evidence of bioturbation could be seen in the sand. Fishes were generally relatively scarce through Cruise III, but more abundant on Cruise IV. Dominant species included the hovering goby, *Ioglossus* sp., and the yellowtail reeffish, *Chromis enchrysurus*. Porgies (Sparidae), wrasses (Labridae), and groupers (Serranidae) were not uncommon. Fishes were often associated with large sponges.

Individually counted organisms observed in underwater television transects on Cruises II, III, and IV at Station 21 included 8 invertebrate taxa and 25 species of fishes in the 30 195 m^2 surveyed. Compared to shallower stations, far fewer kinds of invertebrates could be distinguished. Of the eight individually counted invertebrates at Station 21 (averaged over the three cruises), four were sponges (Table 4.1-15a). The two species which could be identified, *Ircinia campana* and *I. strobilina*, had densities of 696/km^2 and 623/km^2, respectively. Unidentified demosponges had a density of 560/km^2. Unidentified hydroids and holothuroids were also somewhat common (80/km^2 and 23/km^2, respectively).

There were some major differences in the underwater television data for the individually counted invertebrates between cruises, although the areas surveyed remained dominated by sponges. The sponges which could be identified were relatively constant in density; e.g., *Ircinia campana* varied in density from 357/km^2 (Cruise II) to 1463/km^2 (Cruise III). During Cruise II, unidentified sponges (4122/km^2); sand dollars (family Mellitidae) (98/km^2); hydroids (73/km^2); and holothuroids (49/km^2) were recorded. On Cruise III, hydroids were still abundant (117/km^2), but the unidentified sponges, sand dollars, and holothuroids were not observed. On Cruise IV, unidentified holothuroids were once again present (49/km^2).

The most frequently counted fishes in underwater television transects at Station 21 (averaged over the three cruises) were the yellowtail reeffish, *Chromis enchrysurus* (513/km^2); the blue goby, *Ioglossus calliurus* (134/km^2); the red grouper, *Epinephelus morio* (76/km^2); the blue runner, *Caranx crysos* (50/km^2); unidentified *Chromis* spp. (43/km^2); and the reef butterfly fish, *Chaetodon sendentarius* (40/km^2) (Table 4.1-15b).

Cruise II seemed particularly poor for fish observations compared to Cruises III and IV. Only five species were recorded by underwater television on Cruise II, the most abundant of which was *Chaetodon sedentarius* (49/km^2), the only species seen on all three cruises. On Cruise III, 10 species were observed. The most abundant species were *Caranx crysos* (84/km^2), an unidentified *Chromis* (73/km^2), and

Table 4.1-15a Density (No./km^2) of Invertebrates Individually Counted in Underwater Television Transects at Station 21, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 2	CRUISE 3	CRUISE 4	MEAN
PORIFERA				
DEMOSPONGIAE UNIDENT	4122.0			559.7
IRCINIA CAMPANA	1463.4	357.4	1050.4	695.5
IRCINIA STROBILINA	463.4	524.9	916.1	622.6
IRCINIA FELIX			12.2	3.3
CNIDARIA				
HYDROIDA				
HYDROIDA UNIDENT	73.2	117.3		79.5
ALCYONARIA				
ELLISELLA UNIDENT	24.4			3.3
ECHINODERMATA				
ECHINOIDEA				
MELLITIDAE UNIDENT	97.6			13.2
HOLOTHUROIDEA				
HOLOTHUROIDEA UNIDENT	48.8	5.6	48.9	23.2

Table 4.1-15b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 21, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 2	3	4	MEAN
SYNODONTIDAE				
SYNODUS INTERMEDIUS	24.4		12.2	6.6
HOLOCENTRIDAE				
HOLOCENTRIDAE UNIDENT			12.2	3.3
SERRANIDAE				
SERRANIDAE UNIDENT			12.2	3.3
EPINEPHELUS MORIO		39.1	195.4	76.2
DIPLECTRUM UNIDENT	24.4	5.6		6.6
SERRANUS PHOEBE			48.9	13.2
PRIACANTHIDAE				
PRIACANTHUS UNIDENT			24.4	6.6
PRIACANTHUS ARENATUS		5.6		3.3
PRISTIGENYS ALTA			24.4	6.6
CARANGIDAE				
CARANX CRYSOS		83.8		49.7
SERIOLA DUMERILI			122.1	33.1
LUTJANIDAE				
LUTJANIDAE UNIDENT		5.6		3.3
SPARIDAE				
CALAMUS UNIDENT			109.9	29.8
CALAMUS CALAMUS		22.3		13.2
CHAETODOTIDAE				
CHAETODONTIDAE UNIDENT			12.2	3.3
CHAETODON SEDENTARIUS	48.8	16.8	85.5	39.7
HOLACANTHUS UNIDENT	24.4			3.3
HOLACANTHUS BERMUDENSIS			97.7	26.5
POMACANTHUS ARCUATUS		27.9		16.6
POMACENTRIDAE				
POMACENTRIDAE UNIDENT			24.4	6.6
CHROMIS UNIDENT		72.6		43.1
CHROMIS ENCHRYSURUS		39.1	1807.7	513.3
LABRIDAE				
LABRIDAE UNIDENT			134.4	36.4
GOBIIDAE				
IOGLOSSUS CALLIURUS			488.6	132.5
OSTRACIONTIDAE				
LACTOPHRYS QUADRICORNIS	24.4			3.3

Epinephelus morio ($39/km^2$). On Cruise IV, 16 species were observed, the most abundant of which were *Chromis enchrysurus* ($1808/km^2$); *Ioglossus calliurus* ($489/km^2$); *Epinephelus morio* ($195/km^2$); and the greater amberjack, *Seriola dumerili* ($122/km^2$).

Dredge--Triangular dredge samples from Station 21 were dominated by many unidentified sponges (see Table F-7a). Six species of scleractinian corals were collected, including the smooth starlet coral, *Siderastrea siderea*; two bush corals, *Oculina tenella* and *O. varicosa*; the large flower coral, *Mussa angulosa*; the blushing starlet coral, *Stephanocoenia michelini*; and a solitary disc coral of the genus *Scolymia*. No gorgonians were collected at Station 21.

Several attached bivalves were taken by the triangular dredge, includng the spiny oyster, *Spondylus americanus*; the leafy jewel box, *Chama macerophylla*; and an undentified jingle, genus *Pododesmus*. Twelve gastropods were collected at Station 21, including the milk conch, *Strombus costatus*; the Scotch bonnet, *Phalium granulatum*; the cowrie, *Cypraea zebra*; and the murex, *Murex florifer*.

Sixteen species of brachyuran crabs were found in triangular dredge samples, including two box crabs, *Calappa sulcata* and *C. flammea*; two spider crabs, *Mithrax pleuracanthus* and *M. acuticornis*; the arrow crab, *Stenorhynchus seticornis*; two portunid swimming crabs, *Portunus ordwavi* and *P. spinicarpus*; and the lesser sponge crab, *Dromidia antillensis*. Two stomatopods were collected at Station 21, *Gonodactylus bredeni* and *Eurysquilla plumata*. Two anomuran hermit crabs were collected, *Paguristes sericeus* and *Pagurus defensus*, as well as three pistol shrimps, *Synalpheus minus*, *S. townsendie*, and *Alpheus normanni*. Several galatheids, *Galathea rostrata* and *Munida pusilla*, and two penaeids were taken, the rock shrimp *Sicyonia brevirostris* and *Parapenaeus politus*. In addition, samples included a stenopodid prawn, *Stenopus scutellatus*, and a slipper lobster, *Scyllarides nodifer*.

Four species of sea stars usually associated with soft bottoms were collected with the triangle dredge: Oreaster reticulatus, the reticulated sea star; the limp sea star, Luidia alternata; the spiny beaded sea star, Astropecten duplicatus; and A. nitidus. Three ophiuroids were found in samples from Station 21, including the striped brittle star, Ophiothrix lineata; the angular brittle star, O. angulata; and the short-spined brittle star, Ophioderma brevispinum. Six species of soft-bottom or grass-bed echinoids were taken at Station 21: the flat sea biscuit, Clypeaster subdepressus; the green sea urchin, Lytechinus variegatus; the inflated sea biscuit, C. rosaceus; the brown rock urchin, Arbacea punctulata; the pencil urchin, Eucidaris tribuloides; and the sea pussy, Meoma ventricosa. Two holothuroids were also collected with the triangular dredge: the 3-rowed sea cucumber, Isostichopus badionotus, and an unidentified holothuroid.

Algae were recorded in triangular dredge hauls from Station 21 during Cruises II, III, and IV (see Table F-7b). Only one species, the red alga Gracilaria mammilaris, was reported for Cruise II. Another, the brown alga Sargassum cf. hystrix, was collected on Cruise III. Sixteen different species (mainly browns and reds) were collected on Cruise IV.

Trawl--The most abundant fishes at Station 21 were the spotfin and reef butterfly fishes, Chaetodon ocellatus (12 individuals) and C. sedentarius (11 individuals); and the tattler grouper, Serranus phoebe (10 individuals) (see Tables F-7c and F-14). More fishes were collected on Cruise II (68 specimens) than on Cruise III (13 specimens) or Cruise IV (19 specimens). The best represented family from the standpoint of number of species present was the Scorpaenidae (3 species), among 20 families and 32 species total.

Time-Lapse Camera--A time-lapse camera was also installed at Station 21. The initial instrument array was lost, and the data from the first two time periods were not retrieved. A new array was installed at Station 21 on May 28, 1984, during Cruise III. The time-lapse camera in this array took 1801 hourly observations with the record ending on August 10, 1984. Twenty-six taxa were observed during the 75-day, 1-hour data record as listed in Table 4.1-16. Few fishes were seen until day 73, when a large number of small fishes were recorded. These fishes consisted of approximately 1400 small individuals, which could only be identified to the order Perciformes. The daily and hourly distribution of fish counts are presented in Figure 4.1-14. These values are dominated by the Perciformes observed on day 75.

Groupers were three of the top six numerically dominant fishes. These included jewfish [many of which are repeated observations of the same individual(s) (123 data records)], various species of Mycteroperca (43 observations), and the red hind, Epinephelus guttatus (26 observations). As at Station 52, jewfish frequently blocked the camera's field of view.

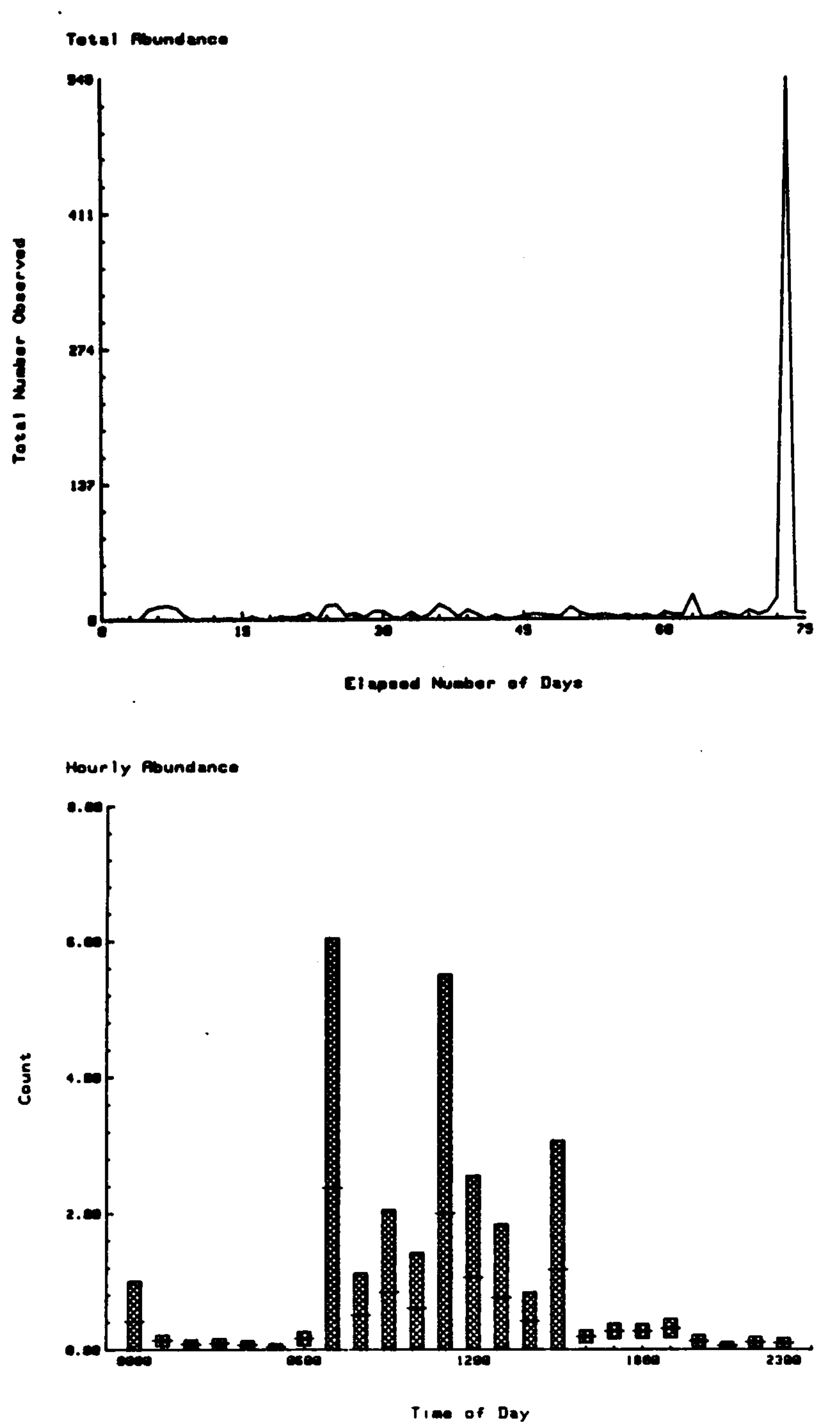
In contrast to Station 52, a jewfish was first observed at Station 21 after only 5 days. Based on similarities in size and color patterns, it is believed that a single individual was responsible for all 123 jewfish observations. Sixty frames were occluded by 50 percent or more by portions of the jewfish.

An interesting pattern developed when jewfish observations were plotted by elapsed number of days since installation as shown in Figure 4.1-15. The daily number observed, where all observations are most likely due to a single individual, also depicts the residence time of the fish within the summed 24 hours of each individual day. Most sightings occurred during daylight hours, from 0600 to 1900 hours. Five distinctive and separate major peaks in number of observations were apparent. The first peak reached the maximum number of observations obtained for this species during any specific 24-hour period. This spike continued for 5 successive days, the longest continuous duration of any jewfish observation.

Table 4.1-16 Fishes Observed with Time-Lapse Camera at Station 21 for Cruises III and IV

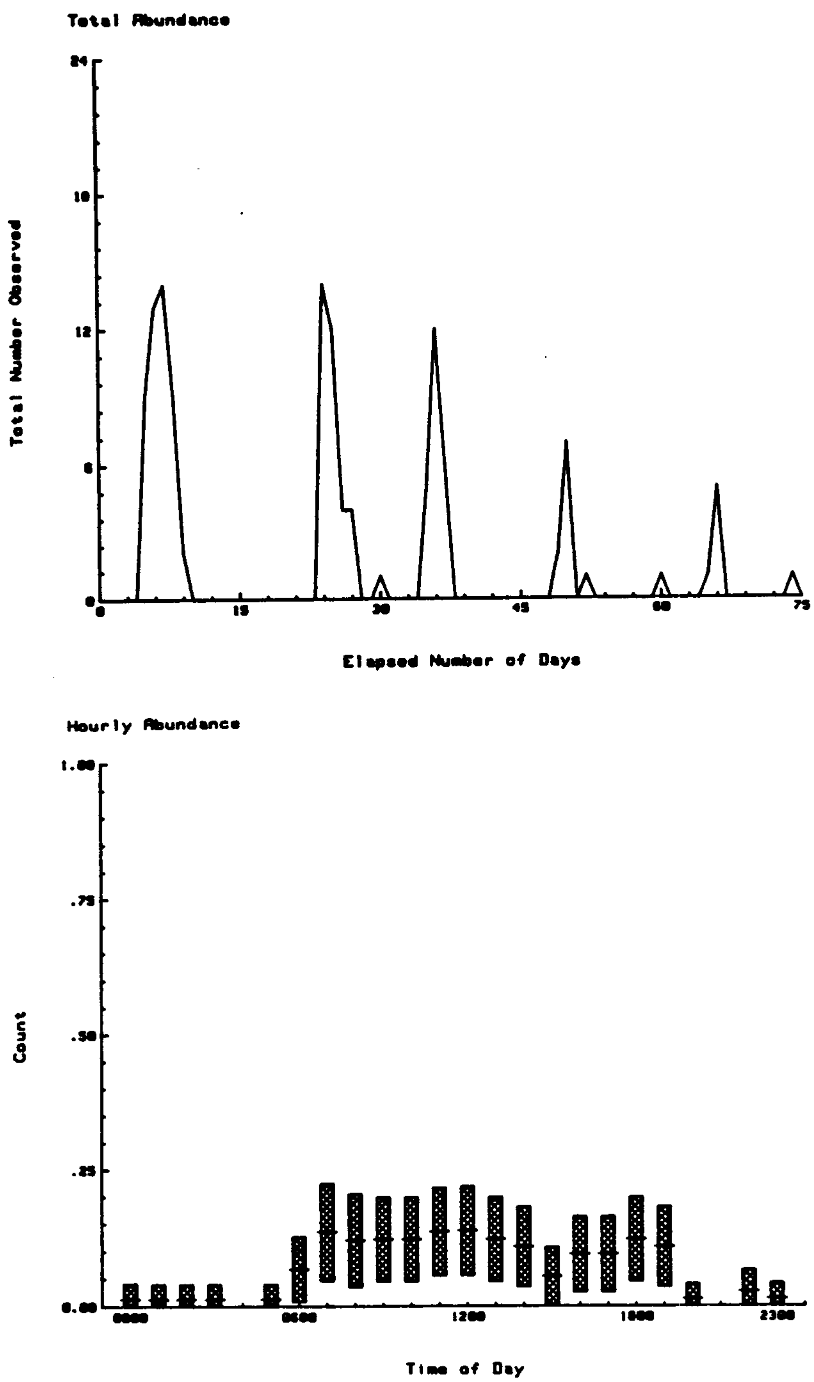
STATION 21

	CRUISE 3-4
PERCIFORMES UNIDENT	561
EPINEPHELUS ITAJARA	123
MYCTEROPERCA UNIDENT	43
POMACANTHUS ARCUATUS	39
EPINEPHELUS GUTTATUS	26
LABRIDAE UNIDENT	16
LUTJANUS ANALIS	11
EPINEPHELUS MORIO	8
CHAETODON OCELLATUS	8
SPARIDAE UNIDENT	7
CHAETODON SEDENTARIUS	5
SERRANUS PHOEBE	4
APOGONIDAE UNIDENT	4
LUTJANIDAE UNIDENT	3
SYNODONTIDAE UNIDENT	3
HAEMULON PLUMIERI	3
HAEMULIDAE UNIDENT	2
POMACENTRIDAE UNIDENT	2
SERRANIDAE UNIDENT	2
DIPLECTRUM UNIDENT	1
CHROMIS ENCHRYSURA	1
EQUETUS ACUMINATUS	1
SYNODUS INTERMEDIUS	1
CANTHIGASTER ROSTRATA	1
MULLOIDICHTHYS MACULATUS	1
POMACENTRUS PARTITUS	1
NUMBER OF OBSERVATIONS	898
NUMBER OF FRAMES	1801



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

Figure 4.1-14 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 21, BEGINNING MAY 1984 - ALL FISHES



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

Figure 4.1-15 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 21, BEGINNING MAY 1984 — EPINEPHELUS ITAJARA

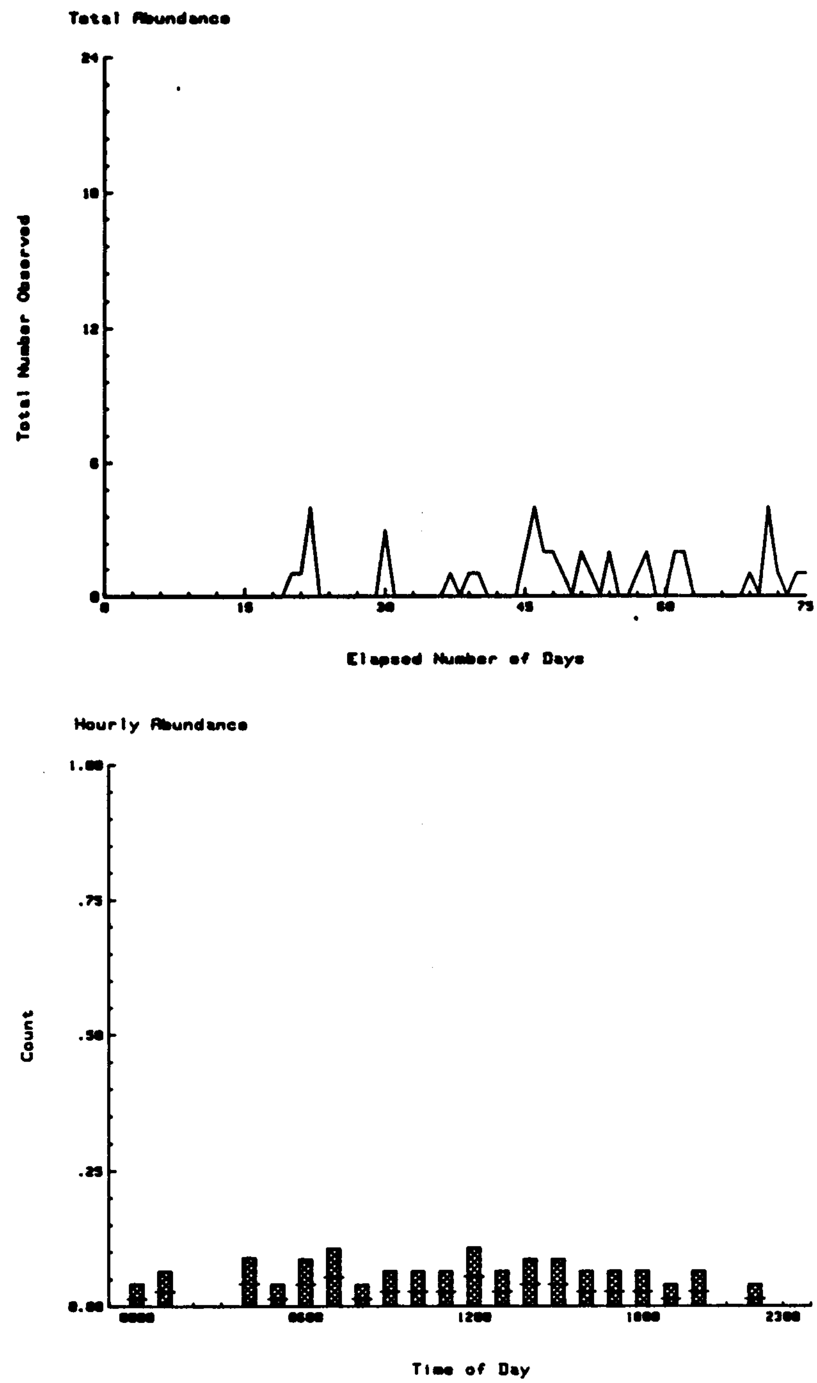
The next series of jewfish observations began 15 days after the previous records. A similar daily residency time (14 of 24 hours) was noted, but the continuous daily duration was shorter, totaling 4 days.

Each of the three subsequent peaks in numbers of observations was successively lower in daily maximums as well as shorter in continuous duration. A possible explanation for the pattern of these observations may be deduced from Figure 4.1-16, depicting the daily abundance of various species of Mycteroperca, the next most abundant taxon. Only 2 of the 43 Mycteroperca observations occurred concurrently within any of the five major abundance peaks for jewfish observations. These peaks accounted for all but 4 of the 123 jewfish observations. The lack of overlap between these two taxa may imply competition for food or space within the array. The most probable explanation is that when jewfish moved away from the array, the Mycteroperca spp. moved in. In addition, the duration of jewfish residency began to decrease as the abundance of Mycteroperca spp. increased. Mycteroperca spp. were present around the clock (Figure 4.1-16).

Other abundant fishes included the gray angelfish, Pomacanthus arcuatus, (39 observations) and various wrasses (Labridae) not visually identifiable to genus (16 observations). Twenty other taxa were observed, nine of them three or more times.

The water was virtually unaffected by turbidity during the recording interval. Only a single frame of 1801 hourly samples was scored other than 0 for turbidity.

A number of general observations of habitat characteristics, fouling community growth, and specific invertebrate records were made during this period. The first significant fouling growth on the metal fouling plate target was not visible until approximately day 26. Shortly after this point, what were apparently hydroids began a rapid growth phase. For a period of 17 days between day 29 and 46, hydroids grew at a rate



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

Figure 4.1-16 TOTAL ABUNDANCE AND HOURLY ABUNDANCE IN TIME-LAPSE RECORDS FROM STATION 21, BEGINNING MAY 1984 — MYCTEROPERCA SP.

of close to 2.4 mm/day, for a total growth of approximately 40 mm. When viewed at a projection speed of 18 frames (sample hours) per second, these hydroid stalks could be seen to lengthen.

Algal biomass was substantial at this station. Both attached algae and large clumps of various drifting species were observed on the bottom and became entangled in the array. A perceptible decrease in algal biomass was recorded over the 75-day period. At the beginning of the record, algae covered approximately 75 percent of the substrate. By the end of the 75th day, benthic algal cover had decreased to about 25 percent, and large areas of sand not visible earlier were exposed.

Other observations of interest included a slipper lobster, *Scyllarides nodifer*, seen at midnight in a single frame; a large cowrie, *Cypraea* sp., seen on top of a fouling plate in one frame at 0400 hours; and a large, brown holothuroid recorded on two other early morning frames at 0300 and 0400 hours. The sea cucumber moved about 2 m between the two exposures.

The time-lapse camera also recorded the evolution of an excavated sediment cone, probably produced by a pelecypod or large polychaete. The cone rose from the bottom over a period of about 4 hours, reaching a diameter of 8 to 10 cm at the base. It then remained visibly unchanged for another 26 hours, then began to diminish in size. It was gone (possibly eroded by current) 10 hours later.

Finally, the camera produced an unusual record of what appears to be the expansion and contraction of a sponge. A gray, massive-bodied sponge grew adjacent to the fouling plate target and sediment measuring rod. By comparison to the divisions on the rod, the sponge when first observed was determined to be about 8 cm tall and 5 cm in diameter. At various times, the sponge could be seen to expand and contract, changing its diameter and height by about 1 cm. These movements were sometimes seen in rapid sucession, and at other times after intervals of several days. No clear pattern of diurnal periodicity was detected.

Station 29

Underwater Television--The bottom at Station 29 consisted of a pavement of coralline algae and reef rock, apparently well consolidated, since few unattached nodules were observed. On this pavement was a community dominated by saucer and leaf corals, *Agaricia* spp.; green algae, *Anadyomene menziesii*; and various sponges. The topography was mostly flat, although some depressions and low hill-like areas were observed. The reef rock and colonies of *Agaricia* formed a complex substrate of plates, mounds, and cavities, which supported high densities of small reef fishes. Species commonly observed included various damselfishes, including the bicolor damselfish, *Pomacentrus partitus*, the purple reeffish, *Chromis scotti*, and the yellowtail reeffish, *C. enchrysurus*. Larger topographic features tended to harbor larger reef fishes, such as the spotfin hogfish, *Bodianus pulchellus*; the tattler, *Serranus phoebe* and other groupers; *Mycteroperca* and *Epinephelus* spp.; and various angelfishes, *Holocanthus* spp.

Individually counted organisms observed in underwater television transects on Cruises I through IV at Station 29 included 10 invertebrate taxa and 31 species of fishes in the 44 751 m^2 surveyed. The most abundant individually counted invertebrates (averaged over four cruises) were gorgonians (*Ellisella*, 114/km^2) and sponges (*Ircinia campana*, 127/km^2; unidentified demosponges, 110/km^2; and *I. strobilina*, 60/km^2) (Table 4.1-17a). Comatulid crinoids were also abundant (87/km^2) at Station 29.

Although there were some differences evident between cruises, the main habitat-forming invertebrates such as sponges and gorgonians were relatively constant in abundance, indicating either fairly widespread and somewhat uniform distributions throughout the study area. For instance, *Ircinia strobilina* varied in density only from 27/km^2 to

Table 4.1-17a Density (No./km^2) of Invertebrates Individually Counted in Underwater Television Transects at Station 29, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	2	3	4	MEAN
PORIFERA					
DEMOSPONGIAE UNIDENT		291.8			109.5
DEMOSPONGIAE SP. 2		6.0			2.2
DEMOSPONGIAE SP. 1		11.9			4.5
IRCINIA CAMPANA	354.4	172.7	6.5	121.9	127.4
IRCINIA STROBILINA	39.4	89.3	51.6	27.1	60.3
CNIDARIA					
HYDROIDA					
HYDROIDA UNIDENT		6.0	103.3	311.4	89.4
ALCYONARIA					
ELLISELLA UNIDENT	216.8	83.4	83.9	176.0	114.0
ZOANTHARIA					
ACTINIARIA UNIDENT				40.6	6.7
MADRACIS UNIDENT		17.9			6.7
ECHINODERMATA					
CRINOIDEA					
COMATULIDA UNIDENT			161.4	189.5	87.1

89/km^2, and Ellisella densities ranged only from 84/km^2 to 217/km^2. Crinoids seemed patchy, with densities from zero (Cruises I and II) to 190/km^2 (Cruise IV).

Station 29 was particularly rich in fishes (Table 4.1-17b). The most frequently counted fishes in underwater television transects (averaged over four cruises) at Station 29 were the yellowtail reeffish, Chromis enchrysurus (2834/km^2); the boga, Inermia vittata (1464/km^2); an unidentified serranid (1247/km^2); and the purple reeffish, Chromis scotti (981/km^2).

Many of the most abundant fishes were present on all four cruises. Although abundances of some species were highly variable, others seemed remarkably constant. Chromis enchrysurus densities ranged from 1319/km^2 to 3621/km^2, and it was the most abundant fish on Cruises I, II, and III. By contrast, Inermia vittata was seen only on Cruise IV, when its density was 8868/km^2. Two chaetodontids (Chaetodon sedentarius and Holacanthus tricolor) were observed on all four cruises with relatively constant densities, and the family in general was well represented (at least five species). There were at least three species of pomacentrids, including Chromis enchrysurus seen on every cruise, and one of them (Chromis scotti) reached densities of 3886/km^2 on Cruise IV.

Dredge--Triangular dredge hauls from Station 29 were dominated by broken coral, mainly the fragile saucer coral, Agaricia fragilis, and leaf coral, A. agaricites (see Table F-8a). Nine other species of scleractinians were recorded, including the saucer coral, Helioseris cucullata; an unidentified disc coral, genus Scolymia; green cactus coral, Madracis decactis; yellow pencil coral, M. mirabilis; M. formosa; M. asperula; lobed star coral, Solenastrea hyades; rose coral, Manicina areolata; and mustard hill coral, Porites astreoides. Only one gorgonian, an unidentified species of Thesea, was collected from Station 29.

Table 4.1-17b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 29, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 1	2	3	4	MEAN
ORECTOLOBIDAE					
GINGLYMOSTOMA CIRRATUM	19.7				2.2
HOLOCENTRIDAE					
HOLOCENTRIDAE UNIDENT	39.4			27.1	8.9
SERRANIDAE					
SERRANIDAE UNIDENT		869.4	2659.4		1246.9
EPINEPHELUS MORIO				13.5	2.2
MYCTEROPERCA UNIDENT		6.0	68.7	121.9	35.8
HYPOPLECTRUS UNIDENT			6.5	13.5	4.5
LIOPROPOMA EUKRINES			6.5	27.1	6.7
SERRANUS UNIDENT			600.3		207.8
SERRANUS ANNULARIS				27.1	4.5
SERRANUS PHOEBE	19.7		303.4	40.6	114.0
CARANGIDAE					
SERIOLA DUMERILI			167.8	27.1	62.6
EMMELICHTHYDAE					
INERMIA VITTATA				8868.1	1463.7
SPARIDAE					
CALAMUS UNIDENT			6.5		2.2
CALAMUS CALAMUS		6.0			2.2
CHAETODOTIDAE					
CHAETODONTIDAE UNIDENT		6.0			2.2
CHAETODON OCELLATUS	39.4				4.5
CHAETODON SEDENTARIUS	177.2	107.2	90.4	297.9	140.8
HOLACANTHUS UNIDENT	19.7	6.0			4.5
HOLACANTHUS TRICOLOR	59.1	35.7	83.9	67.7	60.3
HOLACANTHUS BERMUDENSIS		11.9	19.4	54.2	20.1
POMACANTHUS ARCUATUS	39.4				4.5
POMACENTRIDAE					
POMACENTRIDAE UNIDENT				338.5	55.9
CHROMIS UNIDENT	196.9		19.4		29.0
CHROMIS ENCHRYSURUS	1319.2	2346.1	3621.2	3330.6	2833.5
CHROMIS INSOLATUS				54.2	8.9
CHROMIS SCOTTI	78.8	47.6	903.7	3885.7	981.0
EUPOMACENTRUS PARTITUS	78.8	17.9	154.9	649.9	176.5
LABRIDAE					
BODIANUS PULCHELLUS	19.7	41.7	109.7	176.0	84.9
OSTRACIONTIDAE					
LACTOPHRYS UNIDENT		6.0			2.2
LACTOPHRYS QUADRICORNIS	19.7				2.2
DIODONTIDAE					
DIODON UNIDENT				13.5	2.2

Only one bivalve (an unidentified Arca) and only three gastropods (including two cowries, Cypraea cinerea and another unidentified Cypraea) were found at Station 29. Only four small brachyuran crabs and a single anomuran, the galatheid Munida pusilla, were collected with the triangular dredge. Three species of stomatopods were taken: Gonodactylus bredeni, G. torus, and an unidentified Gonodactylus.

Only one asteroid (Poraniella regularis) was present at Station 29. On the other hand, 13 species of ophiuroids were collected, half the entire species list for all stations. Echinoids included the long-spined sea urchin, Diadema antillarum; the brown rock urchin, Arbacia punctulata; the pencil urchin, Eucidaris tribuloides; and Stylocidaris affinis. A single holothuroid, Thyonella gemmata, and an unidentified comatulid crinoid, were collected.

Six species of algae were recorded for triangular dredges at Station 29 (see Table F-8b). The most striking of these was the large green alga, Anadyomene menziesii. This species was the only one collected on all three cruises for which triangular dredge hauls were obtained.

Trawl--Few fishes were collected by trawling at Station 29, probably because the net was routinely shredded by the Agaricia coral bottom. Only 20 specimens belonging to 9 species (5 families) were taken over four cruises (see Tables F-8c and F-14). The most abundant species was the yellowtail reeffish, Chromis enchrysurus (six individuals).

Station 23

Underwater Television--The bottom at Station 23 consisted of patches of loose to lightly consolidated algal nodules on a basement of carbonate sand. The topography was predominantly flat, with some low relief. Nodules typically covered 50 to 75 percent of the bottom in most areas. The most visible benthic organism was the green alga Anadyomene menziesii. Sponges were not particularly dense, and big sponges were rarely observed. The ichthyofauna was diverse but patchy and of low density. Those fish that were observed (mainly squirrelfishes, Holocentridae; the yellowtail reeffish, Chromis enchrysurus; and the tattler grouper, Serranus phoebe) were usually associated with shallow depressions or prominences on the bottom.

Individually counted organisms observed in underwater television transects on Cruises II, III, and IV at Station 23 included 5 invertebrate taxa and 30 species of fishes in the 39 296 m^2 surveyed. The most abundant individually counted invertebrates (densities averaged over the three cruises) were sponges, including Ircinia campana (15/km^2); Ircinia strobilina (10/km^2); and various unidentified demosponges (8/km^2) (Table 4.1-18a). The spiny lobster, Panulirus argus (3/km^2), and an unidentified diogenid crab (3/km^2) were also recorded.

The most frequently counted fishes in underwater television transects (averaged over the three cruises) at Station 29 were the round scad, Decapterus punctatus (12 724/km^2); the yellowtail reeffish, Chromis enchrysurus (1377/km^2); the tattler, Serranus phoebe (176/km^2); and the jackknife-fish, Equetus lanceolatus (89/km^2) (Table 4.1-18b).

Invertebrates that were individually counted by underwater television at Station 29 were typically fairly low in density and patchy. None of the invertebrates except for Ircinia campana were recorded on more than one cruise. Most of the fishes showed a similar pattern, with half of the species recorded only from Cruise IV. For example, Decapterus punctatus was observed only on Cruise IV, along with 14 other species unique to that cruise. On Cruise IV, high densities were recorded for many species, including Serranus phoebe (120/km^2); Decapterus punctatus (60 125/km^2); Chromis enchrysurus (4413/km^2); and an unidentified wrasse, Halichoeres sp. (180/km^2). Only Serranus phoebe and Chromis enchrysurus were observed on all three cruises.

Table 4.1-18a Density (No./km^2) of Invertebrates Individually Counted in Underwater Television Transects at Station 23, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 2	CRUISE 3	CRUISE 4	MEAN
PORIFERA				
DEMOSPONGIAE UNIDENT	20.2			7.6
IRCINIA CAMPANA	20.2		36.1	15.3
IRCINIA STROBILINA			48.1	10.2
CRUSTACEA				
PALINURA				
PANULIRUS ARGUS		6.2		2.5
ANOMURA				
DIOGENIDAE UNIDENT			12.0	2.5

Table 4.1-18b Density (No./km^2) of Fishes Counted in Underwater Television Transects at Station 23, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 2	CRUISE 3	CRUISE 4	MEAN
HOLOCENTRIDAE				
HOLOCENTRIDAE UNIDENT			12.0	2.5
SERRANIDAE				
SERRANIDAE UNIDENT	20.2			7.6
EPINEPHELUS MORIO		24.9	12.0	12.7
MYCTEROPERCA UNIDENT	40.3		36.1	22.9
MYCTEROPERCA PHENAX			36.1	7.6
EPINEPHELUS FULVUS		6.2		2.5
SERRANUS ANNULARIS			12.0	2.5
SERRANUS PHOEBE	382.9	12.4	120.3	175.6
PRIACANTHIDAE				
PRIACANTHUS ARENATUS			12.0	2.5
PRIACANTHUS CRUENTATUS		12.4		5.1
APOGONIDAE				
APOGON PSEUDOMACULATUS			12.0	2.5
CARANGIDAE				
SERIOLA DUMERILI	26.9		24.1	15.3
DECAPTERUS PUNCTATUS			60125.1	12723.9
EMMELICHTHYDAE				
INERMIA VITTATA			180.4	38.2
SPARIDAE				
CALAMUS UNIDENT			12.0	2.5
SCIAENIDAE				
EQUETUS LANCEOLATUS		217.5		89.1
EQUETUS UMBROSUS		12.4		5.1
CHAETODOTIDAE				
CHAETODON OCELLATUS			24.1	5.1
CHAETODON SEDENTARIUS	40.3		60.1	28.0
HOLACANTHUS BERMUDENSIS			36.1	7.6
POMACANTHUS UNIDENT	13.4			5.1
POMACANTHUS ARCUATUS	6.7		36.1	10.2
POMACENTRIDAE				
POMACENTRIDAE UNIDENT			36.1	7.6
CHROMIS ENCHRYSURUS	812.7	329.4	4413.2	1376.7
CHROMIS INSOLATUS			156.3	33.1
LABRIDAE				
LABRIDAE UNIDENT			48.1	10.2
HALICHOERES UNIDENT			180.4	38.2
HALICHOERES CAUDALIS			12.0	2.5
BALISTIDAE				
BALISTES CAPRISCUS	20.2			7.6
TETRAODONTIDAE				
SPHOEROIDES SPENGLERI		6.2		2.5

Dredge--Triangular dredge samples from Station 23 consisted mainly of calcareous nodules formed by coralline algae, often covered with the green alga Anadyomene menziesii. Only a single scleractinian coral (Madracis asperula) and a single gorgonian (Nicella schmitti) were collected (Table F-9a). Four bivalves were collected, Aequipecten muscosus, Chama congregata, Chlamys benedicti, and an unidentified scallop.

Nine gastropods were found in triangular dredge samples. These included several large species, such as two murexes, Murex brevifrons and M. florifer; the horse conch, Pleuroploca gigantea; the banded tulip, Fasciolaria lilium; and the star turban, Astraea phoebia. The rare abalone, Haliotis pourtalesii, was also collected at Station 23.

Thirteen brachyuran crabs were identified in samples from Station 23. These included spider crabs, Mithrax acuticornis and M. turceps, and portunid swimming crabs, Portunus ordwayi. The anomuran galatheids Munida pusilla and Galathea rostrata were present, as was the hermit crab Pagurus acadianus. Three stomatopods were found: Gonodactylus bredini, G. torus, and an unidentified Gonodactylus. Several pistol shrimps were found among the nodules, including Synalpheus townsendi, S. longicarpus, and S. goodei.

Seven species of asteroids were reported from triangular dredges at Station 23: Echinaster modestus, Poraniella regularis, Luidia barbadensis, Linckia nodosa, Narcissia trigonaria, Henricia antillarum, and Tosia parva.

Eight ophiuroids were collected at Station 23. Species included the ubiquitous angular brittle star, Ophiothrix angulata; Savigny's ophiactis, Ophiactis savignyi; the short-spined brittle star, Ophioderma brevispina; the ruby brittle star, O. rubicundum; Suenson's brittle star, Ophiothrix suensonii; Ophiomyxa flaccida; and unidentified species of Macrophiothrix and Ophiozona.

Echinoids collected at Station 23 included the brown rock urchin, *Arabacia punctulata*; the pencil urchin, *Eucidaris tribuloides*; *Lytechinus euerces*; *L. callipeplus*; and *Stylocidaris affinis*.

Only four species of algae were collected at Station 23 (see Table F-9b). The large green alga *Anadyomene menziesii* dominated the collection and was the only species taken during all four cruises. Another green alga (*Pseudotetraspora antillarum*) and two brown algae (*Dictyopteris* sp. 1 and an unidentified form) were also present.

Trawl--Nineteen fishes belonging to 10 families were taken at Station 23 (see Tables F-9c and F-14). The most abundant species were (in order to decreasing abundance) the tattler grouper, *Serranus phoebe* (89 individuals, spread fairly evenly over three cruises); the blackear bass, *S. atrobranchus* (34 individuals); the spotted scorpionfish, *Scorpaena plumieri* (13 individuals); and the offshore lizardfish, *Synodus poeyi* (12 individuals). The family best represented from the standpoint of number of species was the Serranidae, groupers and basses (four species).

Station 36

Underwater Television--The bottom at Station 36 consisted of a coarse, carbonate sand flat with very low relief. Much of the bottom appeared to be bare sand with ripple marks. There were a few rocky outcrops and shallow depressions, which generally had higher densities of fauna present near them. Comatulid crinoids and sea whips (*Ellisella* spp.) were the most conspicuous fauna observed by underwater television. Fish were rarely seen in video transects. Those that were observed included the bank butterflyfish, *Chaetodon aya*; the bigeye, *Priacanthus arenatus*, various lizardfishes (Synodontidae), and small sea basses (*Serranus* spp.).

Individually counted organisms observed in underwater television transects on Cruises II, III, and IV at Station 36 included

9 invertebrate taxa and 13 species of fishes (Table 4.1-19) in the 18 955 m^2 surveyed. Cruise I data were not obtained due to severe weather conditions which terminated the cruise.

The most abundant invertebrates (densities averaged over the three cruises) were an unidentified species of the gorgonian Ellisella (2569/km^2); an unidentified sea urchin (1308/km^2); and comatulid crinoids (507/km^2).

The only individually counted invertebrate present on all three cruises was Ellisella, which ranged in density from 351/km^2 (Cruise IV) to 8382/km^2 (Cruise III). Densities of other invertebrates were highly variable. For example, the densities of an unidentified sea urchin ranged from zero (Cruise IV) to 4723/km^2 (Cruise II), and comatulid crinoids were abundant on Cruise II (1874/km^2) but not observed on subsequent cruises.

The most frequently counted fishes in the underwater television transects (averaged over the three cruises) at Station 36 were various perciform species (1319/km^2); the tattler, Serranus phoebe (190/km^2); an unidentified serranid (121/km^2); and various lizardfish, Synodus sp. (63/km^2).

Considerable variability characterized fish counts between cruises. The most abundant group of fishes overall (based on averaged of all three cruises), unidentified Perciformes, were recorded only on Cruise IV (2658/km^2). The only fish present on all three cruises was Serranus phoebe, whose density ranged from 11/km^2 (Cruise IV) to 625/km^2 (Cruise II). The bank butterfly fish, Chaetodon ava, was common only on Cruise III (113/km^2), though present (20/km^2) on Cruise II.

Dredge--Dredge hauls from Station 36 were dominated by crinoids (see Table F-10a). Four species of scleractinians were collected: Desmophyllum cristagalli, Solenosmilia variabilis,

Table 4.1-19 Density (No./km^2) of Invertebrates Individually Counted and Fishes Counted in Underwater Television Transects at Station 36, by Cruise (Means Based on Total Area Transected for all Cruises Shown)

TAXON	CRUISE 2	CRUISE 3	CRUISE 4	MEAN
PORIFERA				
DEMOSPONGIAE UNIDENT	58.5	22.6		21.1
HOMAXINELLA UNIDENT			10.6	5.3
CNIDARIA				
HYDROIDA				
HYDROIDA UNIDENT	19.5	22.6		10.6
ALCYONARIA				
ELLISELLA UNIDENT	1619.8	8382.3	350.9	2569.2
MOLLUSCA				
CEPHALOPODA				
CEPHALOPODA UNIDENT		67.8		15.8
ECHINODERMATA				
ASTEROIDEA				
ASTEROIDEA UNIDENT		22.6		5.3
ECHINOIDEA				
ECHINOIDEA UNIDENT	4722.9	135.6		1308.4
CLYPEASTERIDAE UNIDENT		45.2		10.6
CRINOIDEA				
COMATULIDA UNIDENT	1873.5			506.5
FISHES				
SYNODONTIDAE				
SYNODONTIDAE UNIDENT		22.6	10.6	10.6
SYNODUS UNIDENT	214.7	22.6		63.3
SYNODUS INTERMEDIUS	19.5			5.3
TRACHINOCEPHALUS MYOPS	19.5			5.3
SCORPAENIDAE				
SCORPAENIDAE UNIDENT		22.6		5.3
PERCIFOMES				
PERCIFORMES UNIDENT			2658.2	1318.9
SERRANIDAE				
SERRANIDAE UNIDENT		474.5	21.3	121.3
SERRANUS PHOEBE	624.5	67.8	10.6	189.9
PRIACANTHIDAE				
PRIACANTHUS ARENATUS		67.8		15.8
MALACNTHIDAE				
MALACANTHUS UNIDENT		22.6		5.3
MULLIDAE				
MULLIDAE UNIDENT			10.6	5.3
CHAETODOTIDAE				
CHAETODON AYA	19.5	113.0		31.7
CHAETODON SEDENTARIUS			10.6	5.3

Paracyathus pulchellus, and *Rhizosmilia gerdae*. Four gorgonians were taken--an unidentified *Thesea*, *Ellisella atlantica*, *E. elongata*, and *Paramuricea multispina*.

No bivalves were found at Station 36. Two gastropods were collected, the banded tulip, *Fasciola lilium*, and *Sthenorytis pernobilis*. Thirteen brachyurans were present, including the arrow crab, *Stenorhynchus seticornis*; the spider crab, *Mithrax acuticornis*; the portunid swimming crab, *Portunus spinicarpus*; and the box crab, *Calappa angusta*. Four anomurans were collected: two hermit crabs, *Pagurus impressus* and *P. politus*; and two galatheids, *Munida pusilla* and an unidentified species of *Munida*. Four asteroids found at Station 36 included *Tosia parva*, *Sclerasterias contorta*, *Rosaster alexandri*, and *Pectinaster gracilis*. Eight ophiouroids were collected, including Suenson's brittle star, *Ophiothrix suensonii*; *Astropora annulata*; *Astroschema nuttingii*; and six others that could not be identified to species. Echinoids included the urchins *Stylocidaris affinis*, *S. lineata*, *Echinolampas depressa*, *Coelopleurus floridanus*, and *Clypeaster ravenelii*. Two unidentified species of crinoids were collected, one of which appeared to be a *Comactina*.

No algae were collected in triangular dredge hauls at Station 36.

Trawl--Thirty-three fishes belonging to 16 families were present at Station 36 (see Tables F-10b and F-14). The most abundant species were (in order of decreasing abundance) the blackear bass, *Serranus atrobranchus* (163 individuals, taken in large numbers on Cruises II, III, and IV); the offshore lizardfish, *Synodus poeyi* (123 individuals, taken mainly on Cruise IV); the shortwing searobin, *Prionotus stearnsi* (54 individuals); the horned whiff, *Citharichthus cornutus* (41 individuals, taken mainly on Cruise IV); an unidentified lizardfish, *Saurdia* sp. (38 individuals, Cruise IV only); the streamer searobin, *Bellator egretta* (33 individuals); and the tattler grouper, *Serranus phoebe* (29 individuals, taken almost entirely on Cruise II).

The fishes best represented from the standpoint of numbers of species present were the Synodontidae (lizardfishes), six species; the Serranidae (basses and groupers), four species; Bothidae (lefteye flounders), four species; Triglidae (searobins) and the Ogcocephalidae (batfishes), three species each.

4.2 PHYSICAL DYNAMICS OF GROUP II LIVE-BOTTOM STATIONS

4.2.1 CURRENTS

A principal objective of this study is to evaluate the interaction between benthic ecosystems and their physical environment, specifically to determine rates of sediment transport. Only above-average bottom currents exceeding at least 40 cm/s can initiate sediment transport (Sternberg, 1972; Sundborg, 1967; Heezen and Hollister, 1964); thus, the focus of investigation will be on these above-average currents. However, weaker currents can carry suspended sediments once they have been entrained; therefore, typical currents will be evaluated also. The mechanisms which generate currents on the west Florida shelf must also be evaluated, so that the observations of the study may be placed in the perspective of the range of conditions which may be anticipated.

Cooper (1982) presents the most recent and comprehensive review of current conditions of the west Florida shelf, as well as a model of residual (nontidal) circulation. Currents on the shelf are driven by tides, winds, seasonal heating (convection), and effects of intrusions of the Loop Current, including eddies which detach from the current. Cyclonic and anticyclonic eddies have been postulated by Niiler (1976), but the few eddies which have been observed were cyclonic. From a review of data collected during the Shelf Dynamics Experiment (Price and Mooers, 1974a, 1974b, 1974c, 1974d), Cooper (1982) notes a general tendency for the Loop Current to shed alternating cyclonic and anticyclonic eddies. The eddy-induced curent velocities approach 50 cm/s and are associated with temperature changes of about 4°C. The warm core of cyclonic eddies is about 25° to 27°C.

Cooper identified and included the following three forcing mechanisms to model seasonal circulation: the Loop Current, wind, and density gradients. The Loop Current and wind-driven simulated currents adequately predicted observed fall, winter, and spring currents. However, horizontal and vertical stratification were required to model summer circulation. The effects of the Loop Current accounted for most of the residual energy in Cooper's simulation. The wind-induced component of flow had a significant effect on fall-winter circulation. Winds were of greater importance to summer residual currents in water within approximately 100 km from the coast; however, they were less significant seaward of the mid-shelf region. The circulations driven by the Loop Current were relatively uniform with depth, while wind-driven and seasonal stratification resulted in significant vertical shear. Vertical shear was particularly apparent in the southern portion of the shelf (near the Group II stations). In the western portion of the study area (Stations 23, 29, and 36), the model indicates southerly flow at the bottom and little vertical shear in the fall and winter, southeasterly flow in the spring and summer, with a 20 cm/s difference between surface and bottom velocities. Bottom current speeds in this area were simulated to be 5 to 10 cm/s. In the vicinity of Station 52, Cooper's model predicts weak southeasterly flow at the bottom in all seasons, while surface currents vary from southwest in the fall and winter to northerly in the spring and summer, implying significant vertical shear.

Cooper's results may be compared with the bottom seasonally averaged resultant current vectors shown in Figure 4.2-1. Resultant currents of 20 to 25 cm/s to the south were observed in the western portion of the study area in winter, while the resultant current at Station 52 was 7 cm/s to the southeast. These results are in close agreement with Cooper's predictions. Station 52 continues to show the weak southeasterly drift predicted by Cooper through the spring and summer. Station 36 also maintains the southerly flow predicted by Cooper through these seasons, although the other western stations (23 and 29) are more variable with a definite westerly drift at the bottom. The currents observed at Stations 23 and 29 are not in close agreement with Cooper's simulated currents during the spring and summer.

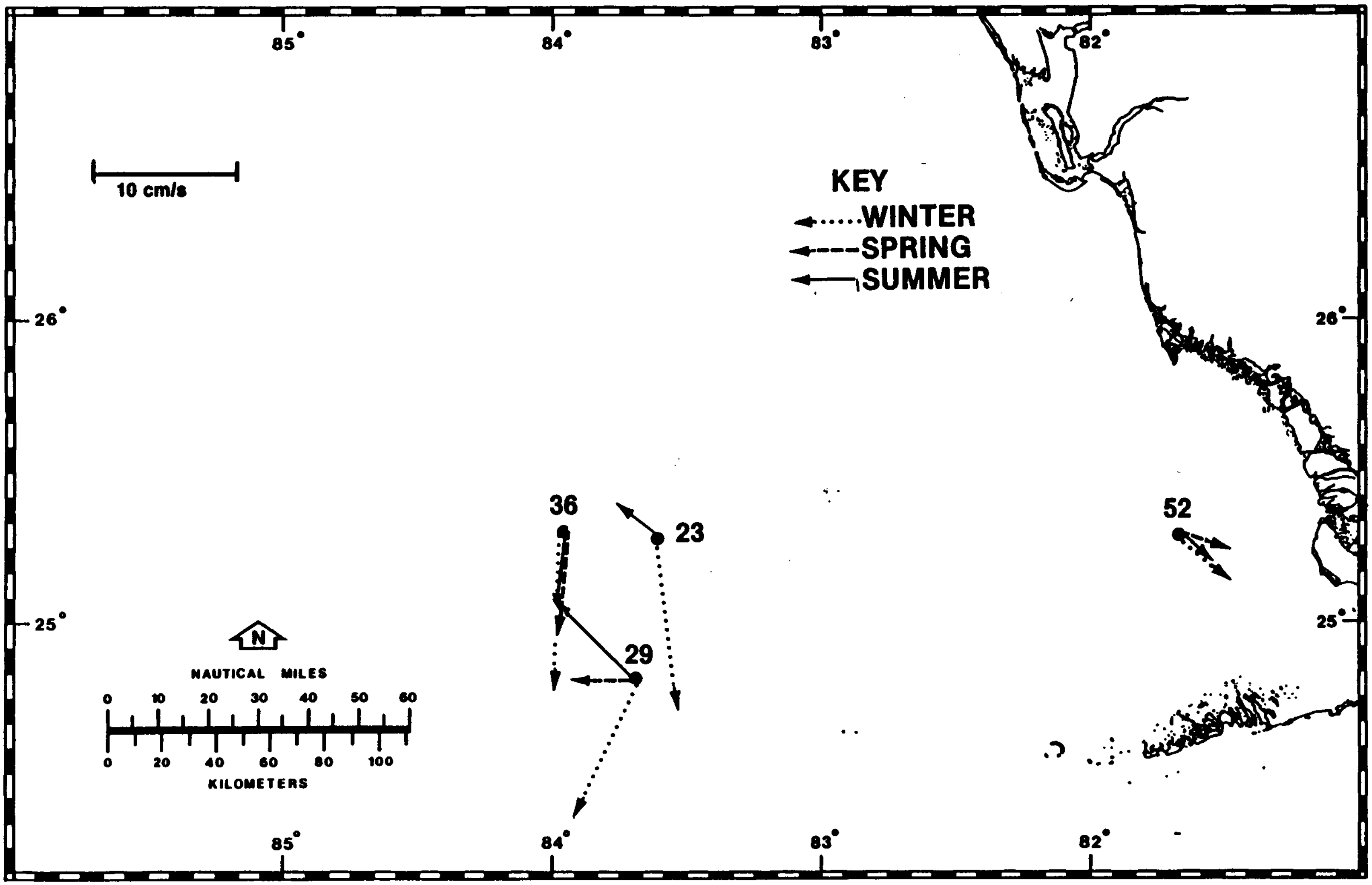


Figure 4.2-1 RESULTANT VELOCITIES – WINTER, SPRING, AND SUMMER

Time Series

Full time-series data from all current meters are provided in Appendix B. Figures 4.2-2, 4.2-3, and 4.2-4 are representative of patterns observed at Stations 52, 29, and 36, respectively.

Station 52 is strongly influenced by the tide whose major axis is east-west (Figure 4.2-4). A consistent southeasterly residual drift is evident. The tide is clearly modulated by a 14-day cycle, being predominantly semidiurnal at the neap, and mixed at the spring tide. Tidal currents are approximately 50 cm/s (tidal current amplitude at 25 cm/s).

During the June period, shown in Figure 4.2-3, Station 29 was apparently influenced by a Loop Current meander or eddy from June 6 to June 21. During this period, the bottom temperature rose from about 20° to 23°C. This event was characterized by strong northwesterly flow with a peak speed of 70 cm/s and a resultant northwest velocity of 40 cm/s over a 15-day period. Net drift, for the remainder of the month, was sluggish to the northwest, and the tidal ellipse was more nearly circular than the consistent east-west motion seen at Station 52. The tidal current amplitude was approximately 15 cm/s.

The exemplary current record for Station 36 (Figure 4.2-4) illustrates the effect of the Loop Current in the western part of the study area in September. During the first 10 days of September, the bottom current at Station 36 flowed south at a resultant speed of 46 cm/s and peak speeds of roughly 70 cm/s. The temperature increased from 18° to 21°C during this period as illustrated in Figure 4.2-5. An even more dramatic intrusion occurred in mid-October with temperature rising to 24°C and peak current speeds exceeding 80 cm/s to the north. Such intrusions occurred at least six times during Year 4 at Station 36. This current reversal could indicate propagation of a detached anticyclonic eddy past Station 36 or it could be caused by a bottom reverse flow counter to the southerly Loop Current as recently reported by Science Applications

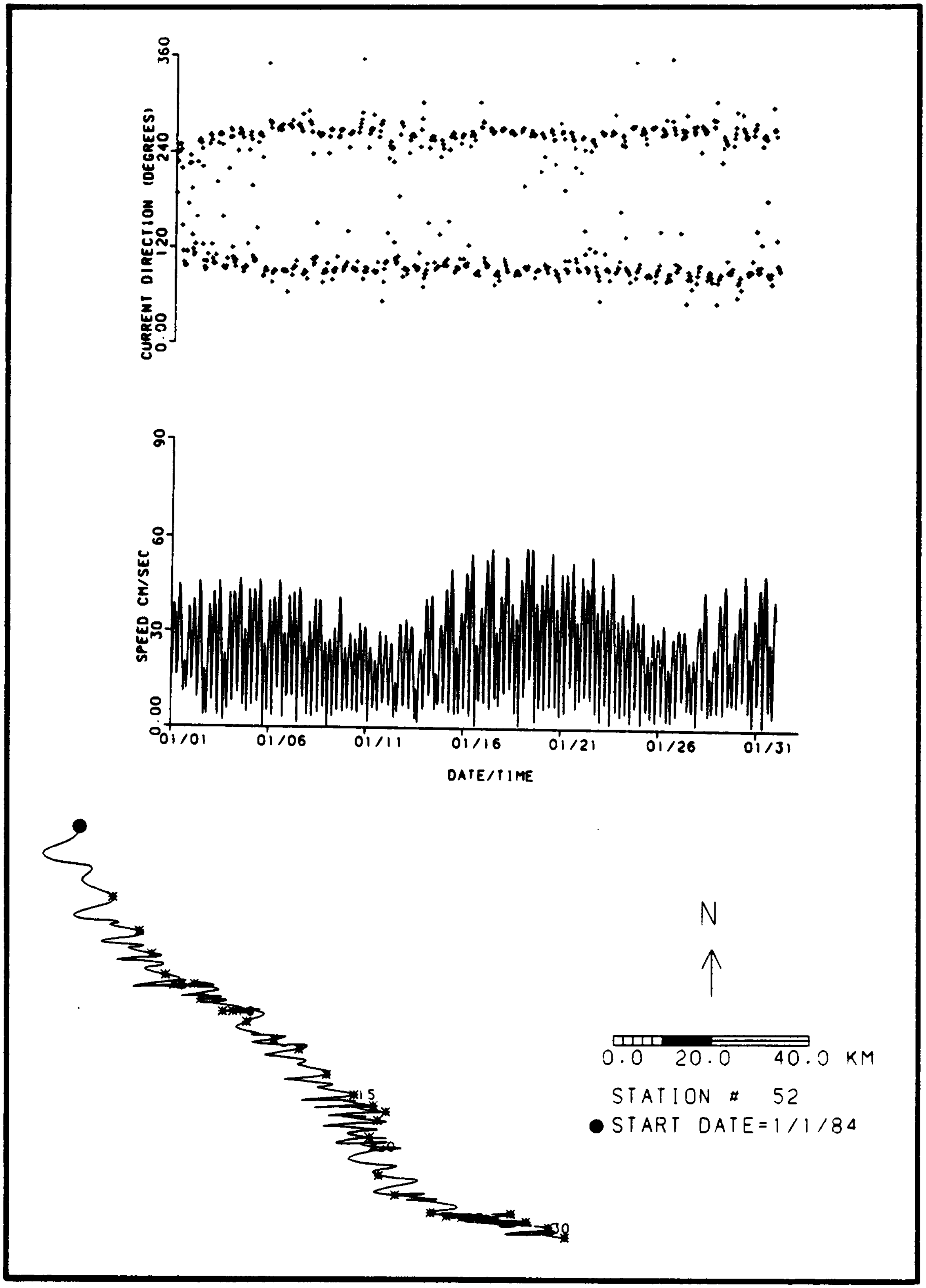


Figure 4.2-2 STATION 52 CURRENT SPEED, DIRECTION AND PROGRESSIVE VECTOR PLOTS - JANUARY 1984

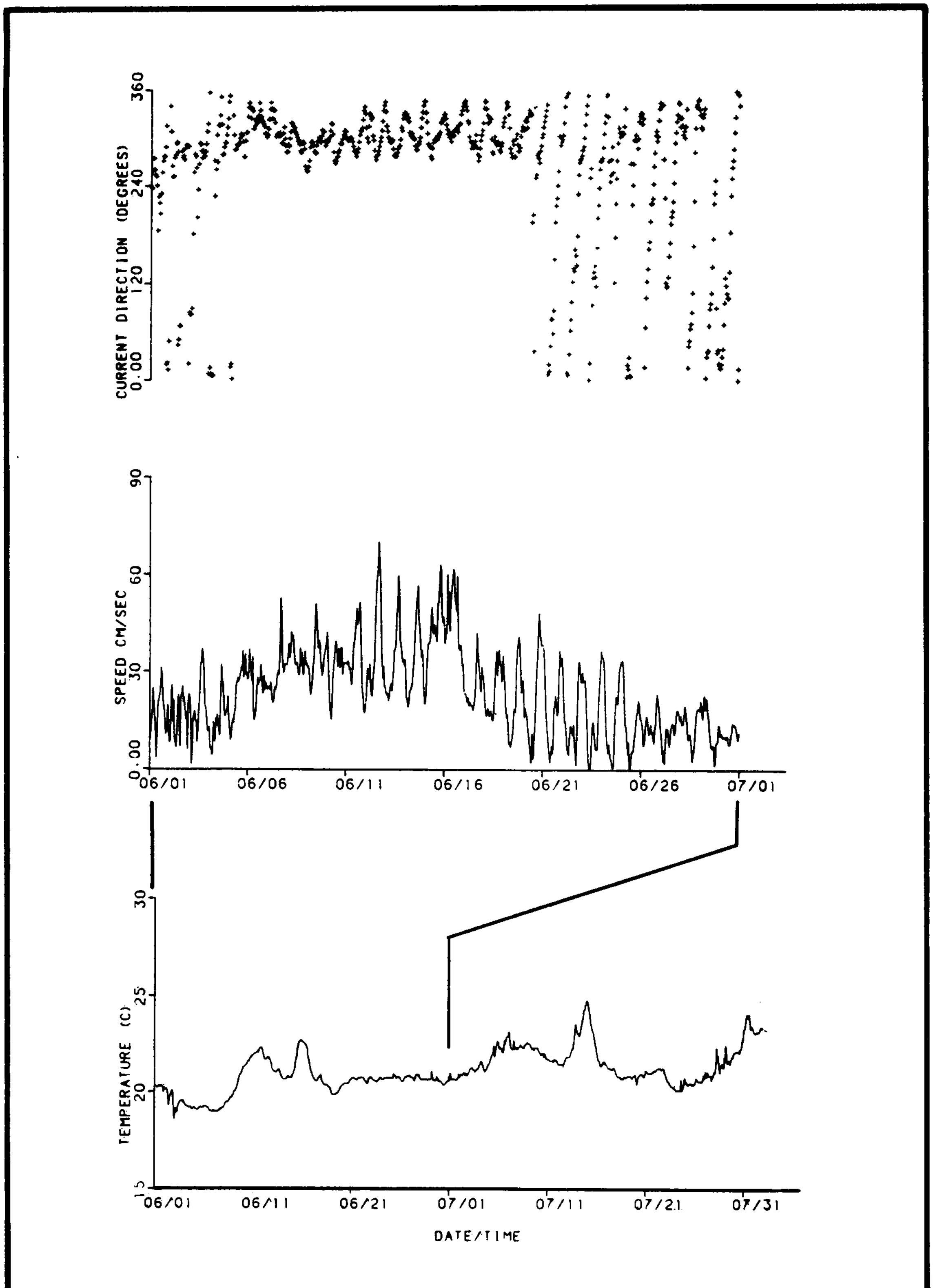


Figure 4.2-3 STATION 29 CURRENT AND TEMPERATURE DATA FOR JUNE 1984 SHOWING LOOP CURRENT INTRUSION

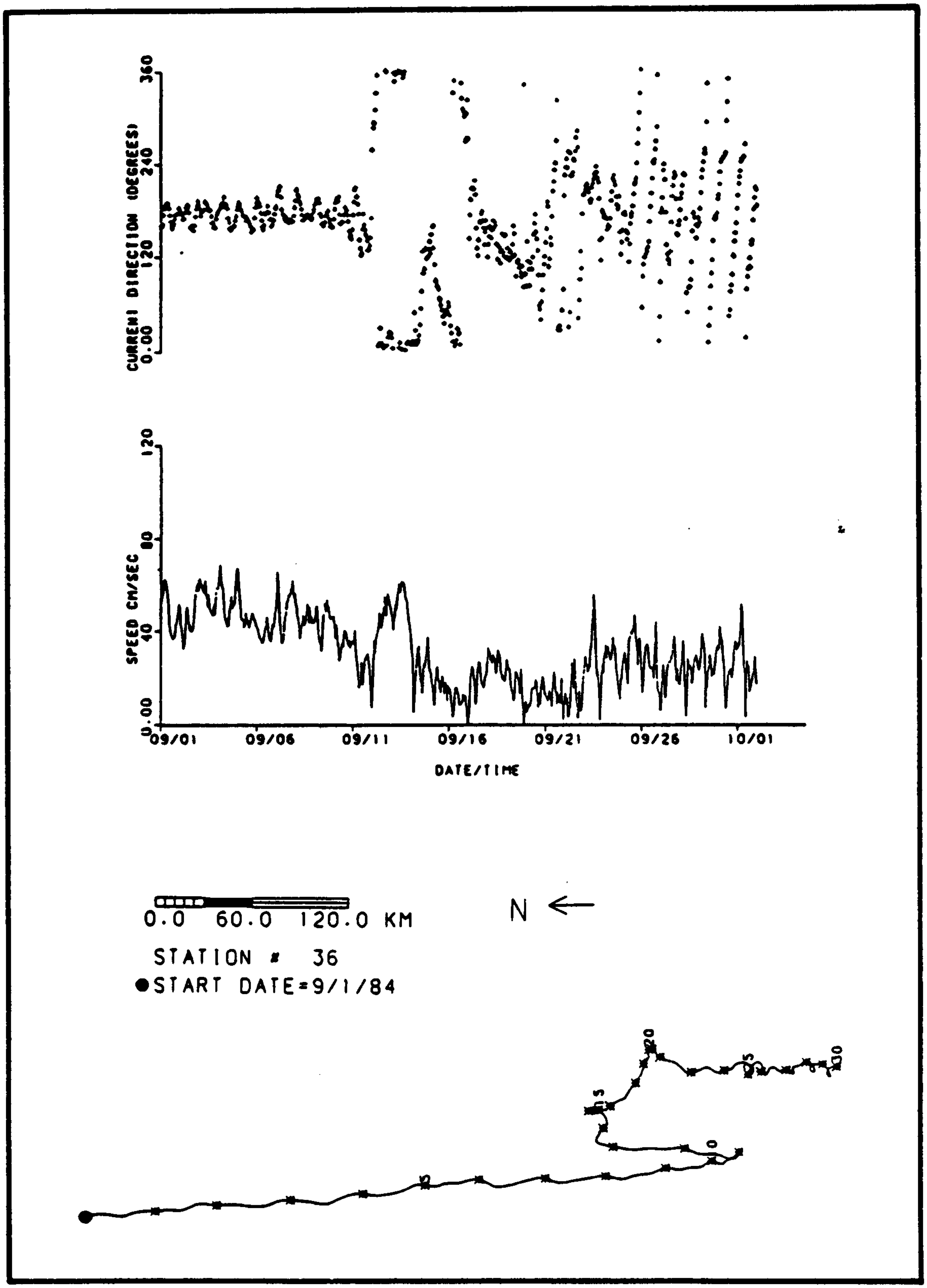


Figure 4.2-4 STATION 36 CURRENT SPEED, DIRECTION AND PROGRESSIVE VECTOR PLOTS - SEPTEMBER 1984

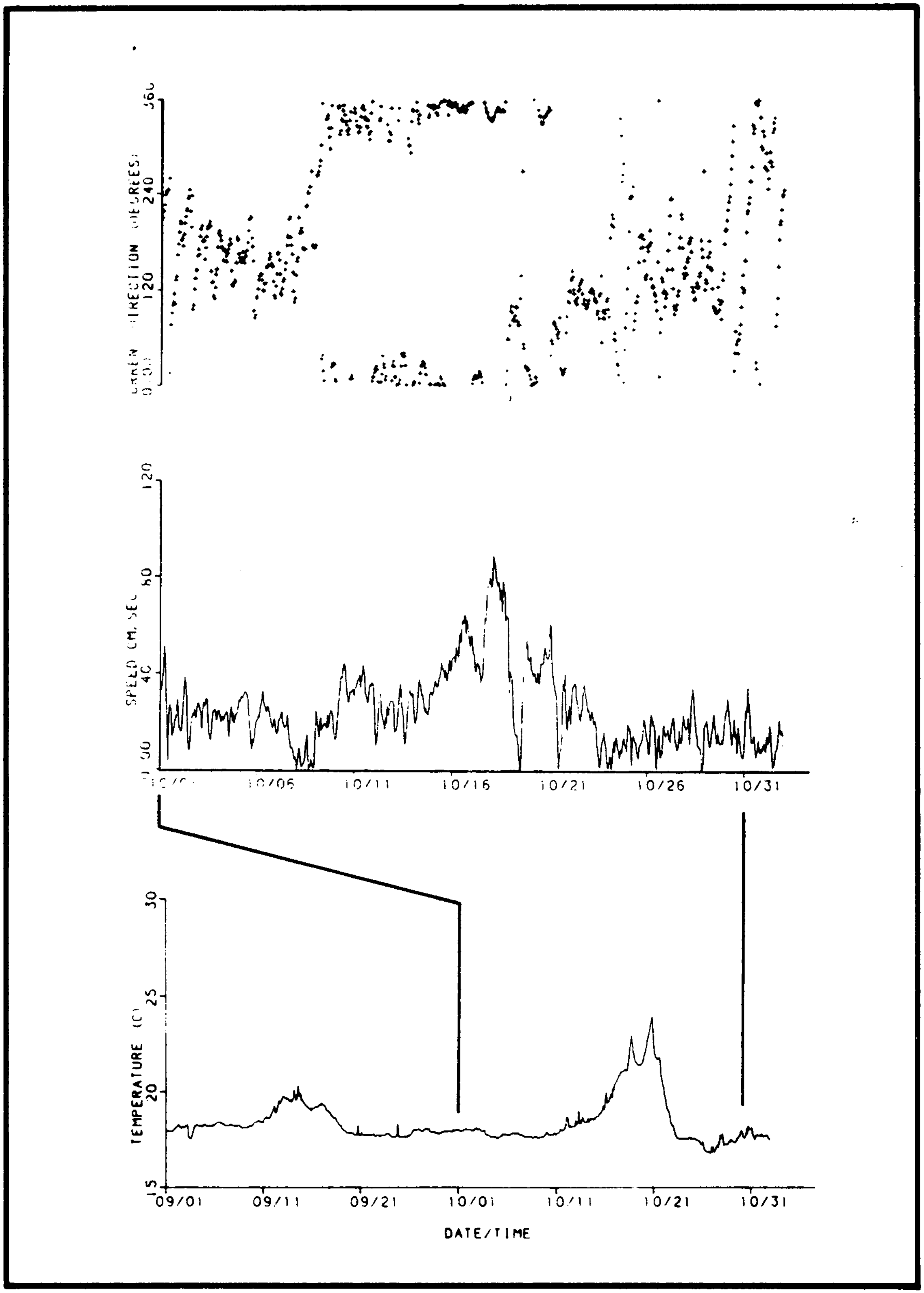


Figure 4.2-5 STATION 36 CURRENT AND TEMPERATURE DATA FOR OCTOBER 1984 SHOWING LOOP CURRENT INTRUSION

International Corp. (1985). At Station 29 this pattern of steady direction, increased water temperature, and current speed, which appears to be the signature of a Loop Current meander or eddy, occurred twice, in mid-June and mid-July; and at Station 23 in mid-January and June. The June event was observed at all three stations (23, 29, and 36), but was very weak and brief at Station 36 where currents were southerly at 20 cm/s. Simultaneously at Station 23 (30 km to the east), currents were northerly at 60 cm/s, while at Station 29, 45 km to the south of Station 23, currents were northwest at up to 70 cm/s. This is suggestive of a very tight cyclonic gyre. Further evaluation of these events will be required to evaluate if they are capable of resuspending and transporting bottom sediments.

Energy Spectra

Preliminary analysis of the time-series records has been performed indicating peaks at the expected tidal frequencies, as shown in Figures 4.2-6 through 4.2-9. Nearly all energy was centered in the tidal components, with the semi-diurnal component being dominant in the shallow water (Station 52) and with mixed tides (both diurnal and semi-diurnal) in deeper water. The energy at Station 52 was nearly all in the east-west component, with a higher energy peak during the winter. The north-south component of tides became greater in deeper water, which indicated that the tidal ellipses changed from nearly linear at Station 52 to almost circular at the deeper stations. Evaluation of the low-frequency domain will be performed upon completion of Year 5 monitoring, when a longer time-series record will be available.

Joint Frequency

Joint frequency tables of current speed and direction by month for each current meter are provided in Appendix B and will be discussed further in reference to sediment transport in Section 4.2.5. Summary statistics of the distributions by month are presented in Table 4.2-1 and briefly for each station in the following paragraphs.

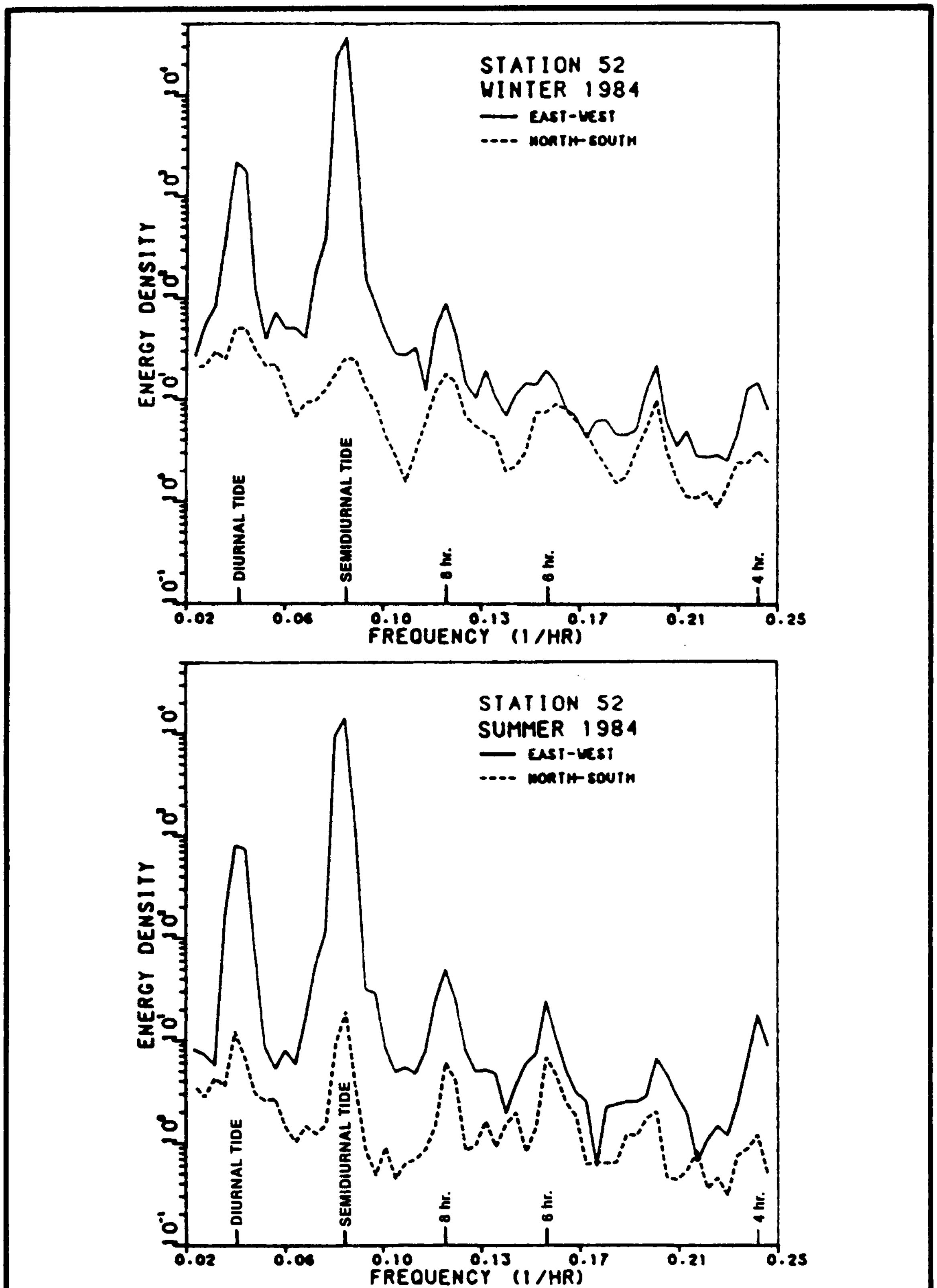


Figure 4.2-6 ENERGY SPECTRA, STATION 52

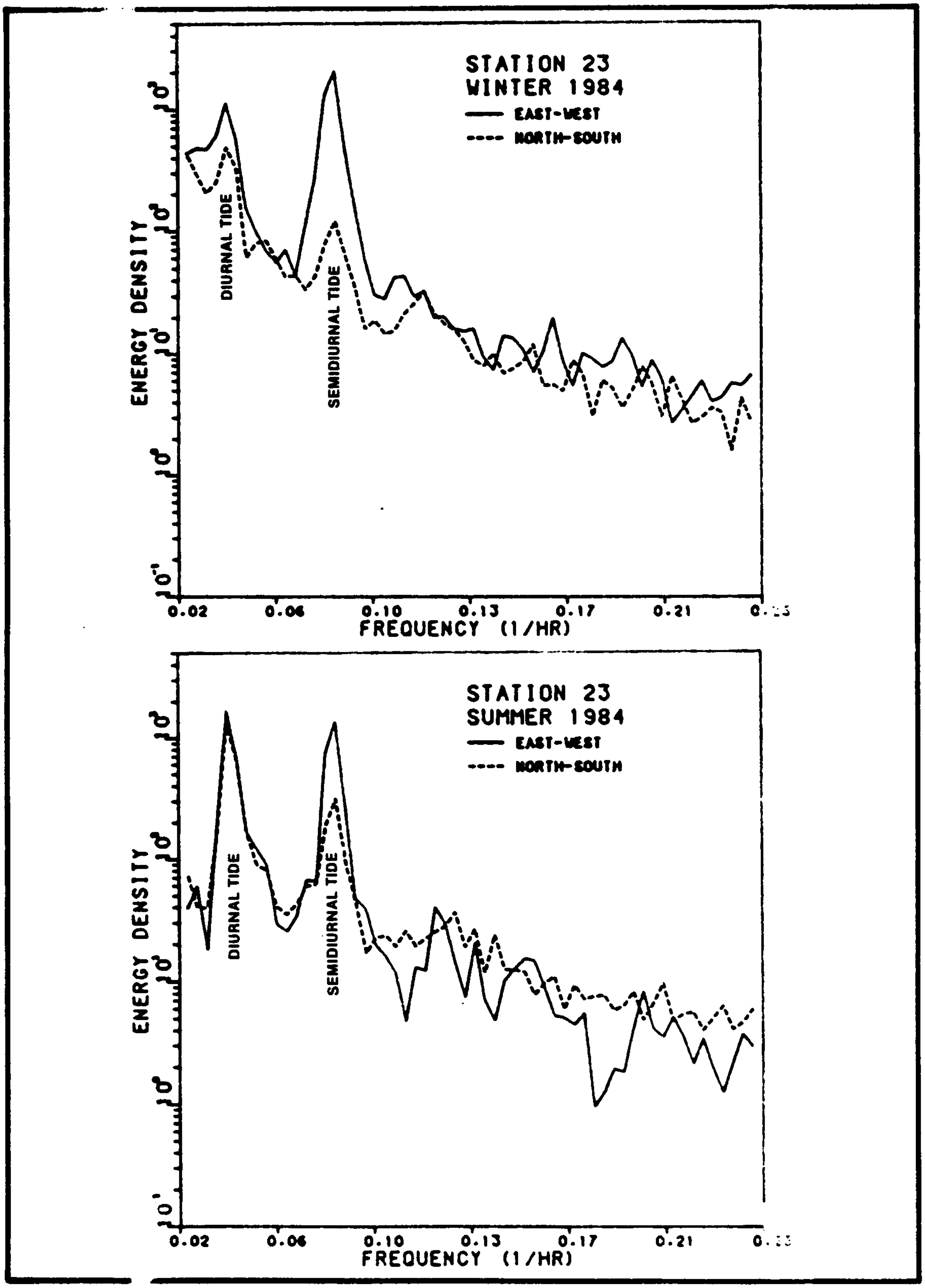


Figure 4.2-7 ENERGY SPECTRA, STATION 23

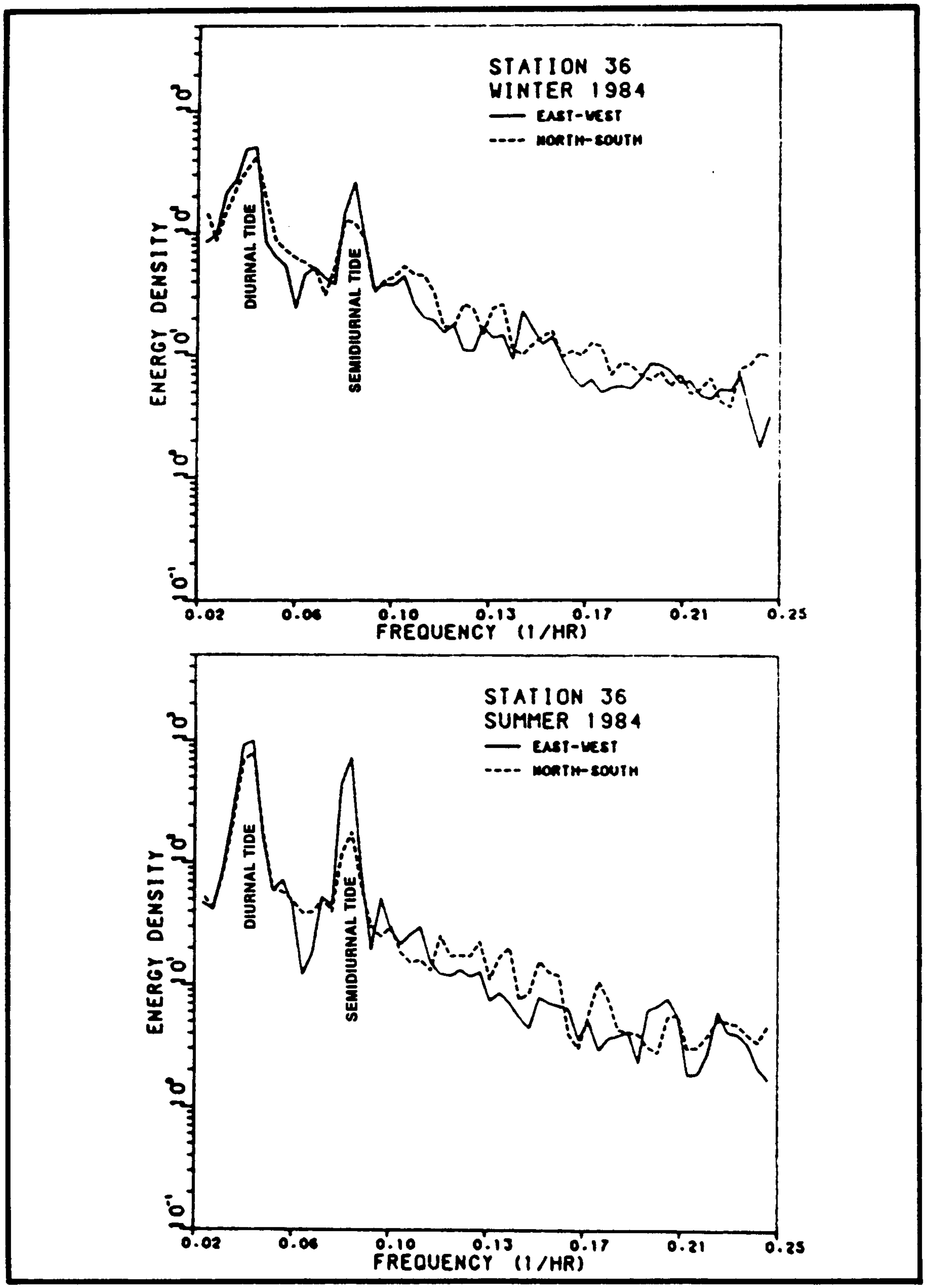


Figure 4.2-8 ENERGY SPECTRA, STATION 36

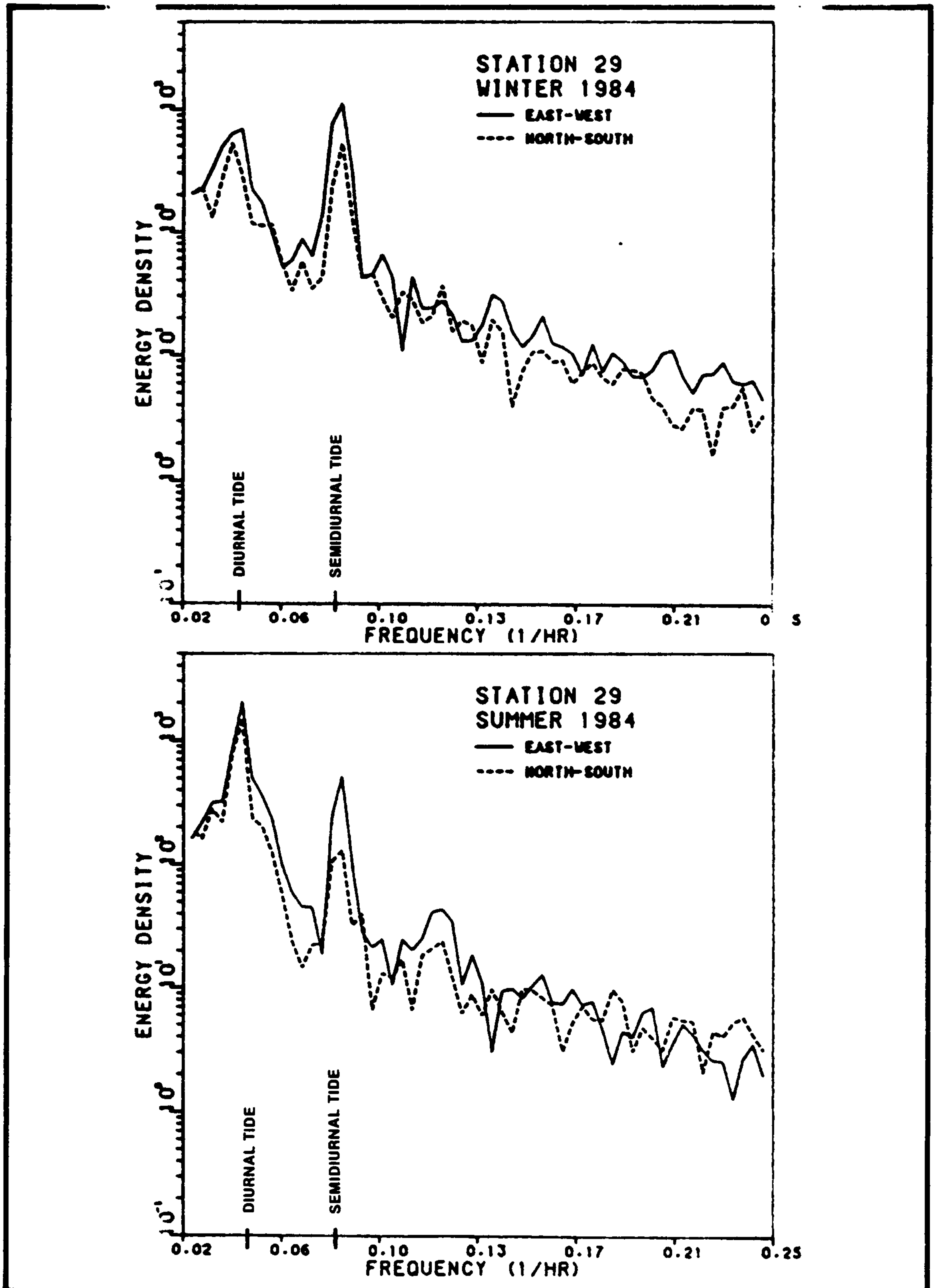


Figure 4.2-9 ENERGY SPECTRA, STATION 29

Table 4.2-1. Summary of Speed and Direction Frequencies

Station	Depth (m)	Month	Average Speed (cm/s)	Modal Speed (cm/s)	Modal Direction	Percent >40 cm/s	Percent >60 cm/s
52	13	December 1983	34	30-35	E	38	8
		January 1984	34	30-35	E	38	9
		February	32	30-35	E	33	8
		March	37	30-35	E	44	16
		April	35	40-45	E	41	13
		May	35	25-30	E	40	13
		June	22	10-15	E	15	2
		July	20	20-25	E	6	0
		August	22	20-25	E	12	2
		September	9	0-5	E	0.1	0
		October	7	0-5	E	0.6	0
23	74	December 1983	34	30-35	SE	30	1
		January 1984	30	25-30	SW	22	3
		February	23	15-20	SE	7	0.4
		March	21	15-20	SE	7	0.4
		April	22	15-20	W	10	1
		May	16	15-20	W	1	0
		June	25	20-25	NW	12	0.4
		July	12	10-15	NW	0.3	0.1
		August	17	20-25	NW	0	0
29	64	December 1983	40	30-35	S	48	10
		January 1984	29	25-35	SW	20	1
		February	24	20-25	W	7	0.1
		March	19	15-20	W	2.5	0.1
		April	22	15-20	W	6	0.1
		May	23	15-20	W	12	1
		June	31	20-25	NW	31	7
		July	20	10-15	NW	4	0
		August	16	10-15	NW	3	0
36	125	December 1983	24	25-30	S	8	0.2
		January 1984	26	10-15	S	20	4
		February	24	10-15	S	21	1
		March	13	0-5	S	0.6	0.2
		April	16	0-5	S	0.4	0.3
		June	15	10-15	N	0.2	0
		July	15	10-15	NW	0.8	0
		August	35	40-45	S	45	7
		September	32	20-25	S	33	4
		October	25	20-25	N	16	5
		November	15	15-20	S	0.4	0
		December	23	15-20	SE	4	2

At Station 52, tidal currents along the east-west axis predominate. Currents were stronger from December through May, when monthly speeds in excess of 40 cm/s occurred 33 to 44 percent of the time. In March and May, more than 2 percent of the observations exceeded 80 cm/s, and these high speeds were predominantly easterly. The principle direction for Year 4 current records was to the east (91°) which resulted from the strong east-west tide and a net southeasterly flow. Directions were more uniformly distributed at the other stations, and speeds tended to be lower.

At Station 23, the monthly occurrence of current speeds exceeding 40 cm/s ranged between 0.0 and 30.2 percent for December 1983 through August 1984. An increase in the average magnitude of the currents (≥40 cm/s) occurred for 30.2 and 21.4 percent of data records during December and January, respectively. Average percent occurrence for current speeds between 10 and 30 cm/s was 60.7 percent, and the average speed was 22.1 cm/s for the entire period of record. The principle direction of the *in situ* current energy was to the east-southeast (120°), but the current headings were more uniformly distributed because of near circular tidal ellipses.

The average current speed at Station 29 was 24.5 cm/s, and the principle direction of the *in situ* current energy was to the southeast (126°) for the period December 1983 to August 1984. Average percent occurrence for current speeds between 10 and 30 cm/s was 54.0 percent for this time period. The monthly occurrence of current speeds exceeding 40 cm/s ranged between 2.5 and 47.9 percent for the entire period of record. An increase in the average magnitude of the currents (≥40 cm/s) occurred for 47.9, 20.3, and 31.0 percent of these records during December, January, and June, respectively.

The average current speed at Station 36 was 22.1 cm/s, and the principle direction of the *in situ* current energy was to the south (174°). Average percent occurrence for current speeds between 10 and 30 cm/s was

54.2 percent for the period December 1983 to December 1984, May 1984 exclusive. The monthly occurrence of current speeds exceeding 40 cm/s ranged between 0.2 and 45.0 for this same period. The average magnitude of these currents ($\geq$40 cm/s) increased during the periods of January to February and August to September when the percent occurrence ranged between 19.7 to 21.0 and 45.0 to 32.7, respectively.

4.2.2 WAVES AND TIDES

Due to the failure of both Sea Data® Wave Gage instruments at Stations 21 and 52, the assessment of wave conditions during Year 4 is based on wave climatology from two gages located along the north and west periphery of the study area. Initially, a zone of significant wave energy is defined for Station 52 and compared to the zone of significant wave energy for the NDBC Data Buoy and University of Florida Coastal Data Networks' Clearwater and Venice Stations.

Figure 4.2-10 defines the locations of wave gages maintained by NOAA and the University of Florida Coastal Data Network in relation to shallow water Station 52. Emphasis on wave climate was placed on Station 52 because it was the only station exhibiting significant sediment resuspension, and simple calculations indicated that all other Group II stations were too deep for wave action to cause significant bottom orbital velocities. Based on the location of Station 52, the adjacent coastlines and the Florida Keys effectively block wave transmission and impose a fetch-limited wave condition. For these reasons, it was deemed appropriate to define a zone of significant wave energy for impingement directions between 210 and 340 degrees. Figure 4.2-10 further indicates the southwest to north-northwest directions from which significant wave energy can be expected to reach Station 52.

Although the Venice station is more comparable to Station 52 than either Clearwater or the NOAA station, the short time records preclude confidence in a statistical analysis of these wave data. However, further information was gained from examining the wave energy distributions for typical weather conditions. A discussion of wave conditions measured at these locations adjacent to the study area is presented to estimate the frequency of occurrence for wave height and period and the associated bottom orbital velocities for the contribution to sediment entrainment.

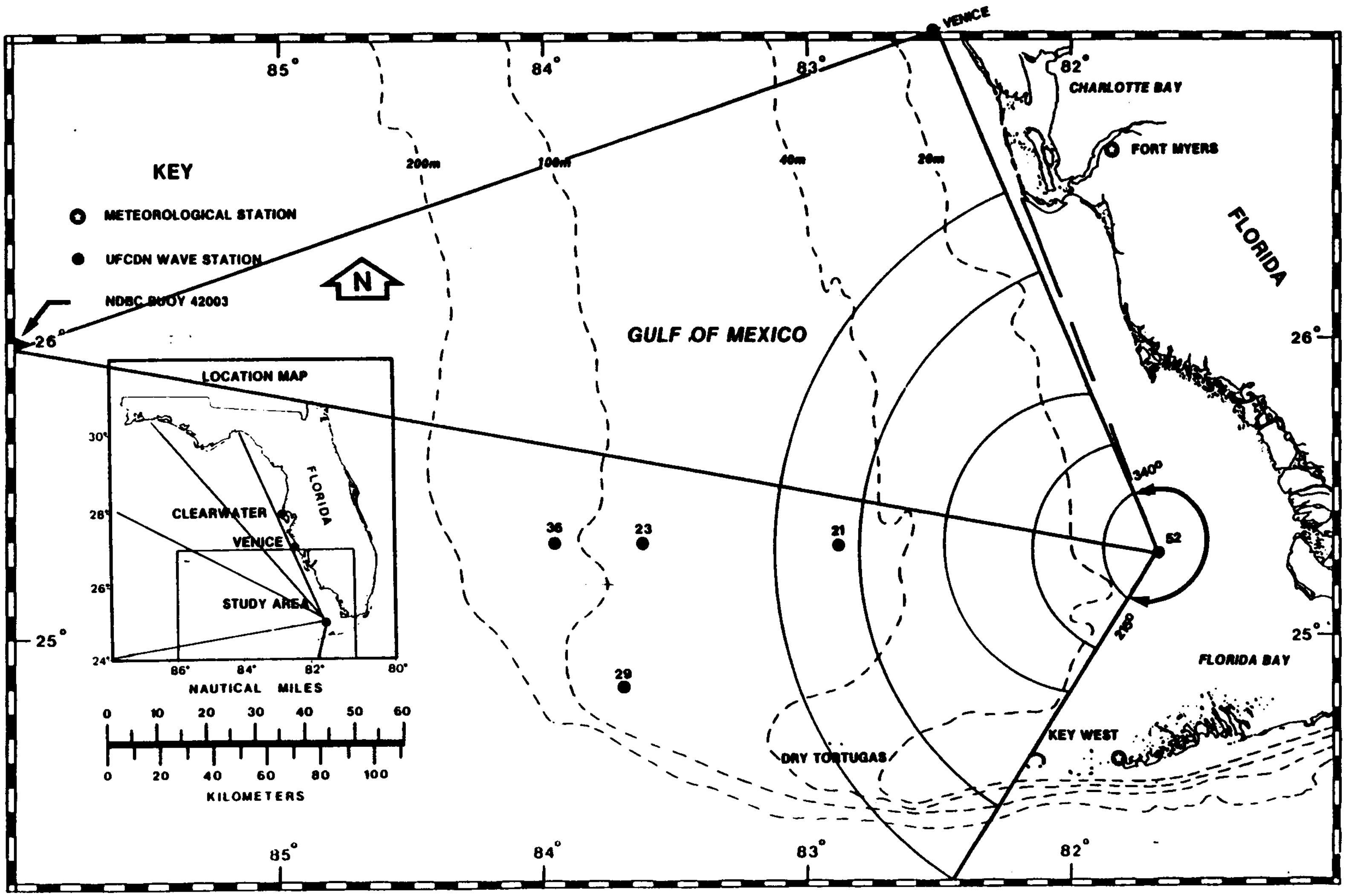


Figure 4.2-10 NOAA AND UFCDN WAVE GAGE LOCATIONS

Measured wave data were provided by the NOAA buoy located approximately 400 km west-northwest from Station 52. This buoy was maintained for a relatively long time period; therefore, these records are useful for defining the climatic frequency of specific wave events. The period of record at the offshore buoy for determining these frequencies was from 1976 to 1982 using approximately 24 500 observations. Significant wave height and average wave period are the two wave analysis parameters computed by the NDBC. Values recorded for significant wave height from storm conditions ranged between 2.0 and 9.0 m, although the majority of the measured waves were less than 1.5 m. The largest wave heights occurred during September, although the greatest percent frequency of extreme wave heights ($\geq$2.5 m) occurred between November and March. Table 4.2-2 summarizes the annual percent frequency of wave height versus wave period for the Clearwater station. The period of record for the Clearwater station was between 1982 and 1984, and the total number of observation days was approximately 430 days.

Extreme wave climates associated with strong west and northwest winds are usually due to passing frontal systems during the winter months. To estimate the wave climate at shallow water Station 52 relative to the offshore NOAA buoy location, a comparison of the wave energy distributions at Venice, Clearwater, and the NOAA stations is briefly discussed. Figure 4.2-11 presents the significant wave height, wave energy, and modal period for a passing frontal system occurring in March 1984 and which is typical for the late fall to early spring seasons. On March 27 and 28, strong west winds occurred changing to northwest on March 29. The dominant wave period agrees for all gage locations during the passage of the weather system. Although the time of peak wave energy occurred at each station on March 29 from 12:00 to 13:00 hours, the significant wave height varied between 4.8, 2.2, and 1.5 m for the NOAA, Venice, and Clearwater stations, respectively. A similar scenario occurred between April 4 and 7. The agreement in wave statistics is probably linked to a comparable fetch and relative direction for the Venice station, when winds are from the west and northwest in contrast

Table 4.2-2. Joint Distribution of Wave Height and Period for Clearwater, Annual 1982 to 1984

Significant Wave Height (m)	JOINT DISTRIBUTION OF HEIGHT AND PERIOD Peak Periods (s)						Total
	3 - 5	5 - 7	7 - 9	9 - 11	11 - 13	>13	
0.1-0.3	888	196	84	1	0	0	1169
0.3-0.6	212	100	45	2	1	0	360
0.6-0.9	40	30	30	3	0	0	103
0.9-1.2	17	7	17	3	0	0	44
1.2-1.5	16	3	9	4	0	0	32
1.5-1.8	5	0	3	3	1	0	12
1.8-2.1	2	0	0	0	0	0	2
2.1-2.4	0	0	0	0	0	0	0
2.4-2.7	1	0	0	0	0	0	1
>2.7	0	0	0	0	0	0	0
TOTAL	1181	336	188	16	2	0	1723

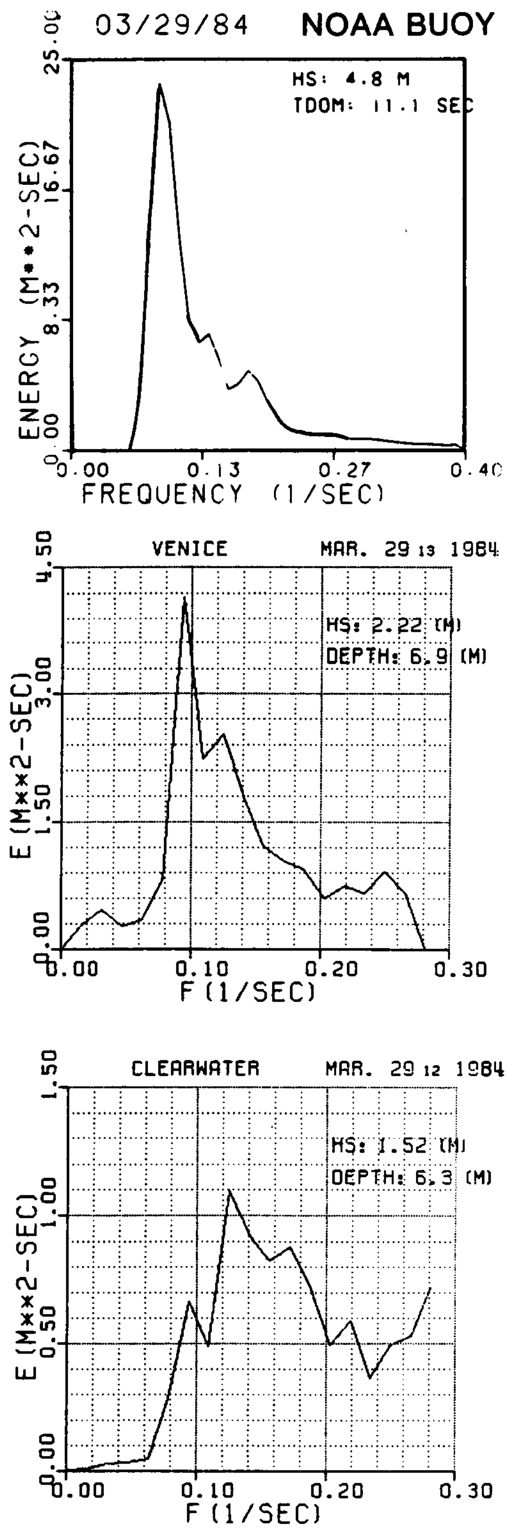


Figure 4.2-11 EXAMPLE FRONTAL SYSTEM FOR LATE FALL TO EARLY SPRING

to the Clearwater station which experiences more moderate wave conditions.

To estimate the relative contributions of waves on resuspending and entraining bottom sediments, calculations of maximum bottom orbital velocities were compiled based on the joint frequency of wave height and wave period from the NDBC Buoy and the Clearwater Station (Table 4.2-2). For average wave conditions, bottom orbital velocities were usually less than 20 cm/s, although these values increased significantly during storm conditions. These maximum bottom orbital velocities that theoretically occur are summarized in Table 4.2-3 for waves with variable height and periods. For example, a wave with a height of 2 m and a period of 7 s would produce a maximum bottom velocity of 55.8 cm/s as read from the table.

These table values were produced using linear wave theory for the water depth at Station 52. Applying the same theory to the wave statistics obtained from Clearwater and the NOAA buoy produces the expected frequency distribution of various wave energies at the bottom for Station 52. For reasons discussed previously, these results are not directly applicable to the study area because the waves were measured at distant sites. Considering the effects of shoaling and fetch limitations, it is clear that the wave records for the NOAA station result in greater wave energy than would normally occur at Station 52, and the wave energy at Clearwater is less than would be expected at Station 52. Consequently, the expected frequencies of occurrence of wave scouring velocities at Station 52 should be between those calculated from the NOAA data and those from the Clearwater station.

The results of these calculations are provided in Table 4.2-4 and present the frequency of occurrence of the maximum bottom orbital velocities using the joint frequency distributions of wave height and wave period for the Clearwater and NOAA stations. The results indicate the frequency of bottom orbital velocities exceeding 40 cm/s at

Table 4.2-3 Maximum Bottom Orbital Velocities (cm/s) at Station 52 for Waves of Various Height and Period

Wave Height (m)	Peak Period (s) 3	5	7	9	11	13	15
0.2	0.03	3.0	5.6	6.8	7.4		
0.5	0.08	7.5	14.0	17.0	18.6	19.5	20.0
0.8	0.12	12.0	22.3	27.2	29.7	31.1	32.0
1.1	0.16	16.4	30.7	37.4	40.8	42.8	44.0
1.4	0.21	20.9	39.0	47.6	52.0	54.5	56.1
1.7	0.25	25.3	47.4	57.8	63.1	66.1	68.1
2.0	0.30	29.8	55.8	68.0	74.2	77.8	80.1
2.5	0.37	37.3	69.7	84.9	92.8	97.3	100.1
3.0	0.45	44.7	83.7	101.9	111.3	116.7	120.1
3.5	0.52	52.2	97.6	118.9	129.9	136.2	140.1
4.0	0.60	59.6	111.6	135.9	148.4	155.6	160.1
4.5	0.67	67.1	125.5	152.9	167.0	175.1	180.2
5.0	0.75	74.5	139.5	169.9	185.5	194.5	200.2
6.0	0.75	89.4	167.4	203.8	222.6	233.4	240.2
7.0	1.05	104.3	195.3	237.8	259.7	272.3	280.3

Table 4.2-4 Maximum Bottom Orbital Velocities for Station 52 Using Joint Frequency Distributions of Wave Height and Wave Period for the Clearwater and NOAA Stations

U_{max} (cm/s)	Percent Frequency Clearwater Station	Percent Frequency NOAA Buoy
0.0-10.0	84.8	2.8
11.0-20.0	10.3	63.0
21.0-30.0	2.5	21.3
31.0-40.0	1.2	6.6
41.0-50.0	0.8	
51.0-60.0	0.2	
61.0-70.0	0.2	4.2
71.0-80.0		1.3
81.0-130		0.3
131-170		0.2
171-200		0.1

Station 52 is expected to be between 1 and 6 percent. It is reasonable to assume that under storm conditions the influence of waves on sediment resuspension is important, and during average wave conditions, the effects of waves are negligible. For the analysis of local wave measurement during Year 5, this approach will be used for determining the influence of waves on sediment transport within the study area. Also, the wave data being collected at Station 52 will be used to compute more accurately the wave statistics for that station.

4.2.3 SEDIMENT DYNAMICS

Analysis of time-lapse photography revealed no evidence of bed load transport. Small surficial sand features, including ripples and areas disturbed by the legs of the arrays, changed little if at all during the period of the time-lapse films. Although some bed load transport must occur during storms, the available data are richer in their ability to quantify suspended load. Theoretical estimates of bed load transport rates during storms will be compared with observed suspended sediment transport data during Year 5. This report focuses on suspended sediments, which appear to dominate transport rates on the inner shelf.

During Year 4, sediment traps were recovered from Stations 21, 23, 29, 36, and 52. Percent recovery exceeded 50 percent for Stations 21, 23, 29, and 52. Significant results for these stations will be reviewed and interpreted here.

The mass of dry, salt-free sediments collected by season and station is summarized in Table 4.2-5. The shallowest station (52) was the only station where appreciable amounts of sediment were collected. During the fall sampling period, 3 g of sediment per trap was collected 1 m above the bottom at Station 21, but all other traps collected less than 1 g per quarter. By visual inspection, the material collected in all traps having less than 1 g of sediment was predominantly comprised of algae which may have settled from the water column, but more likely grew within the traps. From these results, it is apparent that suspended sediment concentrations and sediment transport were appreciable only at Station 52, and perhaps Station 21, during the fall sampling period.

At Station 52, the mass of trapped sediments decreases from the bottom traps to the top traps. This pattern would be expected if the source of the suspended sediments is resuspension of bottom sediments. The pattern is less clear or nonexistent at Stations 21, 23, and 29, further indication that little or no sediment resuspension is occurring at these stations. The lack of data at bottom and upper traps for Station 21

Table 4.2-5. Mass of Sediments Trapped (g per trap/period)

Station	Depth of Station (m)	Elevation of Trap (m)	Season			
			Winter	Spring	Summer	Fall
52	13	0.5	110.0	77.8	ND	ND
		1.0	75.9	63.5	6.1	22.7
		1.5	60.0	47.5	6.3	20.3
21	47	0.5	ND	ND	ND	ND
		1.0	ND	ND	0.56	3.0
		1.5	ND	ND	0.54	ND
23	74	0.5	0.31	0.06	ND	ND
		1.0	0.14	0.04	ND	ND
		1.5	0.20	0.07	ND	ND
29	60	0.5	0.15	0.03	ND	0.76*
		1.0	0.12	0.05	0.10	ND
		1.5	0.12	0.04	ND	0.11

*This average value based on the inclusion of two replicates that contained a gastropod shell and carbonate nodules. If these two replicates were excluded, the average mass was 0.07 g.
ND = No data.

during the fall sampling period prevents observance of such a pattern in that instance. Data on particle size and composition suggest that sediment resuspension probably occurred at Station 21 during the fall. These data will be discussed later in this section.

Particle size distributions were determined for trapped sediments from Stations 52 and 21 during the fall sampling period. These data are summarized in Table 4.2-6. In nearly all samples of trapped sediments, the silt-sized particles predominate, comprising an average of 46 percent of the samples by weight. Thirty-six percent of the trapped sediments were in the clay fraction, with only 18 percent sand. By contrast, bottom sediments in the study area are predominantly sand sized, comprising 98 percent of the bottom grab samples. These results suggest that kinetic energy at the seafloor is rarely intense enough to resuspend sand-size particles, although frequently intense enough to resuspend silt and clay sizes. Since the bottom sediments are practically devoid of silt and clay sizes throughout the study area, these fine particles may remain suspended for a long time and be carried out of the study area before being redeposited. An alternative interpretation is plausible, however. The fine particles on the shelf bottom comprise a small but rapidly cycling reservoir, frequently resuspended and resettled, while the large bulk of the bottom sands is relatively immobile with respect to resuspension. Data evaluation methods to be implemented in Year 5 will permit the distinction between these two plausible explanations (see Section 4.2.4). In summary, trapped sediments are significantly finer than bottom sediments. At the deep water Stations 23, 29, and 36, the trapped material is predominantly algae, while at Station 52 the trapped material appears to be resuspended bottom sediments.

The $CaCO_3$ and organic carbon content of the trapped materials from Stations 52 and 21 are summarized in Table 4.2-7. $CaCO_3$ is the dominant constituent of all trap samples exceeding 1 g per trap. The most interesting pattern observed in these data is a tendency for

Table 4.2-6. Particle Size Distribution of Trapped Sediments

Station	Season	Elevation of Trap (m)	Percent Sand	Percent Silt	Percent Clay
52	Winter	0.5	24	45	31
		1.0	9	52	39
		1.5	11	55	34
	Spring	0.5	14	51	35
		1.0	7	49	44
		1.5	10	44	46
	Summer	1.0	9	Silt + Clay = 91*	
		1.5	34	33	33
	Fall	1.0	28	37	35
		1.5	30	37	33
21	Fall	1.0	10	58	32

*Insufficient amount of sample for pipette analyses; therefore, differentiation into silt and clay was not possible.

Table 4.2-7. Composition of Trapped Sediments

Station	Season	Elevation of Trap (m)	Percent $CaCO_3$	Percent Organic Carbon
52	Winter	0.5	86	11
		1.0	84	17
		1.5	78	13
	Spring	0.5	71	11
		1.0	70	11
		1.5	70	13
	Summer	1.0	59	20
		1.5	65	19
	Fall	1.0	69	15
		1.5	64	17
21	Fall	1.0	59	21

$CaCO_3$ content to increase as the mass of sediment trapped increases ($r = 0.89$). On the other hand, there is a slight tendency for the organic carbon content to be lower in traps with large sediment mass ($r = -0.22$), although this relationship is not statistically significant. These relationships suggest that during periods when large amounts of suspended sediments were trapped, those sediments were predominantly $CaCO_3$, while the organic carbon sedimentation rate may have been more constant throughout Year 4. Thus, when carbonate-rich sediments are stirred up during storms and deposit rapidly in the traps, these sediments tend to dilute the sample with respect to organic carbon. Some of the measured organic carbon undoubtedly resulted from growth within the sediment tube as the traps were usually biofouled upon retrieval.

The mineralogy of the trapped sediments as determined by X-ray diffraction was calcite and aragonite in roughly similar proportions with a small amount of quartz. The aragonite is probably associated with shell fragments, while the calcite was probably derived from the limestone hard rock bottom.

Diffractograms were obtained from a powder mount of the bulk sample, an oriented slide of the insoluble residue, and an oriented slide of the clay-size particles. The diffractogram of the bulk sample indicated the presence of both calcite and aragonite based upon the presence of their strongest peaks, 3.03 and 3.39 angstroms, respectively, and numerous characteristic but less intense peaks.

The insoluble residue showed the presence of quartz, based upon the occurrence of its strongest peak at 3.30 angstroms and numerous other characteristic peaks of less intensity. No other minerals were detected. The diffractograms of the clay-sized particles, like the bulk samples, indicated the presence of calcite and aragonite. No true clay minerals were detected in the clay-sized materials.

Detailed Evaluation of Station 52

Since Station 52 was the only station where appreciable quantities of sediment were trapped, a more detailed analysis of these traps was performed according to the sedimentological analysis procedures described in Section 3.2.1. Specifically, the samples were sectioned at 2-cm intervals through the length of the trap prior to analysis. The objective was to determine the variations in the composition of trapped sediments which might be related to specific storm events. Results from Station 52 are presented in Figures 4.2-12 and 4.2-13. The vertical axis for all these graphs (fraction of total deposition) is defined as the height of the sample from the bottom of the trap divided by the total thickness of sediment in the traps. By this normalized length scale, trapped sediments from different elevations during the same sampling period can be compared more readily. It can be assumed that samples from the same fraction of total deposition (equivalent elevations on the graphs) were deposited at approximately the same time. Only the winter and spring sampling periods are presented graphically since these were the only periods when more than 30 g of sediment were trapped, providing enough sediment to section in this fashion.

The most interesting results were obtained from the winter sampling period (Figure 4.2-12). During the middle of the period, several sections from the bottom sediment trap had high levels of sand (up to 58 percent). No other samples from sediment traps had more than 35-percent sand. This period clearly reflects the most intense sediment resuspension event observed during Year 4. These sections of the trap also exhibited high $CaCO_3$, low clay, and low organic carbon, as expected. It is also clear that the "signature" of this event is largely confined to the bottom-most traps of Station 52, located 0.5 m above the bottom. The middle trap, 1.0 m above the bottom, shows slightly elevated percent sand and $CaCO_3$, reduced clay and organic carbon at the same fraction of total deposition, although the intensity of the event was much less at this middle trap. The upper trap at 1.5 m off the bottom does not follow the pattern. Thus, the most dramatic

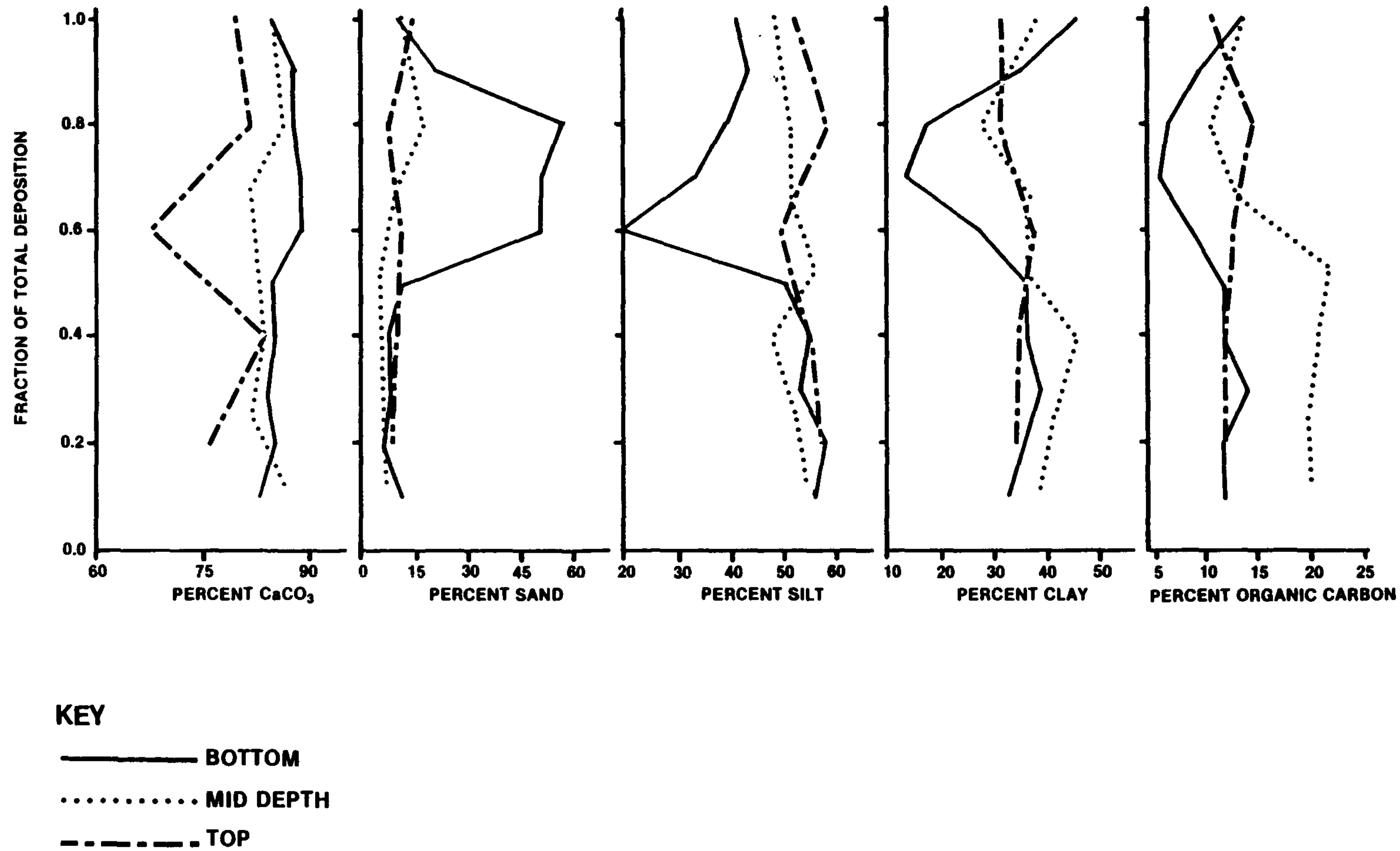


Figure 4.2-12 SEDIMENT CHARACTERISTICS FOR STATION 52 *IN SITU* ARRAY TRAPS FROM DECEMBER 10, 1983, TO MARCH 2, 1984

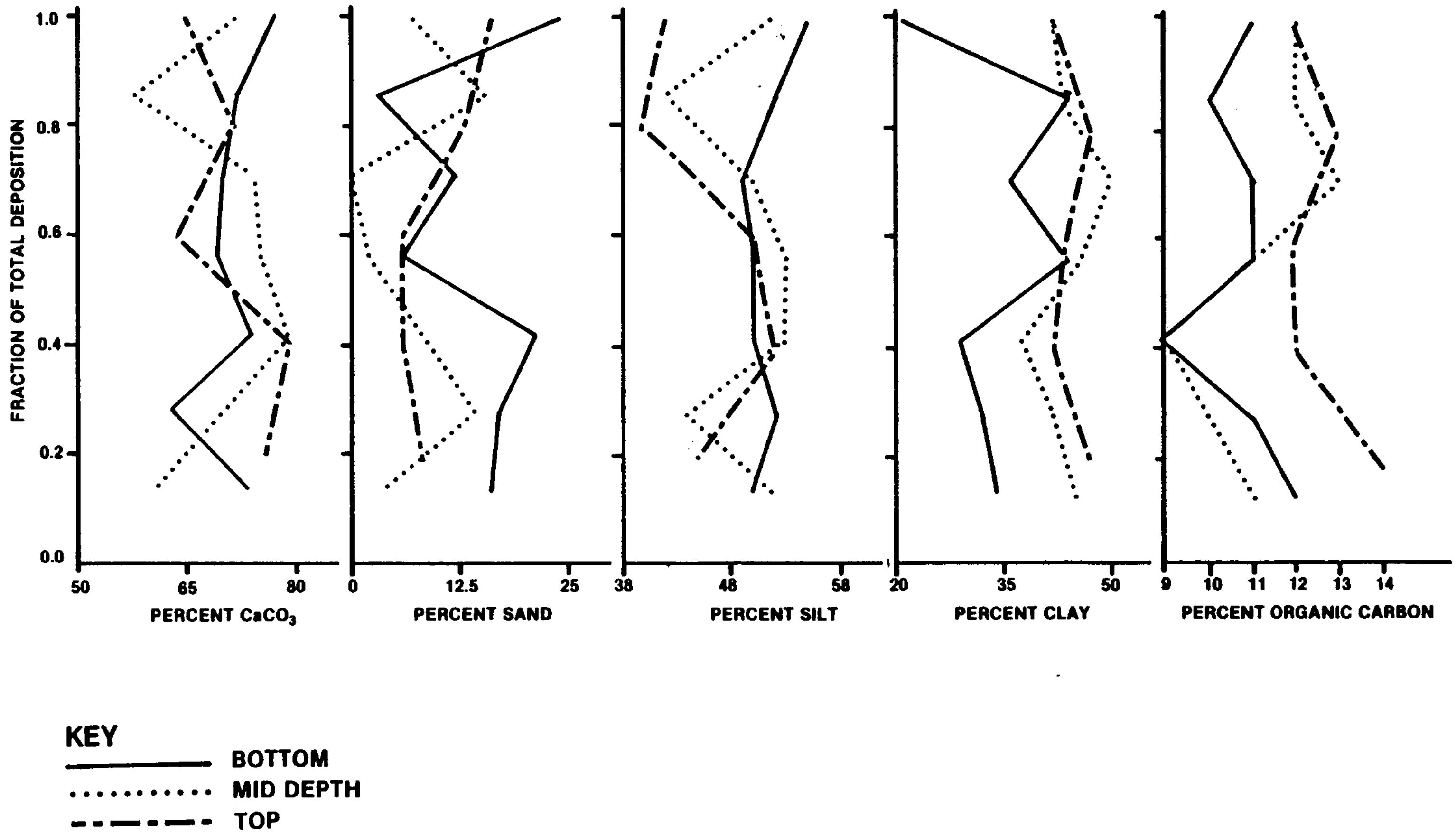


Figure 4.2-13 SEDIMENT CHARACTERISTICS FOR STATION 52 *IN SITU* ARRAY TRAPS FROM MARCH 2, 1984, TO MAY 12, 1984

resuspension event of Year 4 was not intense enough to lift significant quantities of sand more than about 1 m off the sea floor.

Deposition Rates

The average deposition rates during the sampling period are calculated by dividing the mass deposited by the period the trap was deployed. The rate is expressed in units of $g/cm^2/day$, after dividing by the surface area of the trap. Actually, deposition is sporadic, occurring only during and just after resuspension events. The average deposition rate during the periods when deposition occurred was estimated by dividing the sampling period average deposition rate by the fraction of time when visibility was obscured by suspended sediments, as recorded by time-lapse camera. Deposition rates calculated by these two methods are presented in Table 4.2-8.

Suspended Sediment Concentrations

Suspended sediment concentrations within given size ranges can be estimated using the following equation:

$$SS_i = \frac{D_i}{V_i}$$

where: SS_i = suspended sediment concentration within size classification i (g/cm^3),

D_i = deposition rate for size classification i ($g/cm^2/day$), and

V_i = representative settling velocity for particles within size classification i.

The total suspended sediment concentration is given by summing the contributions of the size ranges:

$$T_{SS} = \sum_{i=1}^{n} SS_i$$

Table 4.2-8. Rates of Deposition in Sediment Traps

Station	Season	Elevation of Trap (m)	Average for Sampling Period ($g/cm^2/day$)	Average During Periods of Obscuration ($g/cm^2/day$)
52	Winter	1.5	0.050	0.115
		1.0	0.064	0.146
		0.5	0.092	0.211
	Spring	1.5	0.050	0.185
		1.0	0.067	0.248
		0.5	0.082	0.303
	Summer	1.5	0.005	ND
		1.0	0.005	ND
	Fall	1.5	0.014	NO
		1.0	0.015	NO
21	Fall	1.0	0.003	NO

ND = No data from time-lapse camera.
NO = Visibility was not impaired during the period of time-lapse camera record.

For purpose of this analysis, the various sized particles observed in the traps have been separated into three size classifications. Very fine particles are those smaller than 0.004 mm diameter ($\phi \geq 8$) and includes clays. Fine particles have a diameter greater than 0.004 mm but less than 0.04 mm ($4.65 \leq \phi < 8$) and include medium and fine silts. Coarse particles are those exceeding 0.04 mm in diameter ($\phi < 4.65$) and include coarse silts and sands. These particle size classifications, based on particle diameter rather than ϕ sizes, each represent approximately one-third of all sediments from the sediment traps. By using these size classifications, it is expected that suspended concentrations could be estimated more accurately than could be obtained by arbitrarily categorizing the size range as percent sand, silt, or clay. More precise estimates could be obtained by further disaggregation of the size distribution (i.e., defining more categories), but the degree of disaggregation selected is consistent with the overall precision of this method for estimating suspended sediment concentrations and the precision of the available data.

Representative settling velocities for these size categories are as follows: very fine-0.002 cm/s, fine--0.02 cm/s, and coarse--0.4 cm/s. These were calculated by Stokes law after assuming that clays flocculate in marine waters, forming aggregates in the very fine silt size range ($\phi = 8$, $d = 0.004$ mm). The settling velocities have been calculated for each sampling period, accounting for the effects of seasonal temperature changes on the viscosity of seawater.

Finally, to estimate suspended sediment concentrations during and following storm events, the fraction of the sampling period when significant suspended solids were present was estimated as periods of 0 to 25 percent visibility from the time-lapse photography. It is estimated that suspended sediment concentrations were at least a factor of 5 greater during these periods than in periods of 50 to 100 percent visibility, so periods of higher visibility have negligible suspended sediments.

Applying these assumptions and equations, the typical storm-related suspended sediment concentrations in the defined size categories, as well as total suspended solids, are plotted in in Figure 4.2-14 as a function of elevation above the sea floor at Station 52. No graph is presented for the summer period, since insufficient sample was collected to perform the pipette analysis in the silt and clay range for the 1.0-m elevation trap from this period.

The contribution of the coarse fraction to suspended sediment levels at the 1.5-m level during the summer was 0.06 mg/L; the fine fraction contributed 0.7 mg/L; while the very fine fraction contributed 11 mg/L to the calculated total suspended solids concentration of 12 mg/L. These results consistently indicate that the suspended sediments at Station 52 are comprised predominantly of particles in the very fine size range (clays and fine silts). This interpretation may have a source of error, however. The calculation procedure used here is sensitive to the effective settling velocity of the very fine particles. It is well known that clays tend to flocculate in marine waters, forming aggregates whose effective size and settling velocity far exceed the settling velocity of disaggregated clay particles. The calculation procedure accounts for this by assuming that all the very fine fraction exhibits the settling velocity of very fine silt. The actual settling velocity of these particles is unknown and could be greater than the velocity used in these calculations. If so, the suspended concentration of very fine sediments and the total suspended solids concentrations would be much less than is indicated in Figure 4.2-14. This analysis suggests that, during storms, total suspended solids concentrations ranged from 5 to 700 mg/L in the region from 0.5 to 1.5 m above the sea floor at Station 52. The contribution of sand-size particles to the total suspended solids concentration is consistently less than 1 percent. Most of the suspended sediment is in the clay, fine and medium silt-size range. Suspended sediment concentrations are consistently higher near the sea floor than at higher elevations in the water column.

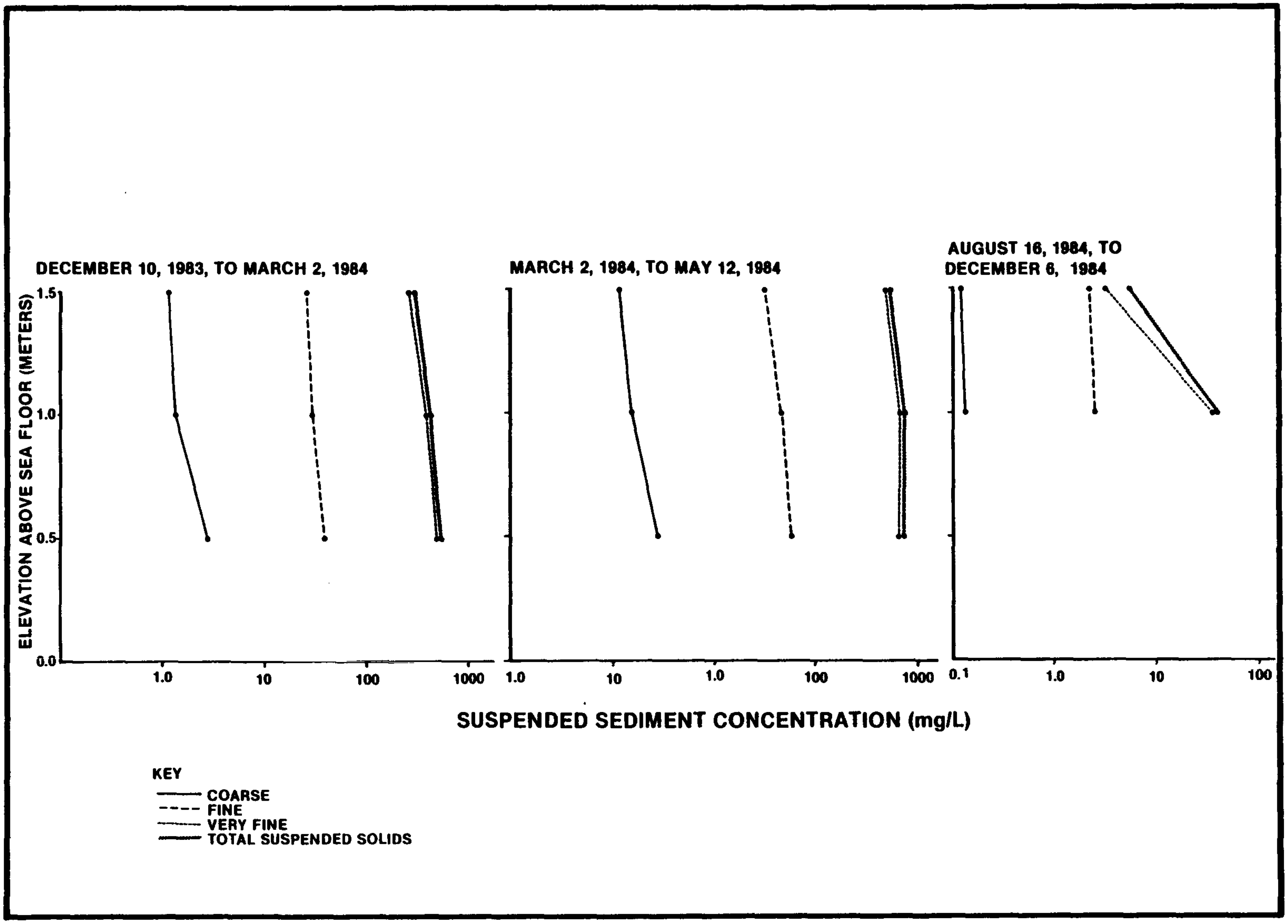


Figure 4.2-14 SUSPENDED SEDIMENT CONCENTRATIONS

4.2.4 SYNTHESIS AND INTERPRETATION

Based on Year 4 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. These conclusions are based on the following interpretations of the Year 4 data.

Substantial quantities of sediment were trapped (resuspended) only at Station 52 at a depth of 13 m. A minor amount of sediment was trapped during the fall at Station 21 at a depth of 47 m. There was no evidence of sediment resuspension at Stations 23, 29, and 36 in depths of 74 m, 60 m, and 126 m, respectively. Thus, to identify the mechanisms responsible for sediment transport, the first task is to identify the difference between Station 52 and the other stations. Obviously, it is the shallowest, and surface waves will generate higher bottom orbital velocities in shallower waters. Resultant current vectors (net drift) are greater at the deep water stations than at 52. Although net drift is a good indication of the ability of current to transport suspended sediments, extreme currents are required to resuspend sediments initially. The lower net drift at Station 52 reflects the dominant contribution of oscillating tidal flow. Average current speeds at Station 52 are slightly higher than at Stations 23, 29, and 36 because of the strong tidal currents at Station 52. The most important statistic, however, is the frequency of current speeds exceeding 60 cm/s. These data are illustrated in Figure 4.2-15, which shows that extreme bottom currents capable of resuspending sediments were much more prevalent at Station 52 in the winter and spring than at any other station in any other season. Winter and spring were also the seasons when the greatest quantities of suspended sediments were trapped at Station 52. The frequency of currents exceeding 60 cm/s at the nearest current meter is closely correlated with the quantity of sediments trapped ($r = 0.83$, significant at 99-percent confidence). Nonetheless,

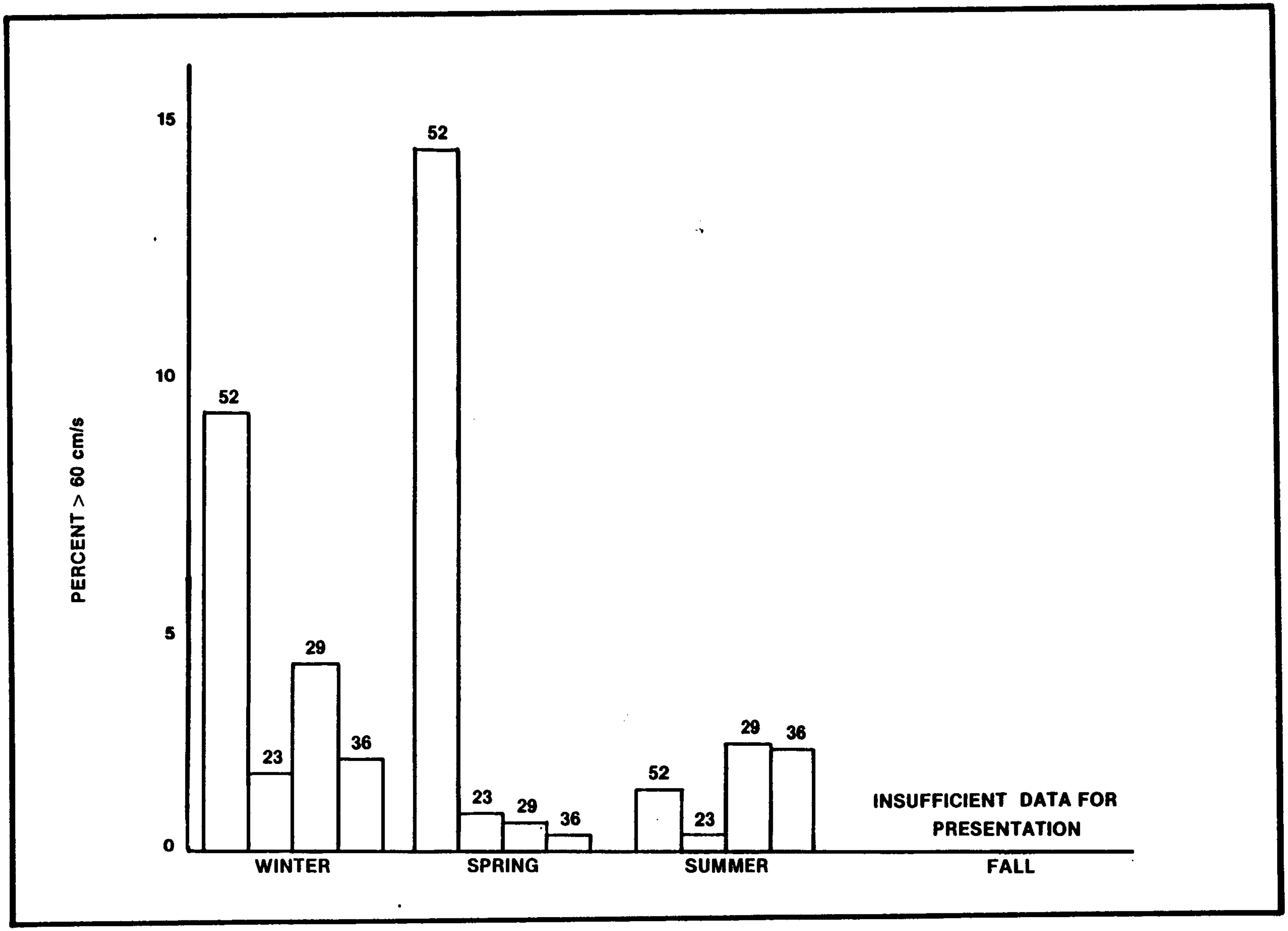


Figure 4.2-15 FREQUENCY OF EXTREME BOTTOM CURRENTS

extreme currents alone explain only about two-thirds of the variability in trapped sediment mass. For example, in the fall, currents at Station 52 never exceeded 60 cm/s, and the frequency of currents in excess of 40 cm/s was lower than observed during the summer at that station (0.4 percent in fall versus 11 percent during the summer), yet the mass of trapped sediments was more than three times greater in the fall than in the summer. As another example, currents during the winter at Station 29 exceeded 60 cm/s 3.7 percent of the time, more frequently than observed at Station 52 in either the summer or fall, yet negligible amounts of sediments were trapped at Station 29 in comparison with Station 52.

Thus, it appears that wave-generated bottom orbital velocities are responsible for some fraction of the sediment resuspension. Wave-generated currents are apparently a secondary contributing factor, since bottom orbital velocities are somewhat less than the flows observed by the current meters. In Section 4.2.2 it was concluded that bottom orbital velocities exceeding 40 cm/s occur 1 to 6 percent of the time at Station 52, while currents exceeding 40 cm/s occurred 25 percent of the time in Year 4. Currents in excess of 60 cm/s occurred 6.5 percent of the time at Station 52 during Year 4 (14 percent during the spring), while bottom orbital velocities exceeding 60 cm/s occurred less than 6 percent of the time. Nonetheless, they are important contributing factors since the current meters recorded high speeds, in excess of 60 cm/s at both deep and shallow stations, but only the shallowest (52) experienced significant sediment resuspension.

These data support the findings of Cooper (1982), in that Station 52 net drift was to the southeast and was stronger in winter and spring than in the summer. Since Cooper's results indicate that net drift in the vicinity of Station 52 is predominantly wind driven, then wind-driven currents are an important driving force for sediment transport on the shallow Inner Shelf. The tidal ellipse at Station 52 is strongly dominated by an east-west major axis reinforcing the southeast wind-driven net flow on the flood tide. Cooper's model also indicates a strong vertical, wind-driven shear in this region, and shear-generated turbulence will enhance sediment resuspension. Wave-generated orbital velocities further enhance the bottom shear stress which ultimately drives sediment resuspension and transport.

On a theoretical basis, the intrusions of the Loop Current bring currents to the Outer Shelf strong enough to initiate sediment transport. The sediment trap data, however, showed no significant sediment resuspension as a result of these events. This provides further evidence that wave action is an important contributing factor in sediment resuspension on the Inner Shelf.

4.3 INTERSITE COMPARISONS AND RELATIONSHIP TO THE PHYSICAL ENVIRONMENT

4.3.1 GROUP I SOFT-BOTTOM STATIONS

The station occurrences of each of the 414 taxa are depicted in a presence-absence table (Table E-24, Appendix E). Of the taxa which were identified to the genus or species level, 50 occurred at 5 or more stations out of 10 (5 stations sampled 2 times). These taxa are listed in Table 4.3-1. The amphipods *Acuminodeutopus naglei* occurred only in December 1983 samples, and *Argissa hamatipes* occurred only in May 1984 samples.

The hierarchical dendrogram produced by normal cluster analysis of 400 binary variables with the Bray-Curtis dissimilarity coefficient and group-average sorting is presented in Figure 4.3-1. Over the entire infaunal collections, the stations were 0.619 dissimilar. Stations 46 and 48 sampled in May 1984 were the least dissimilar at the 0.416 level. Station 50 sampled in December 1983 was the most dissimilar station at the 0.619 dissimilarity level. This same station sampled in May 1984 was, however, linked with Station 43 sampled in May 1984 at the 0.496 dissimilarity level. The only station which linked with itself before linking with any other station was 49, which clustered at the 0.495 dissimilarity level.

Figure 4.3-2 is the hierarchical dendrogram of those 86 taxa which were equal to or greater than 0.9 percent of the total mean density for at least one station. The dendogram was produced using the Bray-Curtis dissimilarity coefficient, group-average sorting, and log transformed data. Station clustering was nearly identical to that produced by binary data. The dissimilarity of the stations, however, was less based on the classification of the 86 numerically dominant taxa. Overall, the stations sampled in December 1983 and May 1984 were 0.459 dissimilar. As in the binary classification, Station 49 in the numeric classification was the only station which linked with itself before linking with another station.

Table 4.3-1. Genera and Species Which Occurred in Five or More Station Collections

Acanthohaustorius sp. A (A)*	Leptochela serratorbita (D)
Acuminodeutopus naglei (A)	Leptochelia sp. A (T)
Aglaophamus verrilli (P)	Listriella barnardi (A)
Ampelisca spp. (A)	Lucifer faxoni (D)
Ampelisca agassizi (A)	Lumbrineris verrilli (P)
Anchialina typica (M)	Magelona pettiboneae (P)
Aoridae genus B. (A)	Mediomastus californiensis (P)
Argissa hamatipes (A)	Metharpinia floridana (A)
Aricidea spp. (P)	Minuspio sp. (P)
Armandia maculata (P)	Myriochele spp. (P)
Axiothella mucosa (P)	Nephtys simoni (P)
Branchiostoma caribaeum (Cp)	Olivella minuta (G)
Calyptraea centralis (G)	Onuphis nebulosa (P)
Campyclaspis spp. (C)	Owenia sp. A (P)
Cerapus sp. A (A)	Oxyurostylis smithi (C)
Chione spp. (B)	Paraprionospio pinnata (P)
Cirrophorus spp. (P)	Photis macromanus (A)
Cumella spp. (C)	Polygordius sp. (P)
Cyclaspis spp. (C)	Prionospio cristata (P)
Cyclaspis cf. unicornis (C)	Processa hemphilli (D)
Eudeuenopus honduranus (A)	Serpula spp. (P)
Exogone dispar (P)	Synchelidium americanum (A)
Garosyrrhoe sp. A (A)	Synelmis sp. B (P)
Gouldia cerina (B)	Tellina spp. (B)
Kalliapseudes sp. A (T)	Xananthura brevitelson (I)

*Key:
A = Amphipoda.
B = Bivalvia.
C = Cumacea.
P = Polychaeta.
T = Tanaidacea.
I = Isopoda.
D = Decapoda.
M = Mysidacea.
Cp = Cephalochordata.

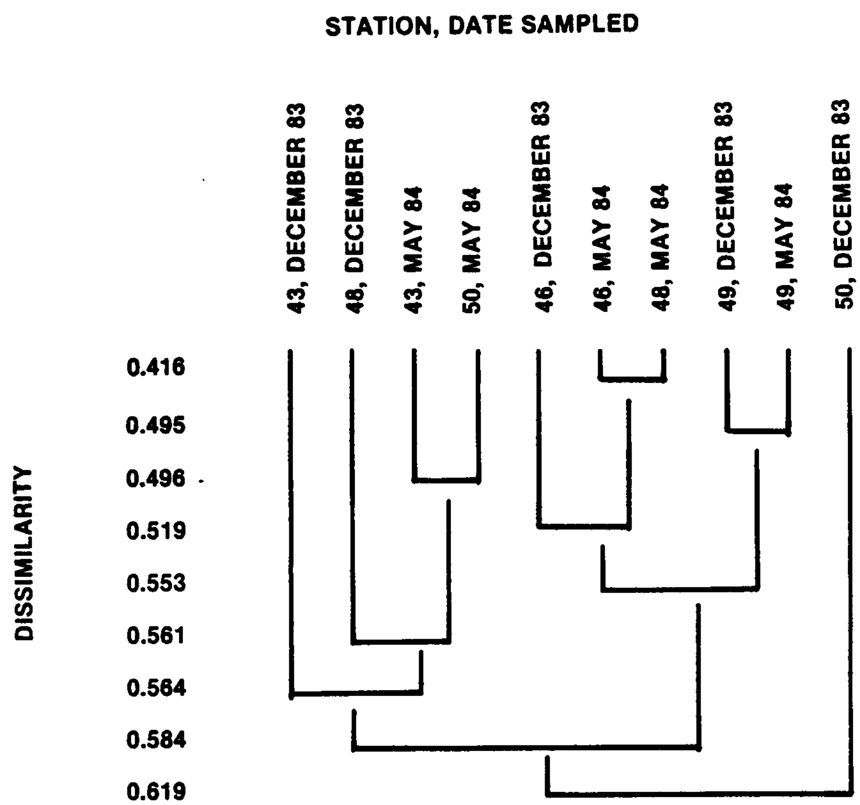


Figure 4.3-1 DENDROGRAM PRODUCED BY CLUSTER ANALYSIS OF 400 BINARY INFAUNAL VARIABLES

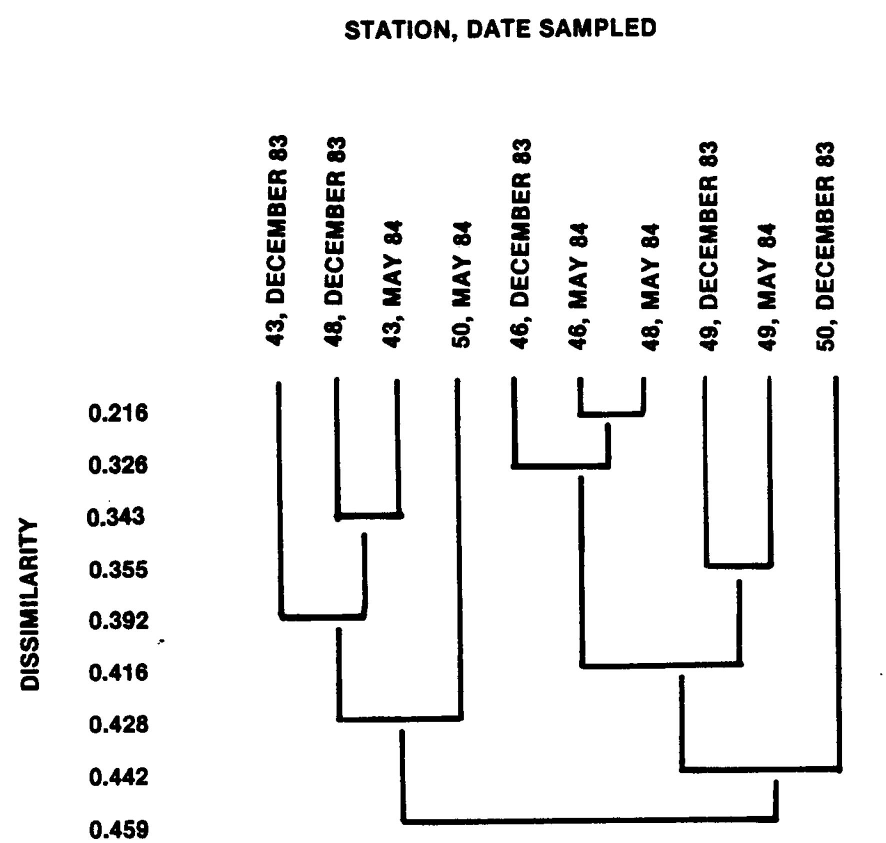


Figure 4.3-2 DENDROGRAM PRODUCED BY NORMAL CLUSTER ANALYSIS OF 86 NUMERICALLY DOMINANT INFAUNAL TAXA

The results of both the binary classification and the numerical classification showed that the level of dissimilarity of soft-bottom infaunal communities was relatively low, or conversely, the similarity between stations was relatively high. This is not unexpected since the stations were all located within a narrow range of depths and a narrow range of sediment types. The station depths ranged from 11 to 18 m. The fact that Station 49 was the only station which clustered with itself in both classification strategies may be due to the depth and sediment chemistry of the station. Station 49 was the shallowest station (11 m), whereas the remaining four stations were between 16 and 18 m deep. Additionally, sediments at Station 49 were low in both $CaCO_3$ (22.9 percent) and organic carbon (0.9 percent) relative to all other stations (see Table 4.1-2). No clustering of stations was readily apparent by sediment grain size. All stations were predominantly sand size sediments ranging from medium sand to fine sand, with medium sand stations clustering with fine sand stations. There was also no readily apparent clustering of stations by sampling season.

The calculated station dissimilarities may be slightly low due to the inclusion of groups of animals which were not identified to the genus or species level. Inspection of Tables 4.3-2, 4.3-3, and 4.3-4 shows that these groups, particularly oligochaetes, ostracods, and rhynchocoels were widespread and numerically important in all collections. These groups were undoubtedly composed of more than one species. However, these same three tables also show a great deal of commonality between stations in the distribution of taxa at the genus and species levels. These taxa which may be considered characteristic of the majority of stations were Branchiostoma caribaeum, Ampelisca spp., Cyclaspis spp. (predominantly Cyclaspis sp. A), Axiothella mucosa, Mediomastus californiensis, Synchelidium americanum, Sabellidae spp. (subfamily Fabricinnae), Armandia maculata, Exogone dispar, Metharpinia floridana, Photis macromanus, Polygordius sp., Xenanthura brevitelson, Oxyurostylis smithi, Paraprionospio pinnata, Prionospio cristata, Cyclaspis unicornis, Aoridae genus B, Eudeuenopus honduranus,

Table 4.3-2. Station Occurrences of 86 Numerically Dominant (≥0.9 Percent of Total Density) Taxa

	Stations									
	December 1983					May 1984				
	43	46	48	49	50	43	46	48	49	50
Ampelisca spp.	X	+	+	+	+	+	X	+	+	+
Branchiostoma caribaeum	X	+	X	+	+	X	+	+	+	X
Cirrophorus spp.	X	+	X	X	X	X	+	+	X	+
Cyclaspis spp.	X	X	+	X	+	X	X	X	X	X
Axiothella mucosa	X	X	X	X	+	X	+	+	X	+
Mediomastus californiensis	+	X	+	X	+	X	X	X	+	+
Oligochaeta spp.	X	X	X	X	X	X	X	X	X	X
Ostracoda spp.	X	X	X	X	X	X	X	X	X	X
Rhynchocoela spp.	X	X	X	X	X	X	X	+	X	+
Synchelidium americanum	+	+	+	+	+	+	+	X	+	+
Sabellidae spp.	+	X	X	X	X	X	X	X	X	X
Aricidea spp.	X	X	X	+	X	X	+	+	+	
Armandia maculata		X	X	X	X	X	X	X	X	X
Bryozoa spp.	X	X	X	+	X	X	+	X		X
Exogone dispar	X	X	X	+	X	+	+	+		+
Metharpinia floridana	X	+	+	+		+	X	+	+	+
Photis macromanus	+	+	+	X		+	+	+	+	+
Sipuncula spp.	X		+	+	+	+	+	+	+	X
Ophiuroidea spp.		+	+	+	X	X	X	X	+	X
Tellina spp.	X	+	+		+	X	+	+	+	X
Polygordius sp.	+	X	+	X			X	X	X	+
Xenanthura brevitelson		X	+	+	+	+	X	+	+	X
Oxyurostylis smithi	X		+	+	+		+	X	+	+
Paraprionospio pinnata	X	X		+		+	X	X	X	+
Prionospio cristata		X	+	+	X		+	+	X	X
Bivalvia spp.	X	+	+				X	+	X	+
Cyclaspis unicornis	X	+	+	+			+	+		+
Aoridae spp.	X		+			+	+	X	+	X
Eudeuenopus honduranus	X	+		X	+		+	+	X	
Lumbrineris verrilli		+	X	+			+	+	+	+
Minuspio sp.		X	+	X	X		+	+		+
Anchialina typica	+			+		+	+	X		+
Cerapus sp. A	+			X		+	+	+		+
Lucifer faxoni	X			+	+	+			+	+
Magelona pettiboneae				+	+	+		+	X	+
Maldanidae spp.	X	+	+		+		+	+		+
Leptochelia sp. A	X	X	X	X	X	+				
Monoculodes nyei		+			+		X	X	X	+
Mysidopsis furca			+		+		+	X	+	+
Owenia sp. A		+		+			X	+	+	+
Nereidae sp.	X	+	+	+		+		+		
Syllidae spp.			X	+	+	X			+	X

Table 4.3-2. Continued

	Stations									
	December 1983					May 1984				
	43	46	48	49	50	43	46	48	49	50
Aglaophamus verrilli		+		+			X	X	+	
Aricidea taylori		+			X		+	+		+
Aricidea philbinae		+		X	+		+		X	
Glottidia pyramidata	+	X	+	+				+		
Echinoidea spp.	+		+			+	+	X		
Magelona spp.		+	+	X	+				+	
Sphaerosyllis spp.			+	+		X			X	X
Synelmis sp. B	+	X	+		+	+				
Apseudes propinquus			X	X	+					+
Aricidea finitima		+			X			+		+
Caulleriella alata					X	+			X	+
Goniadides carolinae	+		X			X				X
Heteropodarke spp.	+		+			X				+
Lembos spp.		+	+		X			+		
Mitrella lunata	+	X					+			+
Spio pettiboneae						X	+		X	X
Tiron tropakis	X			+					+	+
Ancistrosyllis hartmanae	+		+			X				
Aricidea catherinea		+			X			+		
Glycers sp.	X							+		+
Podocerus sp. A					+	+				X
Poecilochaetus jonhsoni			+				X		+	
Protodorvillea kefersteini			+			X				+
Sphaerosyllis aciculata				+					X	X
Streptosyllis pettiboneae				+					X	+
Ceratocephale oculata		+					X	X		
Nephtydae spp.						X	+			+
Chevalia aviculae	X					X				
Haploscoloplos spp.				+					X	
Hydroides bispinosa				X					+	
Encope spp.							+			X
Litocorsa sp.			X			+				
Lysianopsis sp. A		X			X					
Plakosyllis quadrioculata						+				X
Pseudovermilia spp.	X			+						
Prionospio dayi				+			X			
Caulleriella spp.				X						
Chone spp.										X
Lembos unifasciatus reductus		X								
Nereis spp.					X					
Ophelina spp.										X

Table 4.3-2. Continued

	Stations									
	December 1983					May 1984				
	43	46	48	49	50	43	46	48	49	50
Pholoe spp.										X
Schistomeringos rudolphi					X					
Terebellidae sp. A	X									

+ = taxon present.
X = taxon present and ≥0.9 percent of total density.

Table 4.3-3. Numerically Dominant Infaunal Taxa (≥0.9 Percent of Total Density) from December 1983 in Order of Abundance

Group I Soft-Bottom Stations				
43	46	48	49	50
Ostracoda spp.	Polygordius sp.	Bryozoa spp.	Leptochelia sp. A	Sabellidae spp.[4]
Cyclaspis spp.[1]	Sabellidae spp.[4]	Oligochaeta spp.	Photis macromanus	Oligochaeta spp.
Terebellidae sp. A	Paraprionospio pinnata	Goniadides carolinae	Oligochaeta spp.	Minuspio sp.
Bryozoa spp.	Oligochaeta spp.	Ostracoda spp.	Caulleriella spp.	Bryozoa spp.
Cirrophorus spp.	Minuspio sp.	Branchiostoma caribaeum	Sabellidae spp.[4]	Armandia maculata
Bivalvia spp.	Bryozoa spp.	Rhynchocoela spp.	Magelona spp.[5]	Prionospio cristata
Branchiostoma caribaeum	Mediomastus californiensis	Exogone dispar	Cyclaspis spp.[1]	Rhynchocoela spp.
Tellina spp.	Exogone dispsar	Litocorsa sp.	Minuspio sp.	Leptochelia sp. A
Axiothella mucosa	Rhynchocoeala spp.	Armandia maculata	Rhynchocoela spp.	Schistomeringos rudolphi
Rhynchocoela spp.	Aricidea spp.	Aricidea spp.	Ostracoda spp.	Caulleriella alata
Lucifer faxoni	Prionospio cristata	Leptochelia sp. A	Axiothella mucosa	Ostracoda spp.
Exogone dispar	Leptochelia sp. A	Syllidae spp.	Eudeuenopus honduranus	Exogone dispar
Oxyurostylis smithi	Ostracoda spp.	Apseudes propinquus	Armandia maculata	Lembos spp.
Leptochelia sp. A	Glottidia pyramidata	Cirrophorus spp.	Mediomastus californiensis	Cirrophorus spp.
Sipuncula spp.	Synelmis sp. B	Axiothella mucosa	Cerapus sp. A	Aricidea finitima
Glycera spp.	Cyclaspis sp. A	Lumbrineris verrilli	Polygordius sp.	Aricidea catherinea
Eudeuenopus honduranus	Xenanthura brevitelson	Sabellidae spp.[4]	Hydroides bispinosa	Nereis sp.
Pseudovermilia sp.	Mitrella lunata		Aricidea philbinae	Aricidea spp.
Metharpinia floridana	Axiothella mucosa		Cirrophorus spp.	Aricidea taylori
Nereidae spp.	Armandia maculata		Apseudes proinquus	Lysianopsis sp. A
Aricidea spp.	Lembos unifasciatus reductus			Ophuroidea spp.
Paraprionospio pinnata	Lysianopsis sp. A			
Maldanidae spp.[2]				
Oligochaeta				
Cyclaspis unicornis				
Ampelisca spp.[3]				
Aoridae spp.				
Chevalia aviculae				
Tiron tropakis				

Notes: 1. Cyclaspis spp. includes Cyclaspis sp. A and sp. D--majority (66 to 98 percent) were sp. A.
2. Maldanidae were probably juvenile A. mucosa.
3. Includes Ampelisca bicarinata, Ampelisca sp. B and Ampelisca sp. C.
4. Sabellidae spp. were from subfamily Fabricinnae--probably mainly Fabriciola trilobata and Fabricia sp.
5. Magelona spp. probably juvenile M. pettiboneae.

Table 4.3-4. Numerically Dominant Infaunal Taxa (≥0.9 Percent of Total Density) from May 1984 in Order of Abundance

Group I Soft-Bottom Station				
43	46	48	49	50
Armandia maculata	Paraprionospio pinnata	Mediomastus californiensis	Spio pettiboneae	Ostracoda spp.
Rhynchocoela spp.	Sabellidae spp.[1]	Paraprionospio pinnata	Oligochaeta spp.	Oligochaeta spp.
Goniadides carolinae	Ceratocephale oculata	Cyclaspis spp.[3]	Streptosyllis pettiboneae	Ophelina sp.
Oligochaeta spp.	Ostracoda spp.	Oligochaeta spp.	Caulleriella alata	Bryozoa spp.
Sabellidae spp.[1]	Polygordius sp.	Polygordius sp.	Ostracoda spp.	Goniadides carolinae
Chevalia aviculae	Prionospio dayi	Ostracoda spp.	Sabellidae spp.[1]	Sabellidae spp.[1]
Ostracoda spp.	Rhynchocoela spp.	Bryozoa spp.	Monoculodes nyei	Armandia maculata
Cirrophorus spp.	Oligochaeta spp.	Sabellidae spp.[1]	Armandia maculata	Aoridae spp.
Echinoidea spp.	Armandia maculata	Aglaophamus verrilli	Cyclaspis spp.[3]	Spio pettiboneae
Protodorvillea kefersteini	Mediomastus californiensis	Ceratocephale oculata	Sphaerosyllis aciculata	Prionospio cristata
Ophiuroidea spp.	Cyclaspis spp.[3]	Ophiuroidea spp.	Rhynchocoela spp.	Pholoe spp.
Spio pettiboneae	Bivalvia spp.	Monoculodes nyei	Cirrophorus spp.	Chone spp.
Syllidae sp.	Owenia sp. A	Oxyurostylis smithi	Axiothella mucosa	Cyclaspis spp.[3]
Sphaerosyllis spp.	Xenanthura brevitelson	Mysidopsis furca	Bivalvia spp.	Xenanthura brevitelson
Heteropodarke spp.[2]	Ampelisca spp.[5]	Anchialina typica	Aricidea philbinae	Branchiostoma caribaeum
Ancistrosyllis hartmanae	Aglaophamus verrilli	Synchelidium americanum	Magelona pettiboneae	Podocerus sp. A
Cyclaspis spp.[3]	Monoculodes nyei	Aoridae spp.	Paraprionospio pinnata	Sipuncula spp.
Tellina spp.	Poecilochaetus johnsoni	Armandia maculata	Sphaerosyllis spp.	Ophiuroidea spp.
Nephtydae spp.[4]	Metharpinia floridana	Echinoidea spp.	Haploscoloplos spp.	Encope spp.
Mediomastus californiensis	Ophiuroidea spp.		Endeuenopus honduranus	Sphaerosyllis spp.
Bryozoa spp.			Prionospio cristata	Sphaerosyllis aciculata
Axiothella mucosa			Polygordius sp.	Syllidae spp.
Branchiostoma caribeaum				Tellina spp.
Aricidea spp.				Plakosyllis quadrioculata

Notes:
1. See note 4 Table 4.3-3.
2. Heteropodarke spp. includes H. formalis (85 percent) and H. lyonsi (15 percent).
3. Cyclaspis spp. includes Cyclaspis sp. A (61 to 98 percent) and Cyclaspis sp. B (2 to 39 percent).
4. Nephtydae spp. probably juvenile Nephtys.
5. Ampelisca spp. includes Ampelisca sp. B, A. bicarinata and Ampelisca sp. C.

Lumbrineris verrilli, Minuspio sp., Cirrophorus spp., Aricidea spp., and Tellina spp.

Although cluster analyses did not show an apparent grouping of stations by collection date, some individual taxa did have distributions which showed differences between the two collection dates. Leptochelia sp. A, Glottidia pyramidata, Synelmis sp. B, Aspseudes propinquus, and Minuspio sp. were more common in December 1983 while Spio pettiboneae, Paraprionospio pinnata, Monoculodes nyei, and Mysidopsis furca were more common during May 1984.

The west Florida continental shelf has been divided into five zones based on faunal similarity (Lyons and Collard, 1974; Lyons, 1980; Lyons and Camp, 1982). These zones roughly correspond with depth and result from factors such as substrate, temperature fluctuations, overlying water masses, and light penetration (Lyons and Collard, 1974; Lyons and Camp, 1982). The shallow shelf zone extends from roughly 10 m to 30 or 40 m with overlying green, relatively turbid well-mixed water and sediments composed largely of quartz sands (Lyons and Collard, 1974). This shallow shelf zone is the zone in which the present macroinfaunal communities were sampled.

The five sampling stations revealed a macroinfaunal community which was highly diverse, with the high diversity resulting from both relatively high species richness and relatively high evenness among species. Polychaetes taxonomically dominated macroinfaunal collections, followed by crustaceans, primarily gammarid amphipods and cumaceans, and molluscs. These results were consistent with previous shelf studies conducted on the Southwest Florida Shelf (Woodward Clyde Consultants and Continental Shelf Associates, Inc., 1983, 1984), the Northeast Florida Shelf (EPA, 1982b), and off Tampa Bay (EPA, 1982b). This ranking of polychaetes, crustaceans, and molluscs is generally in agreement with results of soft-bottom benthic studies off the east coast of the United States (Maurer et al., 1976; Maurer and Leathem, 1981) and indeed worldwide (Knox, 1977).

Community densities were moderate and comparable with densities found in previous studies conducted in shallow shelf areas of Florida (Woodward Clyde Consultants and Continental Shelf Associates, 1983, 1984; EPA, 1982a). Densities were generally higher in the May 1984 collections, but a great deal of overlap occurred between the two seasons considering the standard deviations of the mean density estimates. The densities may reflect a seasonal pattern, but the data were inconclusive because of the limited sampling events, and because the shallow shelf environment is subject to variability in physicochemical parameters due to both seasonal and aperiodic changes in these parametes.

Dissimilarity between sample stations was relatively low, or, conversely, similarity of stations based on the macroinfauna community was relatively high. This was to be expected as the sample stations were located within a narrow range of depths and sediment type. Woodward Clyde and Continental Shelf Associates (1983) reported in the Southwest Florida Shelf Year II study summary a strong separation of stations along the offshore-nearshore direction, with stations deeper than 86 m most strongly separated. Stations in the shallower depths were less strongly separated from each other but still showed a general pattern of separation by depth. The benthic community sampled in the present study was relatively similar to the shallower communities sampled in this preceding study. Station 49 was the only station in the present study to cluster with itself between the December 1983 and May 1984 collections. This may be the result of the shallower depth of this station (11 m), which is close to the depth (10 m) considered to be the lower boundary of the nearshore faunal zone (Lyons and Collard, 1974; Lyons, 1980; Lyons and Camp, 1982) and the low $CaCO_3$ and organic carbon content of the sediments. The present data are also quite similar to benthic communities described on the shallow shelf off Tampa Bay (EPA, 1982b). All data considered indicate a gradual change in species composition of benthic communities from nearshore to offshore depths.

4.3.2 LIVE-BOTTOM STATIONS

Comparisons between live-bottom stations are made in the following section. Since the live-bottom stations were selected to span a range of different habitat types identified in previous programs, major differences were expected between the communities of the Florida shelf. Such differences were found, but there were also many similarities, as discussed in the following paragraphs. The reader should keep in mind throughout the discussion that sampling intensities within gear types differed during Year 4 from station to station, both as a result of program design and of unexpected events such as heavy weather and equipment failure.

It is likely that the minimum sampling intensity in this program for each gear type surveyed most of the abundant species present at each station. Consequently, the following descriptions rely heavily on presence/absence summaries, which are less sensitive to unequal sampling efforts than are estimates of abundance, especially given the variances usually found in abundance data from marine communities. Summaries are based on underwater television, dredge, and trawl samples. Data from underwater television surveys were particularly useful for comparisons, since the area surveyed was so large compared to other gear types. In addition, underwater television surveys were conducted during daylight hours (in contrast to previous studies of the same area), and high densities of fishes were therefore observed.

Benthic Invertebrates

Many of the stations had major benthic habitat-forming organisms in common (see Tables F-11 and F-12). For instance, all stations had sponges large enough to see on the underwater television. Two species of sponges, *Ircinia campana* and *I. strobilina*, were identified in videotapes from each station except for Station 36. Scleractinian corals were collected by the triangular dredge at all the stations except 51 and 19, and gorgonians at all stations except 51 and 21. However, scleractinians were seen with the underwater television at

Station 51--though not collected with the dredge--and gorgonians were seen in videotapes of Stations 51 and 21. This confirms that these stations were similar in many respects. It also emphasizes the importance of sampling the same community with a variety of gear types.

Six of the stations (44, 45, 47, 51, 52, and 19) spanned a depth range of only 10 m, lying in shallow water along isobaths between 14 and 24 m deep. All of these stations were approximately the same distance offshore and fell within the Inner Shelf region delineated in previous research in this program. Proceeding westward, the sampling program crossed bathymetric contours rather than paralleled them. The next four stations spanned a depth range of 78 m from 47 m to 125 m. These were Stations 21, 29, and 23 (Middle Shelf); and Station 36 (Outer Shelf).

The Inner Shelf stations had much in common. The habitat most frequently encountered was fairly low relief, with occasional patches of hard substrate which cropped up amid plains of unconsolidated sediment. However, at Station 19, higher profile reef rock was observed with the underwater television. The sediment at the other shallow stations sometimes covered everything except large sponges and gorgonians. These organisms are long-lived and slow-growing, and can only settle and survive when attached to hard substrate. Wherever they are observed, it can therefore be inferred that there must be hard substrate beneath a thin veneer of sediment. It can also be inferred that the sand moves and periodically exposes the hard substrate, since various sizes of sponges and gorgonians were observed, indicating ongoing recruitment.

The six Inner Shelf stations were similar to one another in benthic species composition for major habitat-forming taxonomic groups. For example, there was a natural grouping of gorgonians at Stations 52, 44, 51, 45, 47, and 19, and a distinct break between Station 19 (24 m) and Station 21 (47 m) (Tables F-11 and F-12). A faunal break between Station 19 and Station 21 was also evident for scleractinians and holothuroids. Stations 19 and 51 (toward the southern end of the study area) were particularly poor for scleractinians and gorgonians, as well as depauperate for many other groups of organisms.

Many major taxa were habitat-specific within regions (Table 4.3-5). To reduce the disparity between numbers of stations per region, Outer and Middle Shelf stations were grouped together in Table 4.3-5. Percentages should not be compared between regions, since there were six stations in the Inner Shelf and only four stations in the Outer/Middle Shelf category. Some groups of taxa were much more habitat-specific than others. Four of 10 major groups had more identified taxa restricted to the Middle/Outer Shelf stations than to the Inner Shelf stations.

However, considering just those restricted taxa, in 9 of 10 major groups of taxa, higher percentages were shared among stations in the Inner Shelf region than among stations within the Middle/Outer Shelf region. In other words, there was far more overlap (similarity) among benthic macroinvertebrates and plants at Inner Shelf stations than among Middle/Outer Shelf stations. For example, half of the 28 bivalves found exclusively at Inner Shelf stations were collected from more than one of these stations, whereas not one of the eight bivalves collected exclusively at Middle/Outer Shelf stations was taken from more than one station.

The major habitat-forming organisms differed considerably between the four deepest live-bottom stations. Station 21 (47 m) was mainly a sponge community on low-profile sandy bottom. Station 29 (66 m) was dominated by scleractinian corals, primarily *Agaricia* spp., with rocky patches projecting above the substrate, along with the large green alga *Anadyomene menziesii*. Station 23 (75 m) was a bed of algal nodules and rubble, with many sponges and smaller invertebrates (e.g., abalones) in the interstices, and *Anadyomene*. Station 36 was fairly low-profile, but dominated by two species of comatulid crinoids.

Table 4.3-5. Distribution of Invertebrates and Plants in Inner Versus Middle and Outer Shelf Regions, Based on Triangular Dredge Samples

	Number of Taxa Identified	Biogeographic Region			
		Inner Shelf		Middle/Outer Shelf	
		Restricted (%)	Spread (%)	Restricted (%)	Spread (%)
Invertebrates					
Zoantharia	27	19	60	48	8
Alcyonaria	29	83	33	17	20
Bivalvia	40	70	50	20	0
Gastropoda	46	48	36	28	8
Brachyura	56	48	27	36	33
Anomura	12	42	60	33	60
Caridea	14	43	17	21	0
Asteroidea	19	26	40	58	18
Ophiuroidea	26	15	25	62	13
Echinoidea	15	7	100	60	22
Algae					
Chlorophyta	15	73	55	27	50
Phaeophyta	13	38	20	46	17
Rhodophyta	44	70	16	16	0

Note: "% Restricted" indicates the percentage of identified taxa in that group that were found only within that region; "% Spread" indicates the percentage of those taxa restricted to each region that were found at more than one station within that region.

Some invertebrates were widespread. Ophiuroids were notable in this regard. The angular brittle star, *Ophiothrix angulata*, was collected with the triangular dredge at 9 of the 10 stations, and several other species (*O. savignyi* and *Ophioderma brevispina* can be described as ubiquitous. Nonetheless, only 2 of the 16 ophiuroids collected exclusively at Middle/Outer Shelf stations were found at more than one station.

Figures 4.3-3 and 4.3-5 present a station overview regarding major groups of organisms. Figure 4.3-4 presents a key to the nodal constancy and nodal fidelity graphics. Specifically, Figure 4.3-3 depicts the results of a nodal constancy analysis per Boesch (1977) on presence/absence data for invertebrates collected with triangular dredge at the Group I live-bottom stations (all Inner Shelf sampled twice) and at Group II stations (Inner, Middle, and Outer Shelf sampled four times). Figure 4.3-5 presents nodal fidelity analyses in the same fashion. Group I and Group II stations were analyzed separately because of the differences in sampling frequency.

For each station, constancy is the ratio between the number of taxa (within each major taxonomic group) collected to the total number of taxa within the group. High constancy values are one indication of the quality or suitability of a given environment for members of a particular taxon. The better or more suitable the environment for those species, the higher the proportion of possible species that will be there. Where the number of taxa within a group is small, it is possible to achieve very high constancy values with just a few appearances at one station, since the analysis uses presence/absence data. For this reason, major groups of taxa which include only several species are de-emphasized in this discussion.

The height of each bar in the nodal constancy chart corresponds to the number of taxa identified with each major taxonomic group listed at left. The darkness of each bar beneath the stations listed across the

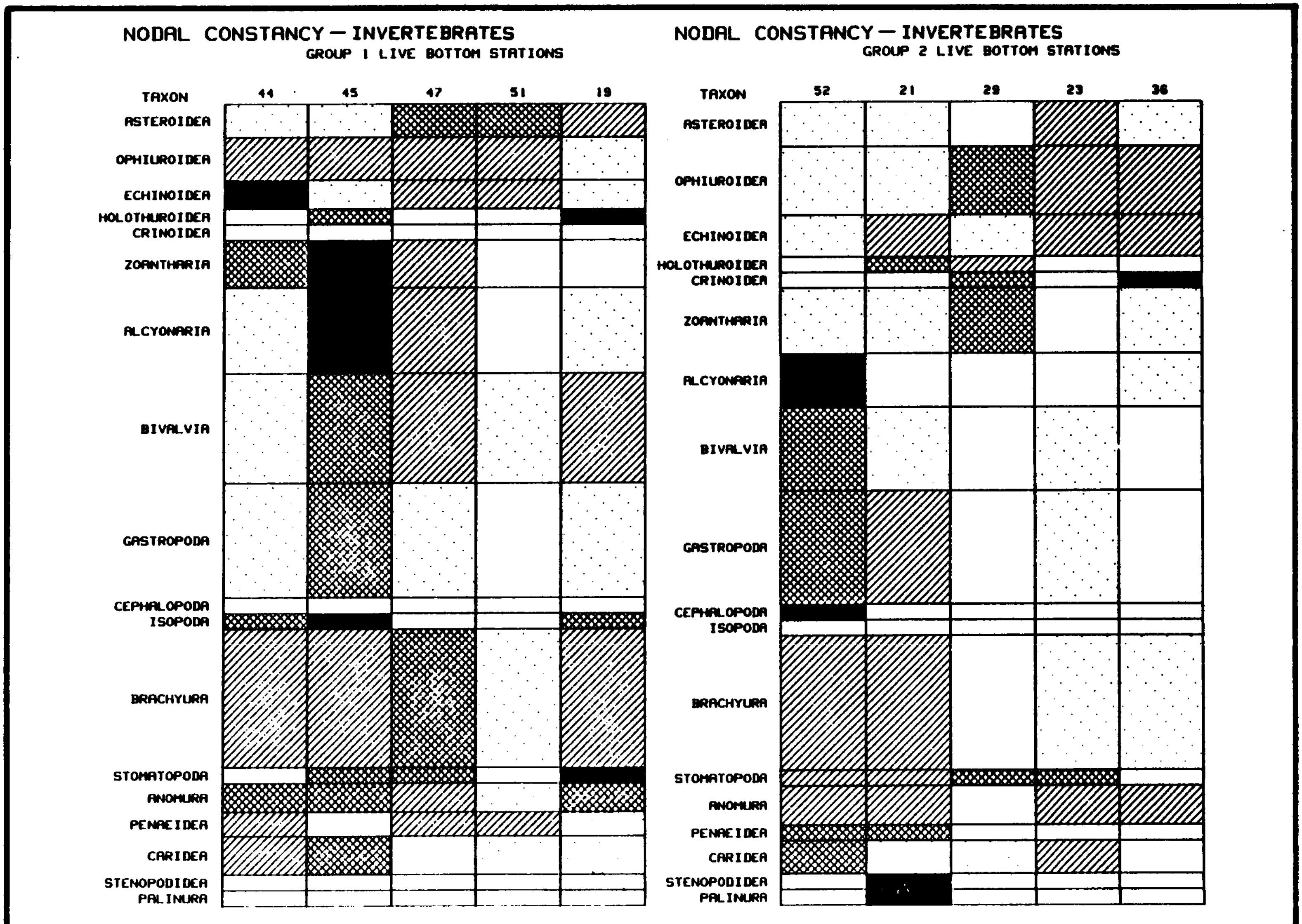


Figure 4.3-3 NODAL CONSTANCY FOR GROUP I AND II LIVE—BOTTOM STATIONS

NOTE: SEE FIGURE 4.3-4 FOR A DESCRIPTION OF THE KEY.

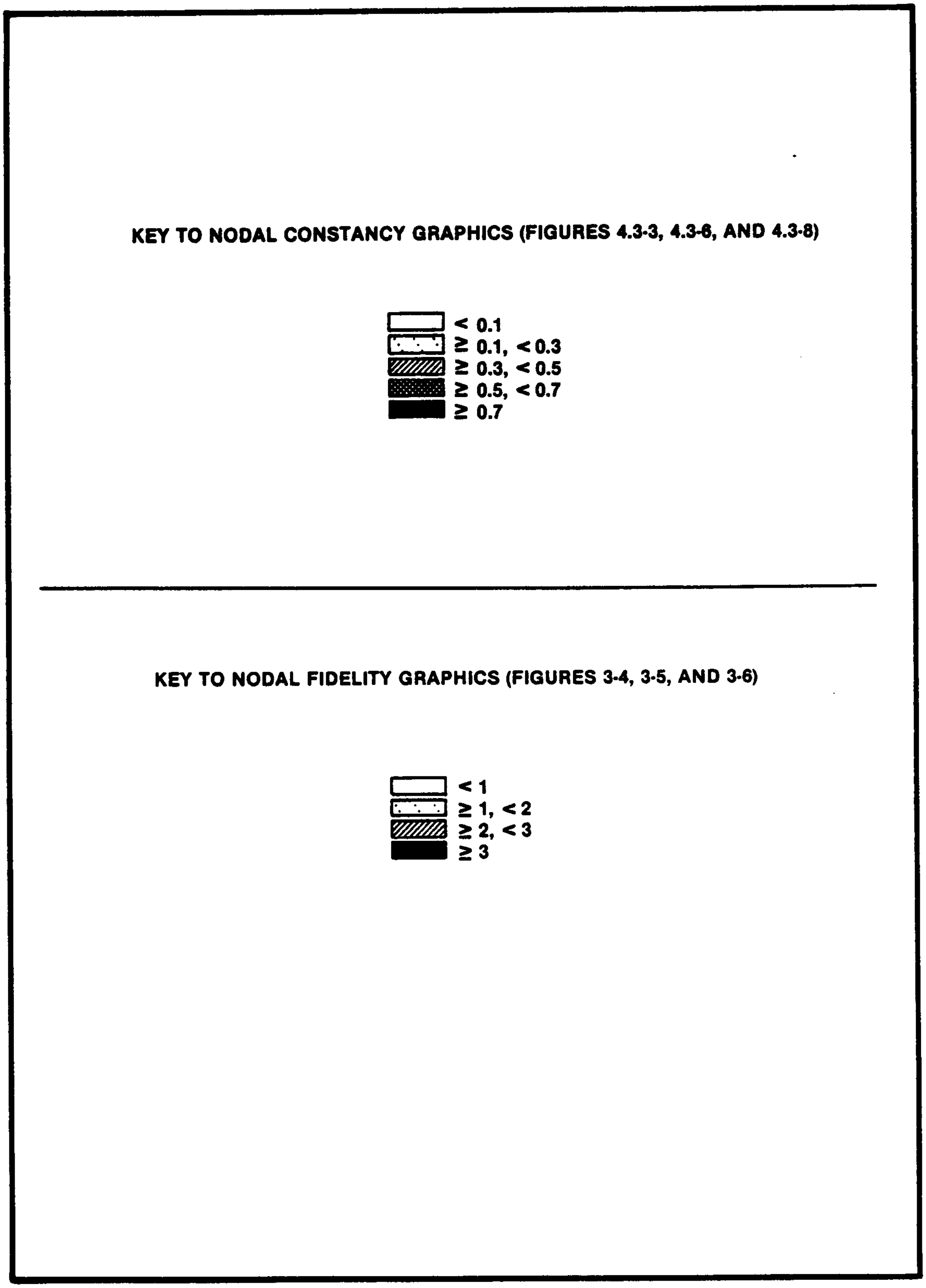
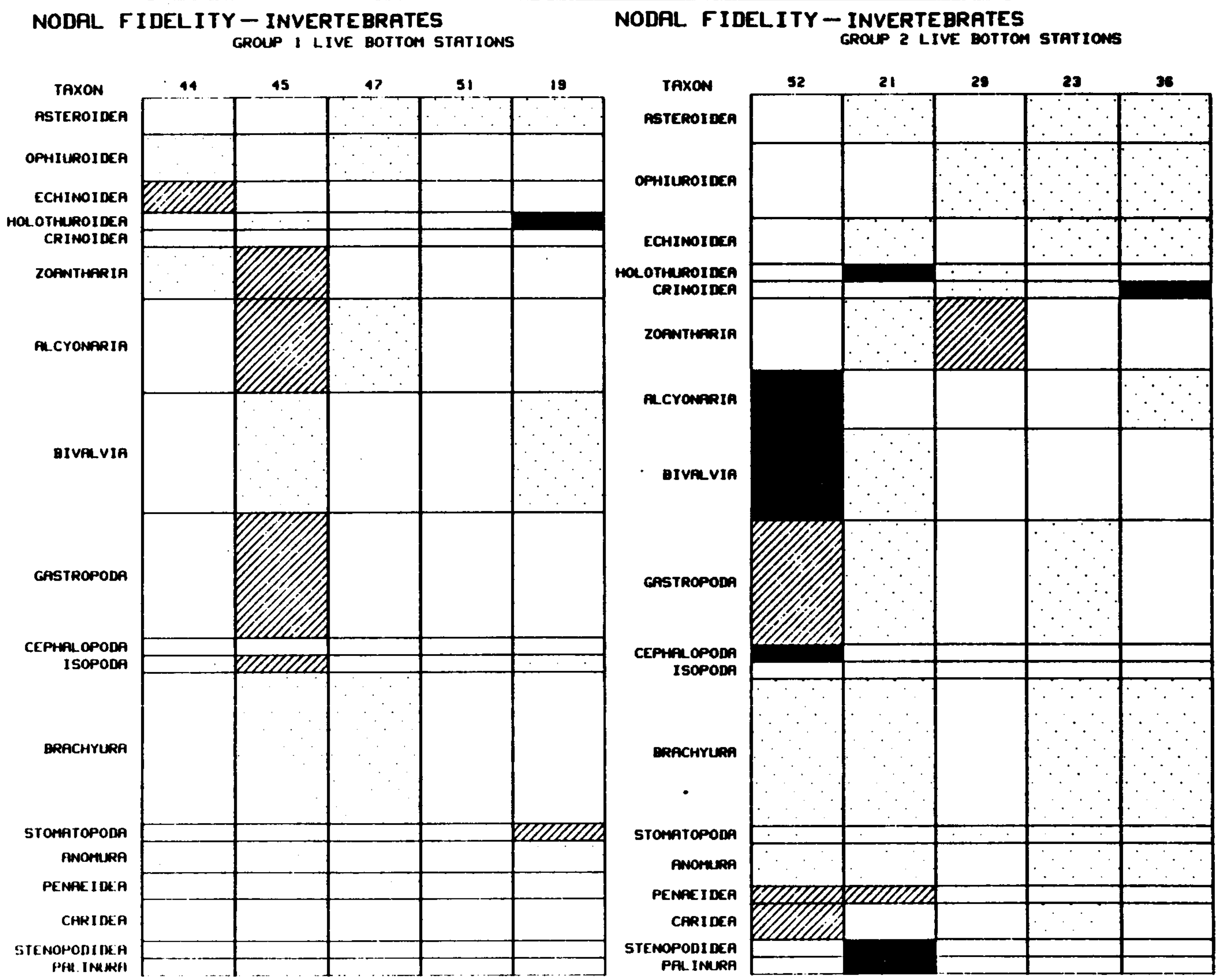


Figure 4.3-4 KEY TO NODAL CONSTANCY AND NODAL FIDELITY GRAPHICS



NOTE: SEE FIGURE 4.3-4 FOR A DESCRIPTION OF THE KEY.

Figure 4.3-5 NODAL FIDELITY FOR GROUP I AND II LIVE—BOTTOM STATIONS top of the figure indicates constancy. Fully darkened boxes indicate that 70 percent or more of the taxa within a major taxonomic group were found at those particular stations, i.e., very high constancy. Cross-hatched boxes indicate high constancy (50 percent or greater); lined boxes, moderate constancy (30 percent or greater); dots, low constancy (10 percent or greater); and blanks, very low constancy (less than 10 percent).

Figure 4.3-3 reveals high or very high nodal constancy at some Group I stations for several large groups of organisms such as zoantharians, which includes the scleractinian corals (Station 44 and 45); alcyonarians, the gorgonians (Station 45); gastropods (Station 45); brachyurans (Station 47); and asteroideans, the sea stars (Stations 47 and 51). Among Group II stations, very high or high constancy values were found for scleractinians (Station 29), gorgonians (Station 52), bivalves and gastropods (Station 52), and several smaller groups at various stations.

Nodal fidelity is the ratio between constancy for a given major taxon at a particular station to overall constancy for that taxon. Positive ratios are shown with dots (low fidelity, ratio = one or greater), lines (moderate fidelity, two or greater), or solid boxes (high fidelity, three or greater), while negative ratios are blanks. Fidelity indices thus reflect specificity in habitat selection. Figure 4.3-5 shows that four large groups of invertebrates were fairly specific in choice of habitat within shallow stations, but that most kinds of invertebrates were widely distributed between stations. Scleractinians, gorgonians, and gastropods all showed moderate fidelity to Station 45; echinoids had moderate fidelity to Station 46. Among Group II stations, many types of invertebrates had high fidelity values, indicating strong habitat preferences. For example, gorgonians, bivalves, and gastropods had high or moderate fidelity to Station 52; scleractinians showed moderate fidelity to Station 29. Brachyurans, ophiuroids, echinoids, and asteroids, which were extremely numerous at most stations, showed low fidelity values, demonstrating broad habitat requirements.

Benthic Algae

Among the green algae, Chlorophyta, there were no species held in common between Inner Shelf and Middle/Outer Shelf stations (Table F-15). There were 15 species collected by triangular dredge; 4 of these were present only at Middle Shelf stations, and the remainder only at Inner Shelf stations. The most spectacular large species, *Anadyomene menziesii*, was collected only at Stations 29 and 23.

There was more overlap among the brown algae, Phaeophyta. Two species were at both Inner and Middle Shelf stations. However, there were clearly defined Inner Shelf and Middle Shelf suites of species.

The red algae, Rhodophyta, had the longest species list and a distinct pattern of station specificity, with lower percentages of species shared between stations than either of the other two groups of algae. Only 5 of the 31 species collected exclusively at Inner Shelf stations were shared between two or more of those stations, and none of the seven species collected exclusively at Middle Shelf stations was present at more than one station.

Fishes

During Year 4, 98 species of fishes belonging to 36 families were collected by trawling (Tables F-13 and F-14). The numbers in Table F-14 have been normalized (number of individuals per 10-min trawl) to eliminate the effects of differential effort from one station to the next. Although trawl distance differed slightly from one haul to the next due to variations in vessel speed, the numbers are a good preliminary indication of catch per unit effort. The trawl data have not been fully verified, and minor errors are possible in Table F-14.

Some taxa were ubiquitous over broad depth ranges, such as the sand diver, Synodus intermedius (eight stations); the fringed filefish, Monacanthus ciliatus (six stations); and the blackedge moray, Gymnothorax nigromarginatus (four stations).

Other families showed clear zonation of species. Clear examples in the trawl data can be seen for the porgies, Sparidae, and for the groupers, Serranidae. Many species seemed to lie on either side of an apparent faunal break between Stations 19 and 21. Examples of widespread species--present at three or more stations--mainly found on the Inner Shelf included the white grunt, Haemulon plumieri; the tomtate, Haemulon aurolineatum; the scrawled cowfish, Lactophrys quadricornis; the gray snapper, Lutjanus griseus; and the red grouper, Epinephelus morio. Other taxa were found exclusively or nearly so on the deeper side of Station 19, such as the lefteye flounders, Bothidae; the scorpion fishes, Scorpaenidae; and the damselfishes, Pomacentridae.

The most common species overall were (in decreasing order of abundance) the blackear bass, Serranus atrobranchus (average = 6.6 individuals per trawl); the offshore lizardfish, Synodus poeyi (4.5 individuals); the tattler grouper, Serranus phoebe (4.3 individuals); the shortwing searobin, Prionotus stearnsi (1.8 individuals); and the horned whiff, Citharichthys cornutus (1.4 individuals). However, since species composition differed so much between stations, overall density averages for most species are not particularly meaningful. Station-by-station summaries are more revealing.

The station with the highest average catch per haul was Station 36 (193.6 individuals), followed by Station 23 (66.3 individuals), and Station 52 (56.3 individuals). The poorest catches were made at Station 19 (14 individuals), Station 44 (11 individuals), Station 51 (8 individuals), and Station 29 (5 individuals).

Although the taxonomic resolution provided by underwater television surveys was not as high as that offered by trawl collection, the area surveyed was much greater, and an excellent overview of fish distribution was obtained (Table F-11).

Several families of fishes censused with underwater television were restricted in their distributions, either to deeper water (e.g., the bigeyes, Priacanthidae; the bonnetmouths, Emmelichthyidae; and the squirrel fishes, Holocentridae) or to the shallow water environment of the Inner Shelf (e.g., the snappers, Lutjanidae, and the grunts, Haemulidae). For example, the grunts, Haemulon plumieri and H. aurolineatum, and the gray snapper, Lutjanus synagris, were seen at all Group I stations and at Station 52, but at none of the deeper stations. Similarly, all four taxa of lizard fishes, Synodontidae, were seen at Station 36, the deepest station; although three of them were sighted at other stations, only at Station 36 did they all co-occur.

Most families, however, included at least a few representatives that were observed at many stations, as well as both species seen mainly on the Inner Shelf or in the Middle and Outer Shelf regions. For example, the groupers, Serranidae, included a high proportion of widespread species. The red grouper, Epinephelus morio, was observed at 8 of 10 stations. Within the same family, the tattler grouper, Serranus phoebe, was seen only at the Middle/Outer Shelf stations (21, 29, 23, and 36). No station had fewer than two species of serranids observed by the television, and stations averaged over four species. Stations 29 and 23 had eight and seven species of groupers (respectively) recorded on the underwater television system. The porgies (Sparidae), butterfly fish (Chaetodontidae), trunkfish (Ostraciodontidae), and the jacks (Carangidae) also included ubiquitous species.

Nodal constancy and nodal fidelity analyses based on presence/absence data were performed for fishes collected by trawling at Group I and Group II stations. Figures 4.3-6 and 4.3-7 show constancy and fidelity,

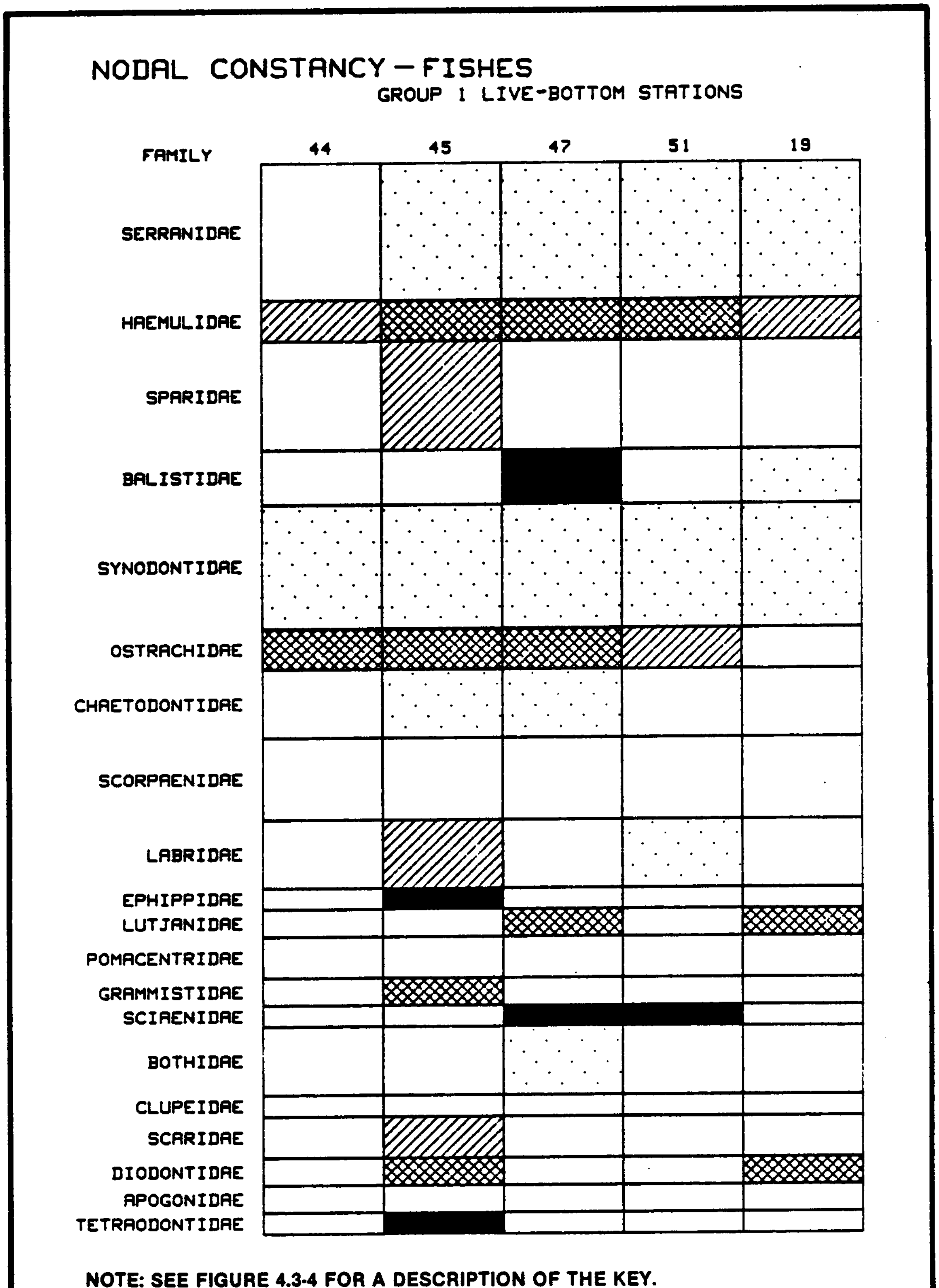


Figure 4.3-6 NODAL CONSTANCY FOR GROUP I LIVE-BOTTOM STATIONS

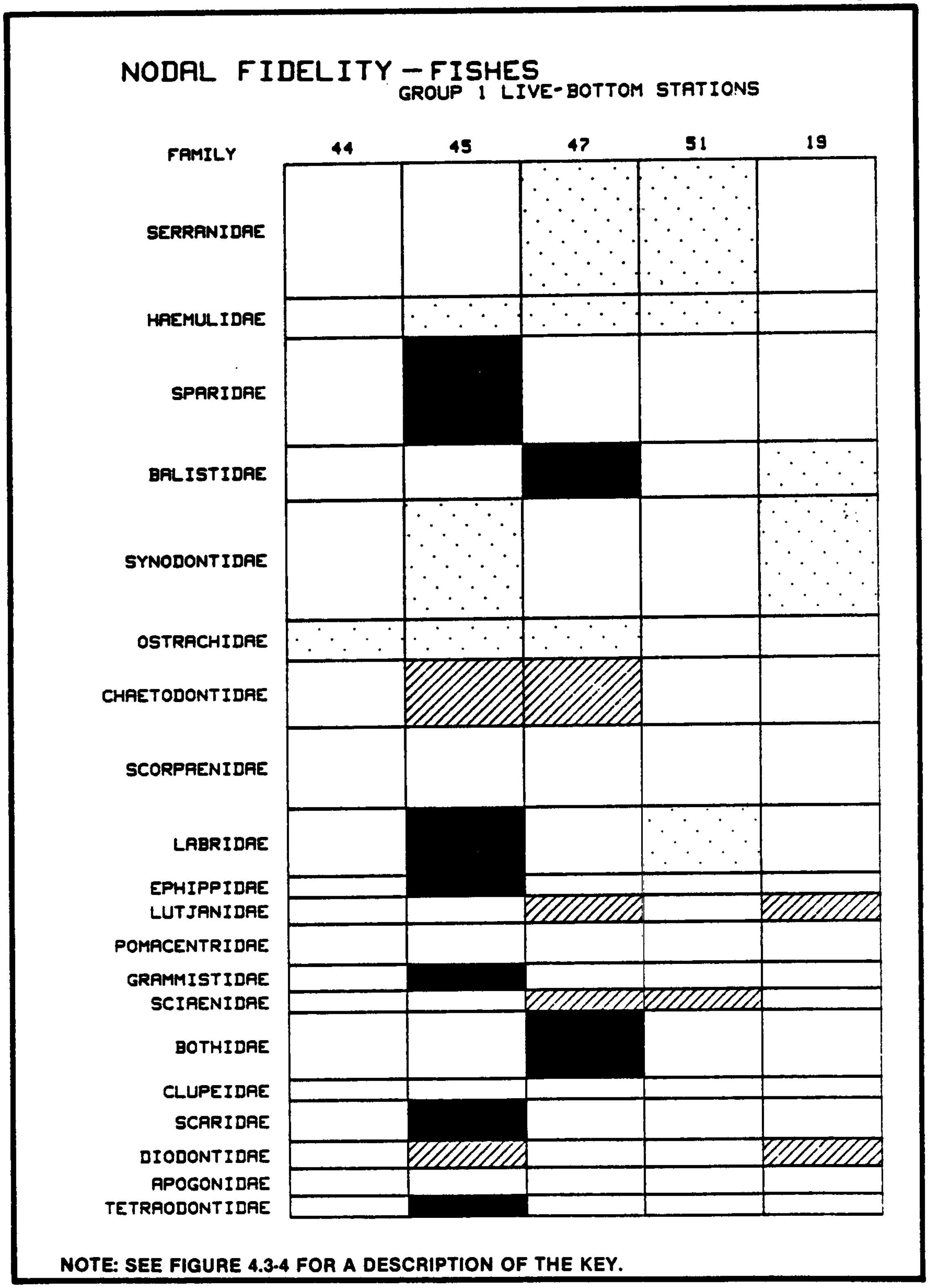


Figure 4.3-7 NODAL FIDELITY FOR GROUP I LIVE-BOTTOM STATIONS

respectively, for families of fishes at the Group I stations. Families showing high or very high constancy at Group I stations included the grunts, Haemulidae, at Stations 45, 47, and 51; the trigger fish, Balistidae, at Station 47; and the trunkfish, Ostrachidae, at Stations 44, 45, and 47. Of these, only the Balistidae showed high fidelity.

Several large families were notable for their lack of both constancy and fidelity, indicating scattered distributions or absences by most members of the family within the shallow stations. These included the groupers, Serrandiae; the lizard fishes, Synodontidae; the butterfly fishes, Chaetodontidae; and the scorpion fishes, Scorpaenidae. High fidelity was observed for several families, including the porgies, Sparidae, and the wrasses, Labridae, at Station 45; and the trigger fishes, Balistidae, and lefteye flounders, Bothidae, at Station 47.

Figures 4.3-8 and 4.3-9 illustrate nodal constancy and fidelity, respectively, for families of fishes at Group II stations. Station 36 was not included due to temporary difficulties with data records. Larger families showing high or very high constancy at Group II stations included the porgies, Sparidae, at Station 21; the trigger fishes, Balistidae, at Stations 52, 21, and 29; and the scorpion fishes, Scorpaenidae, at Stations 21 and 23. Of these, only the wrasses showed high fidelity at Station 52.

A qualitative comparison of stations can be derived by simply noting the number of families within each station showing very high or high constancy, and high or moderate fidelity values (Table 4.3-6). This comparison provides an indirect indication of how "desirable" or suitable each station is compared to other stations within the same group. The results suggest that on a relative scale, within the shallow stations, Stations 44, 51, and 19 were less "desirable" than Stations 45 and 47 to most families of fishes. Similarly, within Group II, species collected from Stations 29 and 23 showed lower constancy and fidelity,

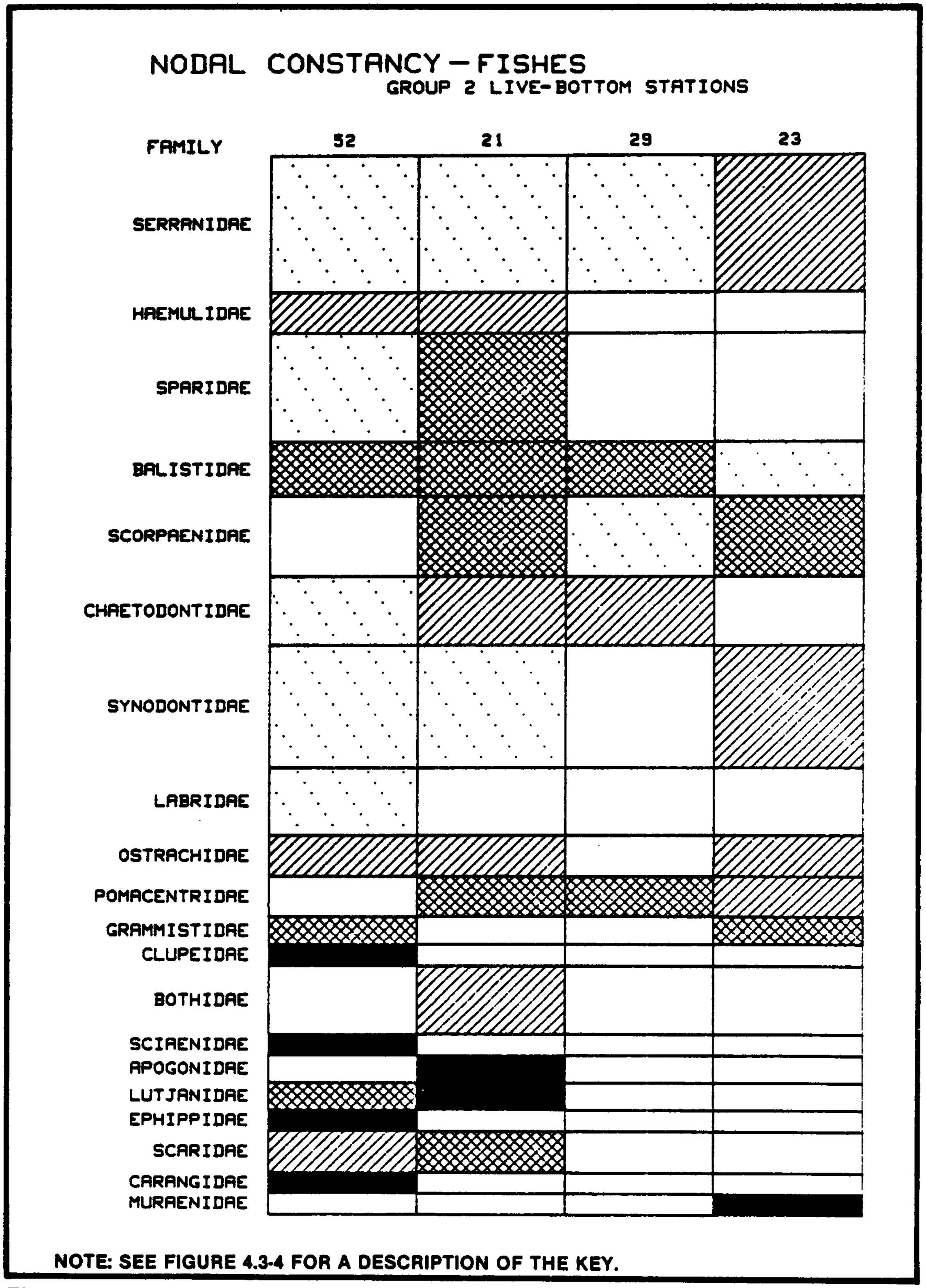


Figure 4.3-8 NODAL CONSTANCY FOR GROUP II LIVE-BOTTOM STATIONS

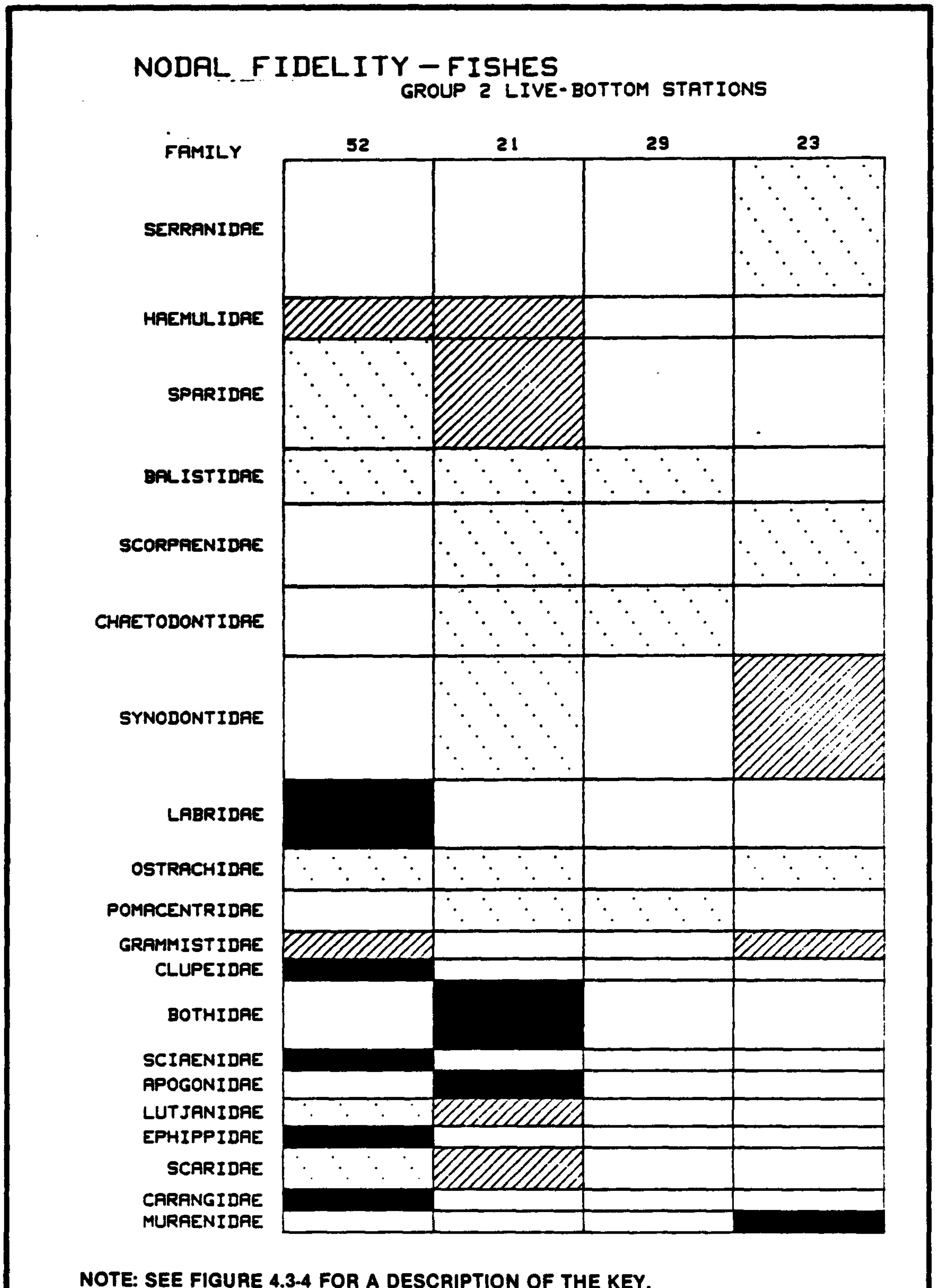


Figure 4.3-9 NODAL FIDELITY FOR GROUP II LIVE-BOTTOM STATIONS

Table 4.3-6. Comparison of Stations Based Upon Nodal Constancy and Fidelity Analyses for Fishes Collected by Trawling

	Station								
	Group I					Group II			
	44	45	47	51	19	52	21	29	23
Constancy									
Very High	0	2	2	1	0	4	2	0	1
High	1	4	3	1	2	3	5	2	2
TOTAL	1	6	7	2	2	7	7	2	3
Fidelity									
High	0	6	2	0	0	5	2	0	1
Moderate	0	2	3	1	2	2	4	0	2
TOTAL	0	8	5	1	2	7	6	0	3

i.e., specificity, than did those from the shallower stations, 52 and 21, which could be considered more "desirable" or suitable for many families.

Underwater television surveying appeared to sample some taxonomic groups not easily collected by trawling at some stations. Conversely, many species observed on the underwater television were collected in the trawl (Table 4.3-7). Since the 3-dimensional area surveyed by television (as opposed to trawls) would be difficult or impossible to compare quantitatively, only general statements as to the capabilities of both gears can be made. The area sampled by each trawl was probably much less than a tenth of the area sampled by underwater television, and the trawl sampled only those fishes on or near the bottom, whereas the television observed fish much higher in the water column and could not census cryptic fauna.

At 7 of 10 stations, far more fishes were identified in television samples, though some could only be identified to the genus level. Many species--especially faster swimmers--observed in videotapes were never collected by trawling. Examples include most of the jacks, Carangidae; the porkfish, *Anisotremus virginicus*; half the butterfly fishes, Chaetodontidae; half the damselfishes, Pomacentridae; and many groupers, Serranidae. On the other hand, the trawl collected some benthic or cryptic species never seen by the underwater television, such as the soapfishes, *Rypticus maculatus* and *R. bistrispinus*, and the blackedge moray, *Gymnothorax nigromarginatus*.

Table 4.3-7. Comparison of Number of Individual Taxa of Fishes Observed on Underwater Television Versus Number Collected by Trawling; Stations are in Order of Increasing Depth

	Station									
	52	44	51	45	47	19	21	29	23	36
Number of Taxa Identified (Underwater Television)	32	17	29	25	15	36	26	33	32	13
Number of Taxa (trawl)	17	3	8	17	16	10	32	9	19	33

5.0 CONCLUSIONS AND RECOMMENDATIONS

This Year 4 Annual Report is essentially a progress report being submitted midway in an ongoing 2-year study to present current information collected on the Southwest Florida OCS. Consequently, final conclusions and potential impact assessments will not be formulated until the data set is complete. However, from the descriptive biological and physical data presented, it is possible to summarize the results to date, present potential areas of concern, and recommend modifications in the focus of certain tasks within the program.

The natural variability of suspended solids, sediment characteristics, and sediment transport is important in assessing stresses on the existing communities and assessing potential impacts of additional stress that may be imposed by introducing drilling muds and cuttings to the environment. The natural sediment at the hard-bottom stations consists of a thin layer of sand over hard substrate. The sand is about 90 percent $CaCO_3$ with no clay minerals present. The $CaCO_3$ consists of both aragonite and calcite, which indicates it is derived from shell fragments and from the limestone bedrock. Even though the sediments consist of 98 percent sand-sized particles, the suspended sediments were 90 percent silt and clay size, indicating the wave and current energy at the shallowest station (Station 52) was sufficient to resuspend smaller particles but not sufficient to readily resuspend and transport sand-sized particles.

Wave action and currents at the shallowest station were very active in resuspending and transporting sediments. Periods of near-zero visibility resulting from suspended sediments loads were recorded by time-lapse camera. The sediment traps indicated that up to 1,000 metric tons per square kilometer per day ($t/km^2/d$) were resuspended to a height of 0.5 m during the most active winter months. This can be compared to a typical drilling rig discharge of mud and cuttings of about 10 metric tons per day (t/d). This sediment resuspension and subsequent deposition were very episodic as indicated by layering in the sediment traps and intermittent periods of high turbidity apparent on the time-lapse camera. In fact, as much as 40 percent of the sedimentation that occurred during the 3-month winter period may have occurred during one storm. No bedload transport in the form of moving ripple marks was observed on the time-lapse camera at Stations 21 (47 m) and 52 (13 m).

Sediment resuspension at the shallowest station (13 m) was due in part to the strong tidal currrents that occurred there. However, currents of equal magnitude occurred occasionally at the deepest station (125 m) and yet no sediment resuspension occurred. Consequently, the addition of the wave energy that was able to penetrate to the bottom at the shallow station was sufficient in conjunction with the currents to produce the velocities needed for the sediment transport observed in shallow water. It was estimated that wave orbital velocities at the bottom for the shallow station exceeded 40 cm/s between 1 and 6 percent of the time. Since almost no wave energy could penetrate to 125 m or even to depths greater than 50 m, little sediment resuspension occurred at the deeper stations.

Once the sediments were resuspended at the shallow station, the net currents indicated the sediment would drift to the southeast toward Florida Bay. The currents in this area were dominated by a strong east-west tidal current, but the net drift was to the southeast during all seasons. Any contaminant entering the water column in this area would be greatly dispersed by the tides, but the center of mass would still propagate to the southeast. It cannot be determined if a potential contaminant would reach Florida Bay, but since the literature search conducted indicated a paucity of data for Florida Bay, a study of its resources and circulation patterns may be justified. One mitigating factor for this area, however, does exist. Even though the net currents are to the southeast, the prevailing winds are generally from the east (as recorded at Key West). This would tend to keep any surface contaminant away from Florida Bay.

Several other characteristics of the currents were apparent in the current meter data. The tides were the dominant periodic component at all stations. The tidal energy varied from a dominant semidiurnal component with nearly all energy in the east-west direction in the shallow water to a mixed tide with nearly circular tidal ellipses in the deeper water. As mentioned previously, the net flow in shallow water was consistently to the southeast. The net flow at the deeper stations varied between seasons with frequent reversals in flows. Obvious intrusions of the Loop Current were apparent in the records from the deeper stations, and some evidence existed that the influence may have reached Station 21 at a depth of 47 m. Loop Current intrusions were recognized in the data as temperature increases of 3° to 5°C and resulted in strong currents to the north. Since the Loop Current flows to the south, these observed currents were either reverse eddies at the edge of the Loop Current or reverse bottom flows beneath the Loop Current. Subsequent analysis of Year 5 data will concentrate on better defining the extent of the Loop Current effects and its charcteristics at these Florida OCS stations. Since the highest currents observed at the deeper stations occurred during Loop Current intrusions, it is possible that subsequent intrusions may cause sediment resuspensions and transport and possibly subject the deep water biological communities to stresses resulting from suspended solids that were not observed during Year 4. If such events occur, subsequent current meter data and sediment trap results will document the occurrence.

The biological data collected during all four seasons of sampling identified a diversity of taxa varying from a very dense epifaunal, hard-bottom community in shallow water to a sparse crinoid assemblage at the shelf break in 125 m of water. The communities are very complex as illustrated by earlier studies that identified over 100 species of sponges in shallow water stations. The lush shallow-water communities, however, are subject to extreme variabilities in suspended sediment concentrations as well as considerable temperature changes over the year. Since the communities are flourishing under these conditions, it is possible they may be more resistant to disruptive activities than communities in less turbid areas. Communities in depths greater than 50 m are not naturally subjected to periods of high suspended solids (according to 1 year of sediment trap data) and, although they may be resistant, it has not been observed as with the shallow stations.

The shallowest water station also exhibited much faster recruitment than the deeper stations. After 1 year, the fouling plates and most of the array structure were completely covered by the fouling community. In contrast, Station 36 at a depth of 125 m had minimal growth consisting primarily of hydroids. This, of course, implies that communities damaged in shallow water may recover more quickly (at least for some species) than those damaged in deeper water.

Most of the biological data, including the underwater television, trawls, fouling plates, and time-lapse camera data, will not be subjected to detailed statistical analysis and comparison to physical parameters for this mid-study annual report (the description information from the sampling is provided in the text). However, a discussion is warranted of the adequacy of the methods and modifications that will be implemented during Year 5 to better meet the objectives of the program.

The underwater television data have provided the detailed information in sufficient quantity to document community characteristics. Only station descriptions were provided from the underwater television data for this report, but once the 2-year data base is complete, seasonal changes, habitat relationships to fish and other motile communities, and responses to physical parameters will be identified. This information will enhance impact assessment of offshore development. Consequently, underwater television work is being continued during Year 5.

The dredge sampling to collect representative epifaunal species proved to be effective. More volume sample was collected than could possibly be processed within the scope of the contract. Consequently, since sufficient voucher specimens were collected dredge sampling was eliminated during Year 5 at stations that were sampled during Year 4. New stations that were established during Year 5, however, will be sampled to collect voucher specimens. Trawl sampling will continue at all stations during Year 5.

The fouling plate studies originally designed for 2 years will continue. Since the data are proving important in documenting highly variable recruitment rates (generally as a function of depth), additional plates will be installed at new stations established during Year 5. The greatest weakness of the plates is that they are susceptible to damage from large fish that occupy the arrays, and many of them were lost during Year 4, particularly at the shallowest station.

One of the most useful biological data collection devices proved to be the time-lapse cameras. They were originally installed to monitor sediment transport but are proving to be valuable in documenting fish behavior around platform structures. Only two time-lapse cameras were installed on a trial basis during Year 4 to investigate their utility. Two things were learned (1) they obtained valuable biological and physical data that could be obtained in no other way, and (2) they are difficult to maintain. Much of the time-lapse camera data were lost during Year 4 primarily from a lost array and from damage by large fish and turtles that took up residency in the array at Station 52. However, because the time-lapse camera data collected proved to be valuable, seven time-lapse cameras have been installed and are being maintained at various depths during Year 5.

The time-lapse camera data presented in this report identified several patterns of fish habits around the array structure. The greatly expanded data base for Year 5 will allow for better observation of these patterns and should allow for documentation of hourly, daily, and seasonal changes in fish activity and recruitment around an artificial structure. The expanded data base may also allow for comparison with physical parameters to determine if structure recruitment or abandonment is caused by currents, tides, or storm activity. It may also help determine if there is some hierarchy established among fish species within a reef structure. This type of information should prove valuable in assessing the effects of offshore structures on fish communities.

In conjunction with the time-lapse cameras, the instrumented arrays proved to be most effective in collecting continuous data. Consequently, the number of arrays was expanded from five to eight during Year 5, and all but the deep water station (125 m) were equipped with time-lapse cameras. Considerable equipment was lost during Year 4 from vandalism and fishermen. As a result of relatively high instrument loss, three backup arrays have been provided for the Year 5 program.

Other recommendations that have been implemented for Year 5 include:

1. Establishment of underwater video and side-scan sonar transects in potentially sensitive areas around the Dry Tortugas,
2. Investigation of a deep hole identified by the Florida Department of Natural Resources,
3. Collection and preservation for 5 years of 100 fish samples that can be used for baseline contaminant levels if required, and
4. Seasonal monitoring of an established transect using a hand-held video system to identify small changes in sedimentation and epifaunal community structure.

REFERENCES CITED

Abbott, R.E. 1979. Ecological Processes Affecting the Reef Coral Population at the East Flower Garden Bank, Northwest Gulf of Mexico. Ph.D. Dissertation. Texas A&M University, College Station, Texas.

Bloom, S.A. 1981. Similarity Indices in Community Studies: Potential Pitfalls. Marine Ecology - Progress Series 5:125-128.

Boesch, D.F. 1977. Application of Numerical Classification in Ecological Investigations of Water Pollution. U.S. EPA Ecological Research Series EPA-600/3-77-033.

Boland, G.S., Gallaway, B.J., Baker, J.S., and Lewbel, G.S. 1983. Ecological Effects of Energy Development on Reef Fish of the Flower Garden Banks. Final Report. Prepared for National Marine Fisheries Service, Galveston, Texas. Bryan, Texas.

Bright, T.J., Baggett, L.S., and Combs, C.L. 1983. Coral Recruitment East Flower Garden Environmental Monitoring Study. Year-End Report to Continental Shelf Associates. Contract 14-14-0001-29142.

Colin, P.L. 1978. Caribbean Reef Invertebrates and Plants. T.F.H. Publications, Inc. Neptune City, New Jersey. 512 pp.

Collette, B.B. and Talbot, F.H. 1972. Activity Patterns of Coral Reef Fishes with Emphasis on Nocturnal-Diurnal Changeover. Los Angeles County Mus. Sci. Bull., 14:98-124.

Cooper, C. 1982. Southwest Florida Shelf Circulation Model; Volume 1, Final Report. New England Coastal Engineers, Inc. Bangor, Maine.

Fedra, K. and Machan, R. 1979. A Self-Contained Underwater Time-Lapse Camera for In Situ Long-Term Observations. Mar. Biol., 55:239-246.

Field, J.G., Clarke, K.R., and Warwick, R.M. 1982. A Practical Strategy for Analyzing Multispecies Distribution Patterns. Marine Ecology - Progress Series 8:37-52.

Folk, R.L. and Ward, W.C. 1957. Brazos River Bar: A Study in the Significance of Grain Size Parameters. Jour. Sed. Petrology, 27, No. 1, 3-27.

Fritts, T.H., Irvine, A.B., Jennings, R.D., Collum, L.A., Hoffman, W., and McGehee, M.A. 1983. Turtles, Birds, and Mammals in the Northern Gulf of Mexico and Nearby Atlantic Waters. Denver Wildlife Research Center, Univ. of New Mexico, Albuquerque, New Mexico.

Heezen, B.C. and Hollister, C. 1964. Deep-Sea Current Evidence from Abyssal Sediments. Marine Geology, 1(1964):141-174.

Inman, D.L. 1952. Measures for Describing Size Distribution of Sediments. Jour. Sed. Petrology, V. 22, No. 3, pp. 125-145.

Kaplan, E.H. 1982. A Field Guide to Coral Reefs of the Caribbean and Florida. Houghton Mifflin Co., Boston. 289 pp.

Knox, G.A. 1977. The Role of Polychaetes in Benthic Soft-Bottom Communities. In: Essays on Polychaetous Annelids. In Memory of Dr. Olga Hartman, D.J. Deish and K. Fauchald, Editors. Allan Hancock Foundation, Los Angeles, California.

Lyons, W.G. 1980. Molluscan Communities of the West Florida Shelf. Bull. Am. Malacol. Union [1979].

Lyons, W.G., and Camp, D.K. 1982. Zones of Faunal Similarity Within the Hourglass Study Area. Third Annual Gulf of Mexico Information Transfer Meeting - December 1982. U.S. Department of Interior/ Minerals Management Service.

Lyons, W.G. and Collard, S.B. 1974. Benthic Invertebrate Communities of the Eastern Gulf of Mexico. In: Proceedings of Marine Environmental Implications of Offshore Drilling in the Eastern Gulf of Mexico, pp. 157-164, R.E. Smith, Editor. State University System of Florida, Institute of Oceanography, St. Petersburg, Florida.

Maurer, D., Kinner, P., Leathem, W., and Watling, L. 1976. Benthic Faunal Assemblages off the Delmarva Peninsula. Estuarine and Coastal Marine Science, 4:163-177.

Maurer, D. and Leathem, W. 1981. Ecological Distribution of Polychaetous Annelids from the New England Outer Continental Shelf, Georges Bank. Int. Revue Ges. Hydrobiol., 66(4):505-528.

McGrail, D.W., Rezak, R., and Bright, T.J. 1982. Environmental Studies at the Flower Gardens and Selected Banks: Northwestern Gulf of Mexico, 1979-1981. Final Report to U.S. Department of Interior, Minerals Management Service, Contract No. AA851-CTO-25.

Niiler, P.P. 1976. Observations of Low-Frequency Currents on the West Florida Continental Shelf. Memoires Societe Royale des Sciences de Liege, 6(10):331-358.

Perkins, T.H. 1984. New Species of Phyllodocidae and Hesionidae (Polychaeta), Principally from Florida. Proc. Biol. Soc. Wash., 97(3):555-582.

Pielou, E.C. 1975. Ecological Diversity. Wiley-Interscience, New York, 165 p.

Price, J.F. and Mooers, C.N.K. 1974a. Shelf Dynamics Fall Experiment, October-December 1973, Current Meter Data Report, RSMAS, University of Miami.

Price, J.F. and Mooers, C.N.K. 1974b. Shelf Dynamics Fall Experiment, October-December 1973, Hydrographic Data Report, RSMAS, University of Miami.

Price, J.F. and Mooers, C.N.K. 1974c. Shelf Dynamics Winter Experiment, February-March 1973, Current Meter Data Report, RSMAS, University of Miami.

Price, J.F. and Mooers, C.N.K. 1974d. Shelf Dynamics Winter Experiment, February-March 1973, Hydrographic Data Report, RSMAS, University of Miami.

Robins, C.R., Bailey, R.M., Bond, C.E., Brooker, J.R., Lachner, E.A., Lea, R.N., and Scott, W.B. 1980. A List of Common and Scientific Names of Fishes from the United States and Canada. American Fisheries Society Special Publication No. 12, 4th Edition, 174 pp.

Science Applications International Corp. 1985. Abstract for Physical Oceanography Study. In: Proceedings, Spring Ternary Gulf of Mexico Studies Meeting Prepared for U.S. Department of Interior, Minerals Management Service. Science Applications International Corp., Raleigh, North Carolina, Contract No. 14-12-0001-29158.

Starck, W.A. and Davis, W.P. 1966. Night Habits of Fishes of Alligator Reef, Florida. Ichthyologica, 1966, 313-356.

Sternberg, R.W. 1972. Predicting Initial Motion and Bedload Transport of Sediment Particles in the Shallow Marine Environment. In: Shelf Sediment Transport, pp. 61-82, Swift, Duane, and Pilkey, Editors. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania.

Strickland, J.D.H. and Parsons, T.R. 1968. A Practical Handbook of Sea Water Analysis. Bulletin 167, Fisheries Research Board of Canada, Ottawa, Canada.

Sundborg, A. 1967. Some Aspects on Fluvial Sediments and Fluvial Morphology, I. General Views and Graphic Methods. Geograf. Ann., 49A, 333-343.

Sverdrup, H.U., Johnson, M.W., and Fleming, R.H. 1946. The Oceans--Their Physics, Chemistry, and General Biology. Prentice-Hall, Inc. New York.

UNESCO. 1981. International Oceanographic Tables, Vol. 3, UNESCO Tech. Pap. in Mar. Sci., No. 39.

U.S. Environmental Protection Agency. 1982a. Environmental Impact Statement (EIS) for The Jacksonville Harbor Dredged Material Disposal Site Designation.

U.S. Environmental Protection Agency. 1982b. Draft Environmental Impact Statement (EIS) for Tampa Harbor, Florida Ocean Dredged Material Disposal Site Designation.

Wishart, D. 1978. CLUSTAN Inter-University/Research Councils Series Report No. 47. Program Library Unit, Edinburgh University.

Woodward Clyde Consultants and Continental Shelf Associates, Inc. 1983. Southwest Florida Shelf Ecosystems Study - Year 1. Final Report and 2 Appendices. Prepared for U.S. Dept. of Interior, Minerals Management Service, Metairie, Louisiana. Contract No. 14-12-0001-29142.

Woodward Clyde Consultants and Continental Shelf Associates, Inc. 1984. Southwest Florida Shelf Ecosystems Study--Year 2. Draft Report. Prepared for U.S. Department of Interior, Minerals Management Service, Metairie, Louisiana. Contract No. 14-12-0001-29144.

ACKNOWLEDGEMENTS

This study was supported by the U.S. Department of the Interior, through the Gulf of Mexico OCS Regional Office of the Minerals Management Service (MMS). Support for this fourth year of the multi-year, multi-disciplinary program was provided under MMS Contract No. 14-12-0001-30071.

This Year 4 Annual Report represents the joint efforts of Environmental Science and Engineering, Inc. (ESE) of Gainesville, Florida, and LGL Ecological Research Associates, Inc. (LGL) of Bryan, Texas. ESE and LGL were assisted by various agencies, institutions, and individuals, all of which we would like to gratefully acknowledge.

We appreciate both the cooperation and understanding, as well as the technical input, provided by Mr. Carroll Day (CO) and Dr. Robert Avent (COTR), both of MMS.

We would like to extend our thanks to the staff at the Florida Institute of Oceanography; Dr. William Behrens, Dr. Murice Rinkel, Mr. Dean Milliken, Mr. Mark Wood, Mr. Eugene Olson, and particularly Captain "Chuck" Horan and the crew of the R/V SUNCOASTER. We would like to thank Mr. Mike Morley and Ms. Debbie Andersen, both of the Naval Ship Research and Development Center, for providing us with the antifouling organo-metallic polymer material crucial to the success of the time-lapse cameras.

ESE and LGL gratefully acknowledge the contributions of the following people.

Environmental Science and Engineering, Inc.--Prime Contractor

Larry J. Danek, Ph.D. (University of Michigan, Oceanic Sciences, 1976)--Program Manager. Responsible for the overall conduct of the study, interpretation of the data, report preparation and editing.

R. Steve LeGore, Ph.D. (University of Washington, Pollution Ecology, 1974)--Project Director. Served as an additional liaison between MMS and contractor, insured that the objectives of the study were met, and provided quality assurance support.

William A. Tucker, Ph.D. (University of Michigan, Oceanic Sciences, 1976)--Sediment dynamics and ocean currents.

Gregory M. Powell, Ph.D., P.E. (University of Florida, Engineering Mechanics--Coastal and Oceanographic Engineering, 1980)--Sedimentology and sediment dynamics.

Gary H. Tourtellotte, M.S. (Old Dominion University, Oceanography, 1979)--Benthic infauna and overall editing of the Annual Report.

Karyn M. Erickson, M.E. (University of Florida, Coastal and Hydraulic Engineering, 1984)--Ocean currents and waves.

Michael S. Tomlinson, B.A. (University of Washington, Geological Oceanography, 1973)--Logistics coordinator, field methods, physical environment descriptions, and overall editing.

George K. Foster, M.S. (University of Florida, Geology/Clay Mineralogy, 1984)--Sedimentation.

W. Thomas Gillespie, M.S. (University of Florida, Water Chemistry, 1976)--Data Manager.

John J. Mousa, Ph.D. (University of Florida, Analytical Chemistry, 1973)--Quality Assurance Manager.

The following people assisted in the field sampling and laboratory analysis: Edward Kellar, Gary Dalbec, Paula Anderson-Findley, Daniel Doebler, Jim Barnes, John Emery, Susan Mikolaitis, and Bruce Neville.

Preparation of the Annual Report was directed by Evelyn Knauft (Document Coordinator) with assistance from Carolyn Granger (Word Processing Department Manager), and Shane Edmond (Graphics Department Manager).

LGL Ecological Research Associates, Inc.--Subcontractor

Benny J. Gallaway, Ph.D. (Texas A&M University, Wildlife and Fisheries Science, 1979)--Data synthesis.

John G. Cole, B.S., C.P.A. (Texas Board of Public Accountancy, 1976)--Subcontract management and contract negotiation.

George S. Lewbel, Ph.D. (Scripps Institution of Oceanography, Biological Oceanography, 1976)--Responsible for all biological data synthesis and interpretation, report preparation, and editing.

Gregory S. Boland, M.S. (Texas A&M University, Biological Oceanography, 1980)--Remote sensing and report preparation.

Joshua S. Baker, Ph.D. (Texas A&M University, Statistics, 1983)--Statistical analysis and data synthesis.

Larry R. Martin, B.S. (Texas A&M University, Zoology, 1968)--Diving safety and laboratory analysis coordination.

Randall L. Howard, M.S. (Lamar University, Biology, 1973)--Fish and epifauna.

In addition, the following people made invaluable contributions to the collection of field data, data management and summarization, laboratory analysis, and taxonomy: Joseph Betor, Dale Bush, Charlie R. Chandler, Joseph M. Chaszar, Tom Czapla, Stephen R. Gittings, Joseph W. Goy, Robert L. Hedderman, Lynn M. Maritzen, James Nance, Sonja Rawls, Andy Tirpak, A.L. Treybig, and Stephen T. Viada.

Taxonomic Consultant

The following individual provided vital assistance in identifying the many organisms recovered during this study.

Richard W. Heard, Jr., Ph.D. (University of Southern Mississippi, 1976), Gulf Coast Research Laboratory, Ocean Springs, Mississippi--Arthropoda.

Finally, we would like to thank those unnamed individuals who contributed their skills as word processors, artists, accountants, and contracts personnel.

The Department of the Interior Mission

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

The Minerals Management Service Mission

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

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

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